VOL. 7 NO. 3
AUTUMN/FALL 2018

POWDER METALLURGY REVIEW

PORITE COMPANY PROFILE

SPUTTERING TARGETS

PM INNOVATIONS AT POWDERMET

www.pm-review.com

Published by Inovar Communications Ltd

Publisher & editorial offices
Inovar Communications Ltd
11 Park Plaza
Battlefield Enterprise Park
Shrewsbury SY1 3AF
United Kingdom

Editor & Publishing Director
Paul Whittaker
Tel: +44 (0)1743 211992
Email: paul@inovar-communications.com

Managing Director
Nick Williams
Tel: +44 (0)1743 211993
Email: nick@inovar-communications.com

Assistant Editor
Emily-Jo Hopson
Tel: +44 (0)1743 211994
Email: emily-jo@inovar-communications.com

Consulting Editor
Dr David Whittaker
Consultant, Wolverhampton, UK

Advertising Sales Director
Jon Craxford
Tel: +44 (0) 207 1939 749
Email: jon@inovar-communications.com

Production
Hugo Ribeiro, Production Manager
Tel: +44 (0)1743 211994
Email: hugo@inovar-communications.com

Submitting news and articles
We welcome contributions from both industry and academia and are always interested to hear about company news, innovative applications for PM, research and more.

Please contact Paul Whittaker, Editor
Email: paul@inovar-communications.com

Subscriptions
Powder Metallurgy Review is published on a quarterly basis. It is available as a free electronic publication or as a paid print subscription. The annual subscription charge is £95.00 including shipping.

Design and production
Inovar Communications Ltd.
ISSN 2050-9693 (Print edition)
ISSN 2050-9707 (Online edition)

This magazine is also available for free download from www.pm-review.com

INOVAR COMMUNICATIONS

Beijing hosts a global celebration of Powder Metallurgy

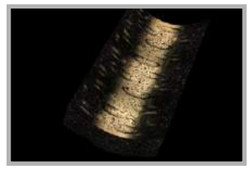
Many of those attending the World Congress on Powder Metallurgy (WORLDPM2018) in China this September would have been impressed by the sheer size and breadth of the country's PM industry. With the fastest growing and largest automotive market in the world, the need for structural components has resulted in rapid expansion of China's PM industry.

Of course, structural parts for the automotive industry are not the only application for PM in China. In contrast to other global regions where the automotive sector accounts for around 80% of part production, in China it was reported to be just over 60%. Other application areas for PM include household components, agricultural machinery and parts for power tools amongst many others.

China is also the world's largest producer of cemented carbide components, has a burgeoning Metal Injection Moulding industry and produces around 95% of the world's permanent magnets. The wealth of the country is growing, and the market for goods containing components made from some form of metal powder is growing with it.

The next issue of *PM Review* will include reports from the WORLDPM2018 congress, focusing on a number of advanced technical developments highlighted during the conference. Congratulations go to the organisers of the first PM World Congress held in China for delivering a dynamic, inspiring and informative event, which offered a unique insight into the region's PM industry.

Paul Whittaker
Editor, Powder Metallurgy Review



Cover image
Porite's award-winning bearing incorporates microscopic dimples on its inner diameter, reducing the friction coefficient by some 40% (Courtesy Porite Group)

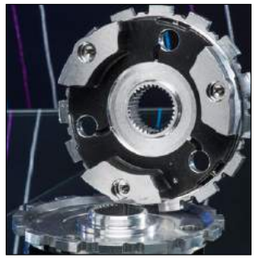
Autumn/Fall 2018

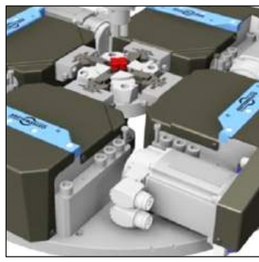
POWDER METALLURGY REVIEW


16


64


73


89


96

in this issue

regular features

industry news

To submit news for inclusion in *Powder Metallurgy Review* contact Paul Whittaker, paul@inovar-communications.com

Worlds largest PM parts producer looks to series production of metal AM components with HP partnership

GKN Powder Metallurgy has announced a strategic collaboration with HP Inc., and will become the first company to deploy the newly-launched HP Metal Jet Additive Manufacturing system into its factories for the production of functional metal parts for automotive and industrial applications.

The Metal Jet is the first metal Additive Manufacturing system from HP and, together with HP, GKN Powder Metallurgy stated that it is working toward the global industrialisation of AM. The HP Metal Jet is said to have the capability to increase its users' productivity 50 fold, compared to other Binder Jetting and Laser Powder Bed Fusion AM methods, and is available at nearly half the cost of other binder jetting systems on the market.

Peter Oberparleiter, CEO of GKN Powder Metallurgy, holds a part produced on an HP Metal Jet system

The new technology is expected to enable GKN Powder Metallurgy to transform its future product development and traditional manufacturing by reducing time-to-market for mass-produced parts from months to weeks, lowering development costs and providing greater design and manufacturing flexibility. Using HP's Thermal Inkjet technology the HP Metal Jet system works by precisely depositing up to 630 million nanogram-sized drops per second of HP Binding Agent onto a bed of powder metal to build parts layer-by-layer. The system uses industry-standard Metal Injection Moulding (MIM) grade powders.

As the largest producer of powder metal parts worldwide, sintering 13 million components per day, GKN Powder Metallurgy stated that it is uniquely positioned to advance the development of binder jetting technology. By integrating the HP Metal Jet into its workflow across its plants, the company expects to leverage its metal expertise to engineer new powders based on customer needs and help them to design new components which were not previously possible.

"Our vision for Additive Manufacturing in the enterprise moves beyond prototypes and small-series production and into mass production. We see a future where every modern digital company will have a cutting-edge 3D printer in their facilities, enabled by GKN technology, design and support, to produce metal parts in 24 hours," stated Peter Oberparleiter, CEO of GKN Powder Metallurgy.

"This strategic partnership with HP is the tipping point to accelerate that vision," continued Oberparleiter. "Powder production and metal part processing are part of our DNA, and we have a long history of collaborating with customers and industrialising solutions that bring great benefits to the entire industry. As we join forces with HP, we want our customers to challenge us to break design barriers and accelerate the adoption of binder jetting technology, as it is a wonderful compliment to our existing Additive Manufacturing technology offerings."

GKN Powder Metallurgy has previously made substantial investments in the industrialisation of Additive Manufacturing, notably as the first automotive supplier to begin series production of metal AM parts, using the MetalFAB1 AM machine from Additive Industries. In the first half of 2019, customers will be able to receive industrial-grade AM parts in higher quantities from GKN Powder Metallurgy, the only partner using the HP Metal Jet within the automotive and industrial market until the machine becomes generally available in 2020.

www.gkn.com/hp
www.hp.com/go/3Dmetals

Sandvik reports record-high orders and revenues in its second quarter 2018

Sandvik AB, headquartered in Stockholm, Sweden, has reported record results for the second quarter of 2018. In the period, both order intake and revenues were said to have increased by 12% year-on-year, and strong positive development was reported in all three business areas, with book-to-bill amounting to 104%.

Björn Rosengren, President and CEO of Sandvik, stated, "On the back of increased demand in all three major geographical regions stemming from positive development in all customer segments, we reported record-high orders and revenues for the second quarter of 2018. The high activity level in combination with a sustained focus on efficiency resulted in both adjusted operating profit and the operating margin of 19.4%, reaching all-time-high levels. I am pleased with the development in the period."

Adjusted operating profit has risen by 36% year-on-year to SEK 5,067 million (Q2 2017: 3,718 million), which Sandvik stated was supported primarily by strong organic growth. Across the Sandvik Group, orders increased significantly in all three major global regions, with Asia showing 17% growth, Europe 16% and North America 8%. Underlying customer activity was said to be high in all customer segments and regions.

All three of the company's business areas reported more than a 20% increase in operating profit. Sandvik Materials Technology reported an adjusted operating profit of SEK 558 million (Q2 2017: 189 million) and a 17% increase in order intake. Revenues grew organically by 8%, with higher alloy prices supporting both order intake and revenues by 4%, primarily related to nickel.

Sandvik Materials Technology also saw a positive impact on its Q2 operating profit of + SEK 72 million from changes to currency exchange rates and + SEK 201 million from changes to metal prices. Sandvik Machining Solutions saw order intake and revenues reach record-high levels, with order intake increasing by 8% and revenues by 10% year-on-year, respectively. Operating profit was reported at a record SEK 2,761 million (Q2 2017: 2,110), an increase of 31% year-on-year. In Sandvik Mining and Rock Technology, orders improved organically by 15% year-on-year and revenues by 16%. Operating profit improved by 24%, amounting to SEK 1,865 million (Q2 2017: 1,508 million).

The six month operating profit for Sandvik Group was reported as SEK 9,314 million (2017: 6,763 million) and the operating margin was 18.7% (2017: 14.9%), negatively impacted in the amount of – SEK 110 million due to changed exchange rates.

www.home.sandvik.com

Carpenter Technology sees positive results for Q4 and full year 2018

Carpenter Technology Corporation, Philadelphia, Pennsylvania, USA, has announced its financial results for the fourth quarter and fiscal year ended June 30, 2018. Net sales for its fourth quarter 2018 were reported at $618 million, up from $507.7 million in its fourth quarter 2017 and its highest quarterly sales in six years. Net sales for the company's full year 2018 were $2,157.7 million, up from $1,797.6 million in 2017.

A net income of $42.8 million was reported for the fourth quarter of the company's fiscal year 2018 (Q4 2017: $25.5 million). Total net income for the year reported at $188.5 million, a significant improvement on the net income of $47 million reported for the full year 2017.

Tony Thene, Carpenter's President and CEO, commented on the results, "Our fourth quarter results marked the culmination of a successful year as strong execution of our strategy, the strength of our increasing solutions-focused customer approach, and growing market demand resulted in our best quarterly operating income performance since the fourth quarter of fiscal year 2014."

"Our performance in fiscal year 2018, and especially during the fourth quarter, demonstrates that our strategy is resonating with customers, and whether it is materials for rotating jet engine parts to medical implant materials to 3D printed parts, we offer the best solutions for our customers," he concluded.

Carpenter's Performance Engineered Product division, the segment of the company that includes the Dynamet titanium business and the Carpenter Powder Products (CPP) business, achieved net sales for the fourth quarter of the fiscal year 2018 of $116.3 million, up from $106.2 million in the fourth quarter of fiscal year 2017. Operating income for this division was said to be $7.9 million, compared to $5.8 million in the previous year.

Thene stated that during its fiscal year 2018, Carpenter has significantly evolved its AM offerings, adding part design and production with its acquisition of metal AM service provider CalRAM, and establishment of an AM Technology Center in Reading, Pennsylvania, USA. Looking ahead to 2019, he stated that Carpenter will offer end-to-end AM solutions across multiple industries, pointing to the company's planned opening of an Emerging Technology Center in Athens, Alabama, USA, in twelve months, and its involvement as a founding partner in GE Additive's Manufacturing Partner Network.

www.cartech.com

GTP expands Tikomet production site

The production extension provides 600m² production space (Courtesy GTP)

Global Tungsten & Powders (GTP), a leading supplier of tungsten and molybdenum powders, semi-finished parts and SOFC components, headquartered in Towanda, Pennsylvania, USA, has announced the expansion of its Tikomet facility in Jyväskylä, Finland.

During the opening ceremony, Hermann Walser, Chief Executive Officer of the GTP group, emphasised how important Tikomet's tungsten carbide zinc reclaimed powders are for the tungsten portfolio of the GTP group. Recycled materials are a frequently requested alternative to virgin material and together with the chemical recycling capabilities at the APT plant in Towanda, the GTP group reports a recycling ratio of almost two thirds. Tikomet not only increases GTP's green credentials, but is also said to help the company be less dependent on unreliable virgin raw material resources.

"With Tikomet being part of an international group, having the full product portfolio of virgin and recycled materials for the hardmetals industry, Tikomet jumped from one to the next sales and production record since it is part of the GTP group. To continue with further growth in the future it is necessary to expand the production capacities. The new building extension here is a prerequisite for that."

The company produces several grades of tungsten carbide-cobalt powders using the zinc reclaim process, with high quality hardmetal scrap used as a raw material. GTP reclaimed powders are used in a wide range of markets including tyre studs, energy exploration, construction, automotive and mining, to name a few. The facility expansion will provide an additional 600 m² (approx. 6450 ft²) of production space.

www.globaltungsten.com

Kennametal announces fourth quarter and full fiscal year 2018 results

Kennametal Inc., Pittsburgh, Pennsylvania, USA, has announced its fourth quarter and full fiscal year results for 2018. In the fourth quarter 2018, the company reported sales of $646 million, up 14% from $565 million in the same quarter 2017. Full year sales were reported at $2,368 million, up 15% from $2,058 million for the full year 2017.

The company is one of the leading global producers of cemented carbide products for cutting tool and wear part applications. Sales growth in the fourth quarter 2018 was said to have been driven primarily by organic growth, and helped somewhat by favourable currency exchange impact and more business days. Sales were said to have grown in all segments, end-markets and regions.

Operating income for the quarter was $98 million, compared with $40 million in the fourth quarter 2017. Adjusted operating income was said to be $103 million, compared with $63 million Q4 2017. Net income attributable to Kennametal was $69 million, a significant increase compared to $25 million in the same period 2017.

For the full year 2018, operating income was reported to be $308 million, compared with $113 million in the previous year. Adjusted operating income was $323 million, compared with $189 million in the prior year. According to the company, adjusted operating income increased primarily due to organic sales growth, incremental restructuring benefits, favourable mix and currency exchange and modernisation benefits, but was partially offset by higher raw material costs, salary inflation and higher variable compensation expense due to higher than expected operating results.

"I am encouraged by the strong results of the quarter, and the progress we have made on our growth and margin expansion initiatives this year," commented Chris Rossi, Kennametal President and CEO. "Every business segment reported significant growth and profitability improvement, and we continue to see strong end-market demand. The robust operating leverage is consistent with our expectations."

The company stated in its outlook for the fiscal year 2019 that it expects strong end markets to continue, contributing to organic sales growth outlook in the range of 5–8%. Kennametal is said to be continuing initiatives in all three of its focus areas – growth, simplification and modernisation. Responding to current concerns over rising trade tariffs, the company stated that it does not expect tariffs to have a material effect on its sales or cost structure.

"We delivered 2018 results in-line with the multi-year profitability improvement plan we presented at our last Investor Day in December. And our fiscal 2019 plan is also on-track and represents another significant step forward in improved profitability for the company," concluded Rossi.

www.kennametal.com

Major facility expansion underway at Atlas Pressed Metals

Expansion is underway at Atlas Pressed Metals' DuBois facility (Courtesy Atlas Pressed Metals)

Atlas Pressed Metals, a producer of Powder Metallurgy parts based in DuBois, Pennsylvania, USA, is expanding its manufacturing facility at its Beaver Meadow Industrial Park site by a reported 45,000 ft^2 (4,200 m^2). The expansion will bring the company's total production area to 100,000 ft^2 (9,300 m^2), and will include additional under-beam clearance for the installation of larger tonnage presses.

The new construction is said to be the first phase of a multi-phase capital investment to address the company's growth strategy. Jude Pfingstler, President of Atlas Pressed Metals, stated that future phases will be concerned with acquiring the equipment and staffing for the additional space. He explained that expansion at the company has been driven by current and projected business in the appliance, automotive, lawn and garden, recreational vehicle, industrial equipment and electric motors markets.

"New equipment for the addition will enable Atlas to grow our capacity in multi-level and higher tonnage equipment," he commented. "Equipment tonnage is a reference to the press equipment used to manufacture powdered metal components, and the higher the tonnage of press the larger the parts that can be manufactured. Multi-level presses reflect the equipment's ability to manufacture more complex componentry."

www.atlaspressedmetals.com

Kennametal names new Vice President and Chief Technology Officer

Kennametal Inc has announced the appointment of Dr Carlonda R Reilly to the position of Vice President and Chief Technology Officer.

Reilly is said to bring more than twenty-two years of extensive research and development leadership experience, most recently serving as Global Technology Director in DuPont's Transportation and Advanced Polymers business. She succeeds Dr Robert Clemens, who will retire from the company in January 2019. Clemens joined Kennametal in 2013 and has served more than five years as Vice President and Chief Technology Officer.

"We have found an innovative business leader with deep expertise in developing and commercialising new products that have proven to deliver significant growth in revenue," stated Chris Rossi, Kennametal President and CEO. "I am confident in Carlonda's ability to lead Kennametal's global research, development and engineering teams to deliver end-to-end innovation."

"At the same time, I want to thank Bob Clemens for his leadership and dedication to advancing Kennametal's technology organisation," Rossi continued. "Bob has served the company admirably as CTO, and we wish him well in retirement."

Reilly holds a bachelor's degree in chemical engineering from the Massachusetts Institute of Technology (MIT) and a master's degree and Ph.D. in Chemical Engineering from the University of Delaware. She serves on the Board of Trustees for the University of Delaware Research Foundation and is a member of the American Institute of Chemical Engineers.

www.kennametal.com

EPMA announces 2019 HIP Seminar

The European Powder Metallurgy Association (EPMA) has announced the dates for its next Hot Isostatic Pressing (HIP) Seminar. The two-day seminar will run in Sint-Niklaas, Belgium, on February 11-12, 2019. Titled 'Conventional HIP and Rapid Cool HIP: Developments in Material Property and Microstructural Relationships,' the seminar programme will feature presentations and case studies, as well as a site visit to Engineered Pressure Systems International (EPSI) in Temse, Belgium.

The EPMA is currently inviting applications from those interested in speaking at the event. Further information on the HIP Seminar 2019 will be available nearer the time.

www.epma.com

AAM to build new manufacturing facility in Barcelona

American Axle & Manufacturing, Detroit, Michigan, USA, which acquired the PM parts manufacturer Metalydyne Performance Group in 2017, has announced plans to establish a new production facility in Viladecans, Spain, to support growth with new and existing European customers. Set to open in January 2019, the new 15,000 m^2 facility, located 20 km southwest of Barcelona, will produce powertrain components for Europe's leading automakers including Renault, BMW, Daimler, Porsche, Audi and Ford.

The new operation consolidates two smaller facilities in nearby Gavà and, at full capacity, will house 170 employees. "As AAM continues to diversify and expand our global customer base and product mix, our new Barcelona facility will be an integral part of our European manufacturing footprint," stated David C Dauch, AAM Chairman and Chief Executive Officer. "The new facility will help AAM meet customer demand for products that help reduce noise and vibrations from downsized engines."

Among other parts, AAM will produce damped gears for Ford, BMW and PSA, PV bonded dampers for Audi, Mercedes and FCA, isolation pulleys for Renault and in-mould bonded dampers for Mercedes, Ford and Porsche.

"The new Barcelona facility will allow AAM to rationalise and improve operations through a lean and efficient layout and production flow and to re-integrate the currently externalised warehouse," added Greg Deveson, President, AAM Powertrain. "As automakers continue to downsize engines, especially with the increased number of hybrid applications, demand for products like damped gears and isolation pulleys will increase. This new facility will help AAM continue to meet and exceed our customers' performance and quality expectations."

The Catalonia Trade and Investment agency, the INCASÒL and the Consorci urbanístic DeltaBCN are reported to have supported AAM with the expansion.

www.aam.com

Micromeritics Instrument Corp acquires Freeman Technology

Micromeritics Instrument Corporation, Norcross, Georgia, USA, a manufacturer of products for advanced materials characterisation, has announced its acquisition of Freeman Technology, Tewkesbury, UK. Freeman specialises in providing instruments for the measurement of powder flow and other behavioural properties to maximise process and product understanding, accelerate R&D toward formulation and commercialisation and optimise powder processes.

"The acquisition of Freeman Technology is very strategic to the growth of Micromeritics," commented Preston Hendrix, President of Micromeritics. "Not only does it expand our portfolio of products and solutions in high-growth market segments where we are already active and have a large, global base of customers, but Freeman Technology's strong scientific and applications focus is very much in line with the pre- and post-sales support customers have come to expect from Micromeritics."

Tim Freeman, Managing Director of Freeman Technology, stated, "We are excited about joining forces with and becoming a Micromeritics company, as they have penetration in complementary segments, global market coverage and the infrastructure to help us to accelerate the growth we have established in our business since 1995."

Micromeritics offerings include techniques for characterisation of the density/volume, surface area and porosity, physical and chemical absorption, size and shape of particles, porous materials and powders. In addition to designing, building and selling its own instrumentation, Micromeritics also offers complimentary OEM and private label instruments under its Particulate Systems brand, through the Micromeritics global sales channel and distributor partners.

The company also operates testing, certification and methods development laboratories under the Particle Testing Authority and PoroTechnology brands in Asia, the Americas and Europe.

Freeman's FT4 Powder Rheometer was designed to characterise the rheology, or flow properties, of powders (Courtesy Freeman Technology)

www.micromeritics.com
www.freemantech.co.uk

H.C. Starck reports positive results across all divisions for 2017

H.C. Starck GmbH, Munich, Germany, has announced its financial results for the full year 2017. The company reported total sales of €767.3 million for the full year, an 11% increase compared to 2016. It stated that this improvement was driven by the recovery of important core markets and by the successful implementation of a series of initiatives aimed at boosting sales and profitability.

The year saw the successful sale of the company's Surface Technology & Ceramic Powders (STC) and H.C. Starck Tantalum and Niobium (Tantalum/Niobium) divisions. H.C. Starck stated that strategic further development of the STC division will continue under the leadership of Höganäs AB, while JX Nippon Mining & Metals will continue the future development of Tantalum/Niobium. "We are delighted to have reached a deal with JX and Höganäs, both of which are buyers that bring with them the industry expertise and experience to lead these two divisions into a successful future," stated Jens Knöll, Managing Director of H.C. Starck.

The Tungsten Division of H.C. Starck posted significantly increased sales and results in 2017 compared with the previous year, along with a noteworthy increase in capacity utilisation. This was said to apply in particular to the division's plant in Goslar, joint ventures in Vietnam and China, and to the plant in Sarnia, Canada.

The division's strategic realignment, which includes programmes to boost efficiency and reduce costs and efforts to intensify sales and purchasing initiatives, was said to have been key in bringing about this positive development. The company's sales results were also said to have been aided by market factors such as increased demand from the hard metals industry and a favourable market environment for ammonium paratungstate (APT).

H.C. Starck Tantalum and Niobium was said to have benefited from strong demand for tantalum for sputter targets and capacitor applications in 2017, continuing its upward trend from 2016 while also strengthening its leadership in important market segments. The development of new products in cooperation with customers and partners was said to have been an important factor in the company's success, with one key example being AMPERTEC, an alloy powder used for the metal Additive Manufacturing of patient-specific medical implants. The sale of the Ta/Nb Division to JX Nippon Mining and Metals Corporation was expected to enable new development potential.

The STC division saw sales a rise in sales year-on-year with particularly strong growth being reported in the Industrial Applications and Oil & Gas/Welding segments. In August 2017, H.C. Starck launched its AMPERPRINT range of metal powders for Additive Manufacturing through this division.

H.C. Starck Fabricated Products (FPR) saw sales stabilised in the 2017 fiscal year, in what the company stated was a tough market environment. Sales in medical technology and for the electronics industry saw positive development, for example in the sputtering targets product segment with applications in semiconductor manufacturing.

www.hcstarck.com

ASCO Sintering achieves certification to new ISO standard

ASCO manufactures over 10 million PM sintered metal components for the automotive industry every year

Powder Metallurgy parts producer ASCO Sintering Co., Commerce, California, USA, recently completed its certification audit to the new ISO 9001:2015 standard administered by SRI Quality System Registrar, concerned with international issues of environment and risk management. The new certification was said to have been achieved with unconditional approval and no major or minor findings during the audit.

Neil Moore, ASCO's President and CEO, commented, "Today, the supply chain is global. ASCO is stepping up to meet the challenge by having a global presence, [with sites in] Coventry, UK and Cape Town, South Africa. This allows us to support the international market. ASCO now has a quality system that is aligned with the tools to deal with the geo-political elements of risk, such as tariffs on steel and aluminium."

Gerald Blythe, Quality Manager at ASCO Sintering Co., added, "All products at ASCO benefit from our adherence to the principals of Six Sigma. Whether it is performing Process FMEAs or Advanced Product Quality Planning (APQP), the intent is to identify and prevent problems before they occur."

www.ascosintering.com

Call for papers issued for POWDERMET2019 and AMPM2019

The Metal Powder Industries Federation (MPIF) has issued a call for papers for POWDERMET2019, the International Conference on Powder Metallurgy & Particulate Materials, set to run from June 23-26, 2019, at the Sheraton Grand Hotel in Phoenix, Arizona, USA.

POWDERMET2019 will be attended by professionals from across the PM industry, including buyers and specifiers of metal powders, tooling and compacting presses, sintering furnaces, furnace belts, powder handling and blending equipment, quality-control and automation equipment, particle-size and powder characterisation equipment, consulting and research services, and more.

Both oral and poster presentations are requested for inclusion in the technical programme and all submissions should be original and unpublished work addressing recent advances in the full spectrum of Powder Metallurgy and materials technologies. Categories for papers include:

- Design and modelling of PM materials, components and processes
- Particulate production
- General compaction and forming processes
- Powder Injection Moulding (metals & ceramics)
- Pre-sintering and sintering
- Secondary operations
- Materials
- Refractory metals, carbides & ceramics
- Advanced particulate materials and processes
- Material properties
- Testing and evaluation
- Applications

A poster programme will also be available, and submissions are encouraged from authors wishing to report important work-in-progress research in Powder Metallurgy. All accepted poster presentations will be eligible for the Poster Awards, and abstracts submitted for the poster programme will not be considered for presentation during the general technical sessions.

www.powdermet2019.org

POWDERMET2019 will take place in Phoenix, Arizona, USA, June 23-26, 2019

Remembering Dr Olle Grinder

Dr Olle Grinder

It is with much sadness that we report the death of Dr Olle Grinder, who passed away on Sunday, July 22, following a short illness.

Olle was a world-renowned powder metallurgist who actively contributed to the advancement of PM technology in Europe, Asia and North America. He made unparalleled contributions in fully dense PM technology and was one of the leading experts on the subject of Hot Isostatic Pressing.

He graduated from the Royal Institute of Technology, Stockholm, Sweden in 1968 and was the recipient of a PhD in metallurgy and material science from the same institute in 1977.

From 1970 to 1975, he worked on research projects in the fields of Powder Metallurgy and surface coating technology at the Axel Johnson Institute for Industrial Research and, after a return to the Royal Institute of Technology as a lecturer in 1976, he joined the Swedish Institute for Metals Research in Stockholm in 1977. There, he managed basic and contract research projects in the fields of PM, solidification and casting, surface coating and rapid solidification technology.

In 1985, Olle established his own consulting company, PM Technology AB, Stockholm. His consultancy activities were primarily within the field of Powder Metallurgy and materials science to companies in Sweden, Finland, Norway, UK, Germany, Austria, China, Japan and USA and to governmental organisations in Sweden and Finland. Olle's commitment to advancing Powder Metallurgy was recognised through an EPMA Distinguished Service Award in 2011 and an APMI Fellowship in 2013.

On a personal note, many of us at Inovar Communications enjoyed a longstanding friendship with Olle and have fond memories of his warmth and good humour. Dr David Whittaker, who worked with Olle on a number of projects through the Global PM Consultants grouping, as well as being a longstanding friend, stated, "I was gratified to learn from his family that he managed to retain his sense of humour right up to the end, and that he had a joke for every doctor and nurse (hundreds of them) that he met during the last weeks of his life. I am sure that anyone who knew Olle well, will readily empathise with this view."

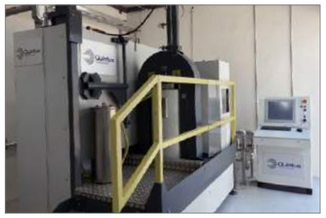
Mexico's Center for Engineering and Industrial Development installs Quintus HIP system

The Center for Engineering and Industrial Development (CIDESI) in Querétaro, Mexico, has installed a Hot Isostatic Press (HIP) produced by Quintus Technologies, Västerås, Sweden. The system, a QIH-15L HIP, is designed for use with advanced materials for demanding applications, especially within the aerospace, automotive, and energy sectors.

Founded in 1984, CIDESI is said to be one of Mexico's most important research and innovation organisations, and plays a key role in driving technological breakthroughs for the country's industry. It is part of a network of research centres managed by Mexico's National Council of Science and Technology, and is certified under the ISO-9001:2008 standard and the AS-9100C standard for aerospace.

The QIH-15L HIP offers a work zone of 186 mm (7.32 in) in diameter and 500 mm (19.69 in) in height, and an operating temperature of 1400°C (2552°F). It is capable of reaching pressures of of 207 MPa (30,000 psi). It is also equipped with Quintus' patented Uniform Rapid Cooling (URC) technology.

"Quintus Technologies has for several years worked with universities and research institutes in the development of education in many research areas, in North America and globally," stated Jan Söderström, CEO of Quintus Technologies. "We are honoured to have been selected by CIDESI to deliver this HIP system. It proves our commitment to deliver reliable HIP systems to this educational and specialised technological sector."



The Quintus QIH-15L HIP system is expected to play a key role in supporting advanced process development and production at CIDESI (Courtesy Quintus Technologies)

www.quintustechnologies.com
www.cidesi.com

Worldwide car markets maintain growth in first half of 2018

Results for the first half of 2018 in the international automotive markets were mainly positive in all regions with the exception of Japan and Korea in Asia, and the UK and Italy in Europe. China, the USA, and Europe (EU28+EFTA) saw total vehicle sales increase to 28.8 million units in the first six months of 2018, an increase of 1 million compared to the same period in 2017. Russia, Brazil and India all recorded double-digit growth.

In Europe, 8.695 million cars were sold in the first half of 2018, representing year-on-year growth of 2.8%. Car and light vehicle production in Europe was up 4% to 10.277 million units in the same period. Marked growth in sales was achieved in France (+9%) and Spain (+8%), with Germany recording a 4% increase. The UK saw sales fall by 3% in the first half, and the Italian market experienced a 7% decline. Vehicles in Turkey were down 12% to 352,467, whilst the Russian market continued its recovery with year-to-date sales reaching 849,200 vehicles – 18% above last year's value. However, sales in Russia are still around 40% below the peak reached in 2012.

In the US, the light vehicle market (cars and light trucks) saw a 1.1% increase in sales in the first half of 2018 to 8.6 million units, whilst sales in Canada climbed by 0.3% year-on-year. US car sales were reported to be down 12% in the period whilst light trucks increased by 10%. Light vehicle sales are forecast to decline for the remainder of the year, but still come in slightly above 2 million and 17 million units sold in Canada and the USA, respectively. Amid growing uncertainty about tariffs on auto parts, materials and vehicles, production of cars and light vehicles reached 8.704 million units in North America in the first six months – a decline of 2.6% compared with the same period in 2017. Year-to-June 2018 car and light vehicle sales in Mexico showed an 8.4% fall to 743,051 units.

Total vehicle production in China increased by 4.2% to 14.05 million in the first half, while vehicle sales increased by 5.6% to 14.06 million. Sales of new energy vehicles (NEVs) in China increased by 111.6% to 412,000. In the first six months of the year, India saw sales increase by 13% to just over 1.7 million units, and Japan reported that automotive sales failed to match last year's level, reaching only 2.3 million cars (-2%). However, passenger car production in Japan for the five months up to May 2018 showed an increase of 1.3% to 3.478 million. Korea also reported a decline in domestic car sales to 785,000 (-3%) for the first six months, and car production declined by 7% to 2,162 million. Both Japan and Korea rely heavily on export markets for their vehicles.

Sales in the Brazilian light vehicle market reached 1.129 million in the first six months – an increase of 13.7%.

Nichols Portland appoints Thomas K Houck as new President and CEO

Nichols Portland LLC, headquartered in Portland, Maine, USA, has announced Thomas K Houck as its new President and CEO. Nichols Portland focuses on the design and manufacture of fluid transfer devices (pumps), as well as producing a wide range of products for the automotive, on-off highway and other industrial markets.

As the former VP of Operations for ARC Group Worldwide, Houck brings over twenty-five years of continued experience in the Powder Metallurgy industry. With Nichols Portland's focus on technology and innovation for the future of the company, Houck commented, "As the President and CEO, my role is to continue to position the company for growth. With over eighty-five years designing and manufacturing gerotors, vanes, gearing and gerotor pumps, the company has a deep-rooted understanding of all types of powdered metal components and pumping systems."

Nichols Portland is said to be a 'one-stop-shop' for Powder Metallurgy components and a CNC solution provider for automotive, off-highway and industrial applications, with compacting presses ranging up to 750 tons. The company also provides systems engineering to its customers as well as a complete fluid power and fluid transfer device package.

In the late 1920s, the W.H. Nichols Company became the world's first manufacturer of gerotors and gerotor pumps. Working in partnership with the inventor of the gerotor (Myron Hill), W.H. Nichols invented the first equipment capable of producing this very complex gear shape. After 85 years of continuous experience in the manufacturing, design, application, testing and validation of these products, today Nichols Portland's customers range from small, niche pump manufactures to major automotive OEMs. "Nichols has helped its customers create innovative products that have cemented their position in the markets they serve," continued Houck. "We are committed to supporting and growing our existing customer base, while also seeking opportunities for new applications in other sectors and markets."

"We would like to take this opportunity to welcome Tom to Nichols Portland LLC, and fully support him in his efforts to lead the company on its next journey," stated Russell Greenberg, Chairman of Altus Capital Partners, the investment firm behind Nichols Portland. With Nichols Portland's long tradition of providing innovative solutions for its customers and Tom's proven track record in growing businesses in Powder Metallurgy, we see a great deal of potential for growth in this sector."

www.nicholsportland.com

Nichols Portland's manufacturing facility in Portland, Maine, USA (Courtesy Nichols Portland LLC)

Nichols Portland produces a wide range of PM components (Courtesy Nichols Portland LLC)

Sandvik acquires US heating element producer Custom Electric Manufacturing

Sweden's Sandvik AB has acquired the privately-owned Custom Electric Manufacturing Co., Wixom, Michigan, USA. The company is a leading manufacturer of original equipment and replacement heating elements for electric and gas furnaces on the North American market, and is said to offer more than seventy-five years of heating element design experience.

In 2017, the company reported revenues of $5.2 million. It employs around twenty staff and is said to operate a strong sales network in North America. Following its acquisition by Sandvik, the company will continue to market its products under its own brand.

Göran Björkman, President, Sandvik Materials Technology, commented, "Through this acquisition we add further strength to our leading position in industrial heating systems. I am pleased to welcome the Custom Electric Manufacturing team into Kanthal and Sandvik Materials Technology."

The business will be reported as part of the Sandvik's Product Area Kanthal within the business area Sandvik Materials Technology. Both parties have agreed not to disclose the purchase price.

www.home.sandvik

www.custom-electric.com

Custom Electric's headquarters in Wixom, Michigan, USA (Courtesy Custom Electric Manufacturing Co.)

Höganäs names Magnus Eriksson its new Chief Financial Officer

Sweden's Höganäs AB has appointed Magnus Eriksson to the role of Chief Financial Officer. Eriksson joins the company from Sandvik Hyperion, where he served as Vice President Finance & IT.

Eriksson has held various senior positions in the areas of Finance and IT within Sandvik over fifteen years, the last five of which were spent at the USA-based Sandvik Hyperion. Prior to joining Hyperion he served as Vice President Finance & IT at Sandvik Hard Materials.

"We are absolutely delighted to welcome Magnus Eriksson to Höganäs," stated Fredrik Emilson, Höganäs CEO. "Magnus has an extensive and solid experience of working in international groups of companies and heavy industry."

"This is the ideal background in view of the expansion phase that Höganäs is undergoing. With his passion for leadership issues and business development, Magnus will be a valuable addition to the Höganäs management team," he concluded.

www.hoganas.com

US researchers develop recycling process for turning HDD magnets into new magnet material

A research team led by the U.S. Department of Energy's Critical Materials Institute (CMI) at Ames Laboratory, Iowa State University, USA, has developed a new recycling process which turns the rare earth magnets in discarded hard disk drives (HDDs) into new magnetic material, in what is reported to be an economical and environmentally friendly manner.

In this new process, scrapped HDD magnets are collected and any protective coatings removed. The magnets are then crushed into a powder which is deposited onto a substrate using plasma spray to synthesise coatings of 0.5-1 mm thick. The properties of the end product are said to be customisable depending on processing controls.

Ryan Ott, a member of the CMI research team operating out of Ames Laboratory, explained that the new process was developed to take advantage of the increasing quantities of discarded electronics globally, and in particular the very high quantity of discarded HDDs, a which have a relatively centralised scrap source and offer a valuable supply of rare earth magnets.

While some methods for extracting the rare earth elements from electronic waste can create unwanted byproducts with a negative environmental impact, Ott stated, "Here we have eliminated as many processing steps as we can, and go straight from the discarded magnet to an end product, which is a new magnet. [...] The waste reduction aspect of this process is really two-fold; we're not only reusing end-of-life magnets, we are also reducing the amount of manufacturing waste produced in making thin and small geometry magnets out of larger bulk materials."

While the new magnetic material produced from HDD magnets cannot retain the exceptional magnetic properties of the original material, it is thought to have the potential to meet the market need for an economical solution in applications where high-strength rare-earth magnets are not required, but lower performance magnets like ferrites are not sufficient. The method could offer an efficient solution for the production of small, strong magnets for applications such as hand-held electronics.

Ames Laboratory is a U.S. Department of Energy Office of Science national laboratory and it creates innovative materials, technologies and energy solutions with the goal of solving pressing global challenges. CMI is a Department of Energy Innovation Hub led by Ames Laboratory and supported by the Office of Energy Efficiency and Renewable Energy's Advanced Manufacturing Office, which supports early-stage research to advance innovation in US manufacturing and promote the country's economic growth and energy security.

www.ameslab.gov
www.cmi.ameslab.gov

Gevorkyan adds post-processing and automation capabilities

Gevorkyan s.r.o., a family-owned business based in Vlkanová, Slovakia, was established more than twenty years ago by military aircraft engineer Artur Gevorkyan. The company reports that it has expanded its manufacturing capabilities in order to offer enhanced solutions to its Metal Injection Moulding (MIM) and Powder Metallurgy customers.

As well as a new hardening operation, a department for automation and robotisation has been established with the intention of accelerating production efficiency. The company's laboratory has also been expanded with new metallographic capabilities.

The company currently produces and supplies metal parts made by PM, MIM and HIP technologies to customers in more than thirty countries worldwide. End-user sectors include the automotive, lock and security systems, garden and hand tool, oil, medical, cosmetic and fashion industries.

The company states that it is reasonably independent of the automotive industry, which accounts for 30% of its total portfolio. The majority of its customers come from Europe, North and South America, but also from China and India. Gevorkyan develops over a hundred new parts each year and manufactures two thousand different types of component annually. A large part of its portfolio is made up of PM and MIM components successfully transferred from conventional technologies such as casting or machining.

Gevorkyan's facility in Vlkanová, Slovakia (Courtesy Gevorkyan s.r.o)

All tooling, whether for powder compaction or injection moulding, is prepared in-house. The company also states that it is self-sufficient with regards to secondary operations, including mechanical machining and heat treatment.

www.gevorkyan.sk

U.S. Army Research Lab to license nanogalvanic aluminium powder for hydrogen generation

The U.S. Army Research Laboratory, Adelphi, Maryland, USA, has reported plans to license its discovery of a nanogalvanic aluminium powder for hydrogen generation. When combined with water or any water-based liquid, the novel, structurally-stable, aluminium-based nanogalvanic alloy powder reacts to produce on-demand hydrogen for power generation without a catalyst.

Dr Anit Giri, a scientist with the lab's Weapons and Materials Research Directorate, explained, "This powder-based alloy includes material that disrupts the formation of an encapsulating aluminium oxide layer, allowing for the continuous production of hydrogen that can be used at the point of need to power a wide range of devices via fuel cells and internal combustion."

Researchers from the lab's Lightweight and Specialty Metals Branch discovered the unique properties of the nanopowder while investigating aluminium alloy compositions for other purposes. The laboratory has posted a Federal Register Notice and is inviting companies to submit their ideas on how best to commercialise this technology. The laboratory will then select the most appropriate partners and collaborators, after which license exclusivity will be determined.

The laboratory stated that aluminium alloy powder has many advantages as a potential energy source (Courtesy U.S. Army Research Laboratory)

The laboratory stated that the powder has many advantages, as a potential energy source which is stable as an alloy powder, is non-toxic and is environmentally friendly. Because it can be transported in powder or tablet form and combined with any available water source, the discovery has the potential to eliminate reliance on high-pressure hydrogen cylinders.

It is also said to be extremely efficient as an energy source, with 1 kg of the powder generating 4.4 kWh of energy – enough to power ten 60 W incandescent light bulbs for more than seven hours, or the equivalent number of LED bulbs for over fifty hours.

"The researchers have demonstrated rapid hydrogen generation rates using powder and tablet forms of the alloy," stated Branch Chief Robert Dowding. "The hydrogen has been shown to be useful for powering fuel cells and is expected to power internal combustion engines."

Dr Giri added that the powder can be produced using current manufacturing techniques, from either pure or alloyed aluminium. "The manufacturing process is easily scalable and it is also very fast," he stated, "with a 75% theoretical hydrogen yield in one minute at standard temperature and pressure, and 100% theoretical yield in three minutes."

"It's a versatile hydrogen source with direct combustion for vehicular power, to use in fuel cells to power any electronic device, and could potentially be used in Additive Manufacturing/3D printing to create self-cannibalising robots/drones," he concluded.

According to Dowding, the researchers are currently characterising the hydrogen generation rates and purity of the gas generated, as well as examining the effects of compositional changes to the alloy and systematic changes in the microstructure of the powders. In order to support a better understanding of the material, the laboratory has established a website to showcase the technology and review the process that will culminate in the granting of one or more patent licenses around September 2018.

www.arl.army.mil

Air Products to relocate its global HQ

Air Products, Allentown, Pennsylvania, USA, has announced that it will begin construction on its new global headquarters in Lehigh Valley, Pennsylvania, close to its existing location. The new headquarters will be based on a fifty acre site and the company expects to break ground in March 2019, with completion targeted for Summer 2021.

The new headquarters will be occupied by approximately 2,000 employees, and include capacity for future growth. Seifi Ghasemi, Air Products' Chief Executive Officer, stated, "From the beginning of this process to develop a new headquarters facility, we have never wavered in our commitment to remain in the Lehigh Valley. Now, we have made the location decision and we begin our preparations to build facilities that represent our world-class company. This is a very exciting time for Air Products as we evolve our headquarters environment to be more beneficial to our employees and take advantage of sustainable technologies to lessen our footprint and reduce operating costs."

As it continues to focus strongly on Industrial Gases, Air Products has divested a number of non-core businesses over the last two years.

Air Products' new global headquarters will be in Lehigh Valley, Pennsylvania

These moves, in combination with other operational changes, are said to have resulted in excess building space at Air Products' present location, compounded by annual maintenance costs of approximately $20 million on the sixty-year-old building. A cost estimate for the new site has not been disclosed at this time. It will include the company's new administration offices, a Research and Development (R&D) facility and an enclosed parking structure for employees.

"The decision to leave our current headquarters location, with its rich history, was not one we made lightly," stated Ghasemi. "But we believe our new location will afford us a special opportunity to modernise and optimise our office space and R&D facilities and invest in a work environment that motivates and energises our employees. As a global company operating in more than fifty countries, this new headquarters will reflect the safety, speed, simplicity and self-confidence that move us forward as a world-leading industrial gas company."

www.airproducts.com

H.C. Starck completes sale of its Tantalum & Niobium Division to JX Nippon Mining & Metals

H.C. Starck recently completed the sale of its Tantalum & Niobium (Ta/Nb) Division to JX Nippon Mining & Metals Corporation (JXNMM), Japan, a global manufacturer of non-ferrous resources and materials. The acquisition of H.C. Starck Ta/Nb was conducted by JXNMM through its German subsidiary, JX Materials Deutschland GmbH (JXMD). With the completion of the transaction, JXNMM stated that it has established a new Technology Group Tantalum & Niobium Division, which will cooperate with JXMD to oversee H.C. Starck Ta/Nb's management.

Based in Munich, Germany, H.C. Starck Ta/Nb converts metal ores and secondary materials into tantalum and niobium-based powders, and has long-standing experience in the development and manufacturing of high-performance metal powders for capacitors and sputter targets, including chemically highly pure oxides. The division currently employs around 600 people.

JXNMM stated that the acquisition is part of a strategy to develop and strengthen its electronic materials business from 2017-2019, in response to the continuing growth of the electronic components and devices market. The company reportedly intends to bring together and put to use the technologies, expertise, networks and various other management resources across the JXNMM Group, and in this way strengthen its sales and product development capabilities, achieve more efficient operations and increase its potential contribution to the advancement of a connected society through a stable supply of materials.

In addition, the company has stated that it places growing importance on its European operations, particularly for its midstream and downstream operations, and sees Germany as a global centre for many metal-related businesses including automotive and electronics, as well as a major source of cutting-edge research. The acquisition of the Munich-based company is expected to further support the JXNMM's goal of "developing and strengthening technology-based businesses that will be mainstays of the future."

www.nmm.jx-group.co.jp
www.hcstarck.com

Eisenmann establishes new facility in heart of America's automotive industry

Eisenmann, headquartered in Böblingen, Germany, has announced the establishment of a new facility in Novi, Michigan, USA.

With the three main US car manufacturers – General Motors, Ford and Fiat Chrysler Automobiles – as well as automotive OEM's and other suppliers being located in and around Detroit, Eisenmann's new facility will be at the centre of the US automotive industry.

"As a globally operating plant manufacturer, it is extremely important for us to move closer to our clients in the US. We are now in the centre of the American automotive industry and will be able to present our latest technologies for the automobile production of the future to our clients locally," stated Cassiano Fabris, who will lead the new branch.

"Strategically speaking, it is a crucial step as the major US automotive manufacturers are currently also intensively working on concepts surrounding Industry 4.0. We have a lot to offer in this field, especially for the automotive paint shop and final assembly, and the interest in our innovative solutions for the connected production is huge. In addition, this customer proximity increases our efficiency in project execution and after-sales service," added Fabris.

www.eisenmann.com

Eisenmann's new facility in Novi, Michigan, USA (Courtesy Eisenmann)

Sandvik acquires rock drilling tools supplier Inrock

Sandvik, headquartered in Stockholm, Sweden, has acquired Inrock, a privately-owned supplier of rock drilling tools and services for Horizontal Directional Drilling (HDD) based in Houston, Texas, USA. Inrock is said to be a market leader in pilot hole bits, reamers, guidance systems, accessories and services for the premium maxi rig segment within HDD.

In 2017, Inrock reported revenues of $46 million and employed a workforce of seventy. As of the third quarter 2018, the company will be reported as part of the product area Rock Tools within business area Sandvik Mining and Rock Technology.

The combined expertise of Sandvik Mining and Rock Technology and Inrock is expected to support further development of the HDD product portfolio to customers operating and servicing infrastructure applications such as oil & gas pipelines, water and sewer, telecommunications, electricity and alternative energy production and storage. This includes expanding into the midi rig segment, accelerating the global footprint of the business and realising synergies within production.

Björn Rosengren, CEO and President of Sandvik, commented, "In line with our strategy, this demonstrates how we gear up for growth organically and through acquisitions in areas where we are stable and profitable, aiming for world-leading market positions. I welcome Inrock to our Group."

"I am pleased to see that we leverage our materials knowledge and supply infrastructure to drive growth in the consumables and service business, since it is important in maintaining and improving our relationship with customers, as well as adding long-term stability to our earnings," added Henrik Ager, Head of product area Rock Tools, Sandvik Mining and Rock Technology.

www.home.sandvik.com
www.inrock.com

MPIF sets the date for its 2018 Management Summit

The Metal Powder Industries Federation (MPIF) will hold its 2018 Management Summit and 74th Annual MPIF Business Meeting at the U.S. Grant Hotel, in San Diego, California, USA, October 27-29.

The event, which is open to MPIF members only, will provide a range of networking opportunities for all attendees. This year's summit is expected to offer:

- A new format to maximise networking opportunities
- A number of key speakers discussing timely business topics
- MPIF and association business meetings aimed at driving future directions and the development of budgets for 2019

The MPIF stated that attendees will have the opportunity to connect with customers at C-level or senior management level to discuss industry challenges and discover opportunities for growth in the PM industry.

www.mpif.org

Plansee Japan celebrates forty-year anniversary

Plansee Japan Ltd, Tokyo, recently celebrated its forty-year anniversary in a ceremony attended by 170 guests. During the event, Peter Aldrian, Plansee Japan's Managing Director, offered guests an insight into the Japanese subsidiary's origins and development since its founding.

Austrian-based Plansee Group founded Nippon Plansee K.K. with the opening of offices in Tokyo and Osaka in 1978, followed shortly after by an office in Fukuoka. In 1991, Plansee began local production in order to safeguard its future growth, and Japan Vacs Precision was established as a joint venture of Metallwerk Plansee GmbH and Japan Vacs Metals.

Japan Vacs Precision established itself as a reliable supplier to Japan's high-tech enterprises and, in 2009, Nippon Plansee, Japan Vacs Metals and Japan Vacs Precision consolidated to form Plansee Japan. The company currently employs 130, and produces precision components for the electronics, medical engineering, automotive, lighting and semiconductor industries in Esashi, Japan, which it markets through its sales offices in Tokyo and in Osaka.

Peter Aldrian, Managing Director, Plansee Japan, addressed 170 guests during the company's 40th anniversary celebration (Courtesy Plansee Japan Ltd)

According to Plansee, 30% of the products manufactured at its Japanese site are exported to customers internationally. In addition, the company purchases materials, products and components from other Plansee Group companies for sale to the Japanese market. According to Aldrian, Plansee Japan continues to invest in modern manufacturing equipment, staff development and the ongoing development of its service offering in order to ensure that it remains an innovative and reliable business partner for the region.

plansee.com

WORLDPM2020 Congress and Exhibition moves to Montréal

The 2020 World Congress on Powder Metallurgy & Particulate Materials (WORLDPM2020) will be held in Montréal, Quebec, Canada, from June 27–July 1, 2020. Organised by the MPIF and APMI International, the event will be held in conjunction with Additive Manufacturing with Powder Metallurgy (AMPM) 2020 and the Tungsten, Refractory and Hardmaterials Conference 2020.

The congress will cover the full range of Powder Metallurgy topics, from metal powder production and technology, powder compaction, sintering and post-processing to Metal Injection Moulding, cemented carbides, porous materials, Additive Manufacturing and the design and simulation of PM parts.

In addition to the conference, there will be a major international exhibition, providing an opportunity for networking with material and equipment suppliers, part producers and end-users.

WORLDPM is held every two years and took place in Beijing, China, September 15-19, 2018.

www.mpif.org

Höganäs installs 'next generation' Eisenmann sintering furnace in Shanghai

A pilot model of a new 'next generation' sintering furnace commissioned by Höganäs and produced by Eisenmann Thermal Solutions, Bovenden, Germany, is in operation at the Höganäs Tech Center (ATEC)'s newly built laboratory complex in Shanghai, China. The new furnace is said to make it possible to precisely model and compare the sintering processes in conventional conveyor furnaces and the newer high-temperature roller furnaces, and can display a wide range of sintering times and product throughputs at temperatures of up to 1400°C, with the cooling zone being separate from the rest of the workpiece transport system.

One reportedly unique feature of the pilot roller furnace is that the conveying speed is continuously variable and can be precisely adjusted to suit any product specifications. It is said to be the first production facility to have attained homogeneous cooling rates of up to 8 K/s in the component at sintering temperatures of 1250°C. Due to its closed furnace design, it is also said to greatly reduce energy and gas consumption during sintering, with the vacuum system making it possible to save up to 50% of the nitrogen that would normally be used.

The plant reportedly offers highly precise atmospheric controls, achieved using an additional air seal as well as a sophisticated arrangement of connections for gas injection and atmospheric measurement. These features allow for extensive gas analysis and active carbon control.

A number of experts from companies manufacturing sintered parts were recently invited on a tour of the newly built laboratory complex, where Eisenmann's new furnace was demonstrated. During the tour, Peter Vervoort, Vice President of Product Development & Technology at Eisenmann, gave an introduction to the sintering furnace, while Simon Tan of Höganäs ATEC presented the first production results since its commission.

Tan stated that, with its new sintering laboratory, Höganäs is now able to offer its customers "outstanding capabilities" in process data determination and PM part analysis. Using Eisenmann's plant technology, he also stated that the laboratory has been able to make distinct improvements to product quality while greatly reducing its operating costs.

www.eisenmann.com
www.hoganas.com

Visitors from sintered parts companies view the pilot plant at ATEC, Shanghai (Courtesy Eisenmann Thermal Solutions)

EPMA to launch club project on micro-mechanical testing of hardmetals

The European Powder Metallurgy Association (EPMA) has announced that it will launch a club project titled 'Micro-mechanical testing: a quantitative method for measuring local mechanical properties in hardmetals – Stage 2' in partnership with Centro de Estudios e Investigaciones Técnicas de Gipuzkoa (CEIT), San Sebastian, Spain, The National Physical Laboratory (NPL), London, UK, and Polytechnic University of Catalonia (UPC), Barcelona, Spain.

This is the second stage of a programme aimed at the development of robust metrology for the mechanical characterisation of key microstructural features in hardmetals. The proposed project focuses on two aspects of micro-sample testing to measure the mechanical properties of hardmetals at the local scale: the effect of geometry on the repeatability of the tests and the characterisation of interfacial strength.

In a previous exploratory study, microsamples of different geometries were machined using Focused Ion Beam (FIB) machining and tested with different nanoindenter systems. The force-displacement measurements obtained demonstrated good repeatability, captured the effect of WC orientation for fracture and discriminated WC-WC interfaces with different relative orientation.

The overall cost of the project to its partners will be €60,000, which is to be shared by the participants. It is planned that the project should begin in the coming months and will last 12 months overall. The project is open for all companies to participate in; interested organisations are advised to contact Dr Olivier Coube, EPMA Technical Director.

email: oc@epma.com
www.epma.com

Netzsch offers grinding and classifying of rare earth powders for PM magnet production

Netzsch Trockenmahltechnik GmbH, Hanau, Germany, states that it has developed a new grinding process for the production of raw material for the manufacture of neodymium-iron-boron-magnets. In order to produce raw materials which give the highest quality and properties for permanent magnets, the company's patent pending grinding process includes downstream classifying of rare earth powders. The system includes newly-developed jet mills and ultra-fine classifiers with which sensitive Nd-Fe-B-compounds or other rare earth alloys can reportedly be ground reliably to fine powders under inert gas operation, giving a narrow particle size distribution and defined upper particle size limit with reproducible results.

With Netzsch M-Jet, a combination of a spiral jet mill with a dynamic air classifier, the highest reproducible finenesses independent of the load in the gas jets can be obtained. One advantage offered by the M-Jet, compared to fluidised bed jet mills or target mills, is the possibility of the automatic rejection of components which are difficult to grind. This requires only a few seconds and takes place during operation of the M-Jet.

By automatically rejecting components which would be too difficult to grind and transporting them into the filter, the M-Jet avoids problems which could be caused by contamination of the product-conveying piping with coarse product particles and/or problematic components. Furthermore, the product content during the grinding phase of the M-Jet is said to be 20–25 times lower than that of a fluidised bed jet mill with the same amount of grinding gas.

This high product content results in a very low level of product loss during product change, due to the smaller volume of the grinding chamber. In addition, it is said that almost no fluctuations in throughput capacity, and especially in the particle size distribution, occur during starting and stopping of the plant. It is further noted that selective grinding of individual alloy components does not take place during the M-Jet's grinding operations.

The dynamic air classifier integrated into the M-Jet is designed to ensure a clearly defined maximum particle size of the ground product. In a subsequent step, undesirable finest particles are separated out by classifying the ground material with a NETZSCH High-efficiency Fine Classifier M-Class to obtain a powder with a defined, narrow particle size distribution. The higher grade of the raw materials produced using Netzsch's new process is reported to be reflected in the quality of the magnets manufactured from them. Compared to magnets produced using ground powder only, rare earth magnets produced using classified powder are said to offer a higher coercive field strength and significantly improved knee-field strength. This could aid their ability to meet future challenges for the magnet industry, including progressively increasing miniaturisation.

www.netzsch.com

With its patent-pending grinding process for rare earth powders, Netzsch states that it can guarantee excellent quality of the raw materials (Courtesy Netzsch Grinding & Dispersing GmbH)

Carbolite Gero offers updated retort furnace for PM and AM applications

Carbolite Gero has launched an updated GPCMA/174 Retort Furnace, which it states is suitable for a variety of laboratory, pilot-scale and industrial applications requiring heat treatment to 1150°C. The completely revised 174-litre furnace reportedly reduces O_2 levels to below 30 ppm and offers uniform temperature distribution and gas tightness, ensuring minimal usage of expensive gases.

Continuous monitoring of inert gas flow volumes and forced cooling for faster cycle times are further features said to ensure safe and efficient operation. Designed with a modified inert atmosphere for annealing and sintering of Powder Metallurgy and metal AM parts, the furnace can be fitted for compliance to AMS 2750E Class 1 (+/-3°C) and equipped with instrumentation type A, B, C or D.

The GPCMA/174 features cascade control for load-temperature sensing, as well as a swing door design for ease of loading and unloading, and is said to be ideal for applications which call for a single platform furnace and small volume requirements for one-off components.

www.carbolite-gero.com

MPIF reports success of AMPM2018 and POWDERMET2018

The annual AMPM and POWDERMET event, held at the Grand Hyatt San Antonio, Texas, USA, from June 17-20, 2018, was attended by 872 delegates from twenty-five countries, reports organiser the Metal Powder Industries Federation (MPIF). The co-located conferences comprised four days of the latest research and development in metal Additive Manufacturing, Powder Metallurgy and particulate materials, as well as its annual awards presentations and a number of popular networking events.

During the Opening General Session, John Sweet, the MPIF's President, provided an overview of the current State of the PM Industry in North America. In his address, he stated that 2017 saw modest growth for the PM industry, with PM tooling and equipment makers reporting favourable results. Based on the 2018 PM Pulse Survey conducted by the MPIF, sales are expected to remain the same or increase throughout 2018. Keynote speaker Casey Selecman, Associate Director, Advisory Services, IHS Markit, followed the overview with a discussion of disruptive forces in the automotive industry.

Several key changes were incorporated into this year's conferences to meet the growing demand for content relating to metal Additive Manufacturing. The AMPM2018 conference was extended with an additional day of technical sessions, and all AMPM registrants were offered the ability to attend the full programme of POWDERMET2018 technical sessions and events. Additionally, a new exhibit hall event, the 'PM Evening Alehouse', was introduced to allow attendees to network with exhibitors after the close of technical sessions on Monday, June 18.

For the second year running, the National Science Foundation sponsored 40 US college and university students to attend POWDERMET2018. The 2018 programme was enhanced by providing students with an opportunity to present their posters during Grant TNT: Talk 'N Technology sessions throughout the conference. Students also attended a meet-and-greet reception for students and mentors, and student resumes were posted at the conference and within the conference app for iOS and Android. Four CPMT/Axel Madsen Grant recipients were also included in all student opportunities.

Other conference events included the PM industry Luncheon, which recognised the second ever Vanguard Award recipient, the 2018 Distinguished Service to PM Award recipient and APMI Fellow recipients, and the Design Excellence Awards Luncheon, at which nineteen award-winning components were revealed.

www.mpif.org

The MPIF announced the winners of its Design Excellence Awards during POWDERMET2018 (Courtesy MPIF)

Former ZF CEO named Procurement Chief at Volkswagen

Volkswagen Group will name Stefan Sommer, former CEO of automotive supplier ZF Friedrichshafen AG, as its new Procurement Chief. Sommer will assume the role beginning in January 2019.

Sommer, who departed ZF at the end of 2017, holds a Ph.D. in engineering, specialising in automation. He began his professional career in 1994 as a development engineer at ITT Automotive Group Europe GmbH. In 1997 he moved to Continental Automotive Systems as Director Electronics & Sensor Development. After occupying several positions in the Continental Group, the last of which being Senior Vice President EBS Customer Center, he was appointed to the Board of Directors at ZF Sachs AG, taking charge of the suspension division.

In 2010 Sommer became a member of the Board of Management of ZF Friedrichshafen AG, with responsibility for materials management. Sommer was named Deputy Chief Executive Officer in January 2012, and served as Chief Executive Officer from May 2012 until the end of 2017.

As Volkswagen's Procurement Chief, Sommer will succeed Francisco Javier Garcia Sanz, whose departure was announced in April 2018.

www.volkswagen.com

EPMA reports success of Quality for PM Seminar

The European Powder Metallurgy Association (EPMA) held its Quality for Powder Metallurgy Seminar in Seville, Spain, from May 17-18, 2018. The two-day technical seminar, held at the NH Sevilla Viapol, focused on a number of aspects relating to quality techniques and technology for PM structural parts.

The seminar was attended by more than thirty individuals from the PM supply chain to enhance their understanding of a range of quality management subjects, with topics including Advanced Product Quality Planning, Techniques for Continuous Improvement and Basic Metrology Characteristics and Measurement Methods. A number of relevant case studies were also presented for discussion.

According to the EPMA, the seminar sessions were devised to cover some of the areas that end-users are becoming involved with in the hope that by increasing skill levels throughout the supply chain, companies will be able to offer a competitive advantage when negotiating new components. For example, the lecture 'New Mobility, Automated Driving, New Business Models – Challenges for Warranty and Reliability Management', presented by Dr.-Ing. Andreas Braasch, Institut für Qualitäts und Zuverlässigkeitsmanagement GmbH (IQZ), examined the increased expectation of warranty periods for components in the automotive sector, from 24 months through to 72+ months.

The lecture looked at the techniques the supply chain employ and how it can adapt to meet the challenges set out by the OEM customers, addressing overall company organisation and the importance of up-to-date internal processes. Robust contract management and methodical reporting on tooling and production capacities, and adherence to quality management initiatives such as reliability analysis & prognosis during service life, were some of the areas Braasch highlighted.

Attendees at the EPMA's Quality for PM seminar (Courtesy EPMA)

www.epma.com

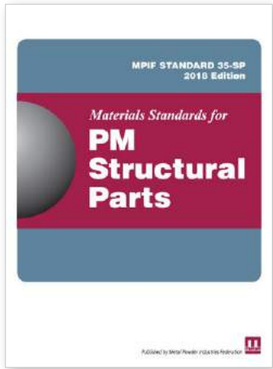
MPIF releases 2018 edition of its Materials Standards for PM Structural Parts

The Metal Powder Industries Federation (MPIF) has released the latest edition of its MPIF Standard 35 – *Materials Standards for PM Structural Parts*. First published in 1961, the 2018 updated standard aims to provide design and materials engineers with the latest engineering property data and information available to specify materials for structural Powder Metallurgy parts.

Each section of the standard is divided into subsections based on the various types of PM materials in common commercial use within that sector. Details are provided on the characteristics of each material in that subsection, with data tables in both inch-pound and SI units. Engineering information is also included, covering hardenability, machinability, fatigue, fratcure toughness, corrosion resistance and guidelines for specifying a PM part.

This revised and expanded standard includes new data for the AC-2014-T8 aluminium alloy as well as four heat-treated prealloyed steels: FL-3905, FL-4005, FL-4805 and FL-4905. It also includes data on hardenability (Jominy), strain-controlled fatigue and CTE data, and the steam oxidation of ferrous PM materials.

This particular standard does not apply to materials for PM self-lubricating bearings, powder forged or metal injection moulded products. These are covered in separate editions of MPIF Standard 35.



MPIF Standard 35 – Materials Standards for PM Structural Parts is available via the MPIF's website (Courtesy MPIF)

www.mpif.org

BMW to expand European production network with new Hungarian plant

BMW Group has announced the expansion of its production network in Europe with the commissioning of a new facility close to the town of Debrecen, Hungary. The group will invest approximately €1 billion in the new facility, which it states will offer a production capacity of up to 150,000 units a year and create over 1,000 new jobs in the area.

Europe is said to be the most important market for the BMW Group. In 2017, it accounted for almost 45% of all vehicle sales, with 1.1 million units sold. Up to the end of June 2018, the BMW Group grew in many markets across the continent, with vehicle deliveries totalling more than 560,000 units – a year-on-year rise of 1.2%. The decision to expand its European production network follows the group's principle of balanced global growth, and is said to represent the next logical step in the implementation of a group strategy labelled 'NUMBER ONE > NEXT'.

Harald Krüger, Chairman of the BMW AG Board of Management, stated, "The BMW Group's decision to build this new plant reaffirms our perspective for global growth. After significant investments in China, Mexico and the USA, we are now strengthening our activities in Europe to maintain a worldwide balance of production between Asia, America and our home continent. Europe is the BMW Group's largest production location. In 2018 alone we are investing more than €1 billion in our German sites to upgrade and prepare them for electric mobility."

"In the future, every BMW Group plant in Europe will be equipped to produce electrified as well as conventional vehicles," added Oliver Zipse, BMW AG Board Member for Production. "Our new plant in Hungary will also be able to manufacture both combustion and electrified BMW models – all on a single production line. It will bring greater capacity to our worldwide production network. When production commences, the plant will set new standards in flexibility, digitalisation and productivity."

BMW Group has been operating a representative office in Hungary since 2004 and stated that Debrecen is the ideal location for an expansion of its production network; offering very good infrastructure, suitable logistics connections and proximity to the group's established supplier network. The group enjoys long-standing, positive relations with suppliers in the country, and in 2017, materials and services worth €1.4 billion were purchased in Hungary.

www.bmwgroup-plants.com/debrecen/en.html

Vehicle assembly at a BMW Group facility (Courtesy BMW Group)

Bodycote to open new heat treatment facility in UK

Bodycote, headquartered in Macclesfield, UK, has announced the opening of a new facility in the Advanced Manufacturing Park, Rotherham, Yorkshire, UK, to support the aerospace and power generation markets in the UK and Europe.

Simon Blantern, Vice President of Sales Europe for Bodycote's Aerospace, Defence & Energy heat treatment division, stated, "This investment demonstrates Bodycote's continuing commitment to align resources to serve both the aerospace and power generation markets."

With more than 180 accredited facilities in twenty-three countries, Bodycote is the world's largest provider of heat treating and specialist thermal processing services. Through classical heat treatment and specialist technologies including Hot Isostatic Pressing (HIP), Bodycote improves the properties of metals and alloys, extending the life of vital components for a wide range of industries, including aerospace, defence, automotive, power generation, oil & gas, construction, medical and transportation.

The new facility will be fully operational in 2018 and offer a number of heat treatment processes. The company plans to obtain major OEM approvals, along with Nadcap accreditation.

www.bodycote.com

Hagen Symposium 2018 programme published; Skaupy prize announced

The 37th Hagen Symposium on Powder Metallurgy, organised by the Fachverband Pulvermetallurgie (FPM), will take place in Hagen, Germany, November 29-30, 2018. The German-language event will include presentations on a wide range of PM technologies, as well as discussions on how a digitised industry 4.0 will impact the Powder Metallurgy sector.

It has been announced that the recipient of this year's Skaupy Award, to be presented during the symposium, is Dr Ing Thomas Weissgärber, Fraunhofer IFAM, Dresden. In his opening Skaupy lecture, Dr Weißgärber will discuss the production of Powder Metallurgy composites with functional properties.

In addition to the symposium presentations, a new Practical Day will take place on November 29, consisting of three dedicated workshops on press technology, sintering, and quality assurance. An exhibition will also bring together those supplying the industry, and a programme of social events will allow delegates numerous networking opportunities.

www.pulvermetallurgie.com

Metalysis begins production with first industrial-scale metal powder plant

Metalysis Ltd., Rotheram, South Yorkshire, UK, has launched its first commercial metal alloy powder production plant at its facility in Wath upon Dearne, South Yorkshire, UK. The Generation 4 (Gen4) project was mechanically completed in Q4 2017 and has since undergone hot commissioning, trial runs and optimisation. The handover from testing to operation signifies Metalysis' transition into commercial production, following more than a decade of phased technology development.

Gen4 is the first facility to take Metalysis' solid-state, modular, electrochemical process to industrial scale and is said to be able to produce tens-to-hundreds of tonnes per annum of high value, niche and master alloys. The facility creates a new source of supply for global end-users in advanced manufacturing disciplines including Additive Manufacturing, aerospace, automotive, batteries, light-weighting, magnets and mining.

One of the reported benefits of Metalysis' technology is its multi-metal capability, which enables the company to produce alloy 'recipes' that comparable processing routes cannot. Where conventional technologies are unable to combine elements with melting and density differentials, this technology can because it is a solid-state process. It is said to enable Metalysis to commercially produce a demand-driven product mix of titanium alloys, master alloys including Scandium-Aluminide, compositionally complex alloys including high-entropy alloys, magnet materials, high-temperature materials and platinum group alloys.

The modularity of the technology is said to offer further benefits, such as its ability to offer a wide range of order quantities. Throughout phased expansions, the technology has also presented opportunities to reduce all-in costs and environmental footprints compared to traditional melting production routes.

"In powering up and operating our industrial plant, Metalysis is poised to achieve its target to generate significant profits from our new South Yorkshire production facility," stated Dr Dion Vaughan, Chief Executive Officer, Metalysis. "Ours is a true British success story with international implications. Metalysis has grown from the 'lightbulb moment' at Cambridge University in the late-1990s, relocated to South Yorkshire to benefit from regional excellence in operational skillsets in the early-2000s, and now onwards towards a bright commercial future."

In March 2018, the company announced that it had raised £12 million to fund state-of-the-art post-processing facilities, feedstock and provide working capital to support the roll-out of Gen4. Overall, approximately £25 million has been raised to fund the project to completion.

www.metalysis.com

Ametek SMP reports growing demand for stainless steel powders in India's automotive industry

Ametek SMP Eighty Four, a division of Ametek Specialty Metal Products based in Eighty Four, Pennsylvania, USA, states that it anticipates a growing demand for its stainless steel metal powders from the Indian automotive industry. According to Ametek, most of the world's major car manufacturers now have operations in India, with the automotive sector being a significant contributor to the country's economy. As the industry prepares for the introduction of stricter emissions regulations, vehicles will need to be fitted with stainless steel exhaust systems.

To meet the resulting growth in demand which Ametek SMP predicts for its stainless steel water atomised powders, the company states that it is investing substantially in India. Ametek Eighty Four produces structural powders typically used in a variety of manufacturing processes, primarily press and sinter Powder Metallurgy, Cold Isostatic Pressing (CIP), Hot Isostatic Pressing (HIP) and roll compaction, but including metal Additive Manufacturing (AM) and Metal Injection Moulding (MIM). Ametek's metal powders are manufactured in accordance with strict quality standards and certified to ISO 9001 status.

For the automotive industry, the main stainless steel alloy powders used are 409L and 434L, as well as 304L and 316L.

300 series powders are austenitic stainless steels typically used for press and sinter PM applications to make near net shape parts for a variety of applications. 304L is a corrosion-resistant material that exhibits good property stability below 1000 degrees F, making it a good choice for parts that will not be subjected to demanding machining operations. 316L offers the highest degree of corrosion protection available in standard stainless steel grades, providing very good strength at extremely high temperatures.

The key reasons for using 400 series stainless steel atomised powders in the production of automotive components can include their good atmospheric and saline corrosion resistance, hot oxidation resistance and elevated temperature yield strength, as well as their comparatively low cost. Components produced using these powders include exhaust flanges and exhaust support brackets, as well as rear-view mirror mounts, sensor rings and seals. 409 is a ferritic, weldable grade of stainless steel, which is said to offer high compressibility, enhanced green strength and good sinterability, while 434 is a low-carbon stainless steel used in mildly corrosive environments.

Ametek Eighty Four produces structural powders used in a variety of manufacturing processes (Courtesy Ametek SMP)

The major advantage of metal powder-based manufacturing technologies for the automotive industry, typically a replacement technology for stamping or machining, is a reduction in material costs. Because the process enables the production of components to net shape or near net shape, little scrap metal is produced in comparison with traditional manufacturing technologies.

www.powderclad.com

Tessa Stillman receives MPIF's 2018 Distinguished Service to PM Award

The Metal Powder Industries Federation (MPIF) Awards Committee announced Tessa Stillman as the recipient of its 2018 Distinguished Service to Powder Metallurgy (PM) Award during POWDERMET2018, the International Conference on Powder Metallurgy and Particulate Materials held in San Antonio, Texas, June 17–20. This annual award recognises individuals who have served the North American PM industry in an active capacity for at least twenty-five years and who their peers believe deserve special recognition.

Tessa Stillman, the MPIF's Senior Manager, Standards & Technical services , began her career with the federation in 1973 as a part-time typist. Over the years, she has held various management and administrative positions and has worked with numerous boards and committees for the MPIF and APMI. She works closely with the MPIF Technical Board and is said to have guided the annual MPIF/APMI Technical Program Committees, and the related speakers/session chairmen activities, since 1980. Stillman has also been involved in all MPIF standards development work since the early 1980s.

She received SAE International's Forest R. McFarland Award in 2001 for her PM Materials Committee activities, and in 2017 was recipient of ASTM International's B09 Committee on Metal Powders and Metal Powder Products Distinguished Service Award. After forty-five years working with the MPIF, it was announced that she will retire at the end of this year.

www.mpif.org

Caroline Larsson receives Höganäs's Ulf Engström Award 2018

Caroline Larsson has been named as recipient of Höganäs AB's Ulf Engström Award, given annually to an individual working at the company who is said to have laid ground for a commercially successful development in the Powder Metallurgy industry. Larsson works in product management for the company and received the award for her successful development and qualification of Astaloy® PMo, Distaloy® DC, Distaloy® DH, Distaloy® HP, Distaloy® AQ, Distaloy®ACu and the high precision toolbox for Fe+Cu+C mixes.

She was also said to have contributed to development, qualification and launch of other PM powders, such as Starmix® 500i, Intralube® S and Intralube® HD. Each of these products has reportedly played a vital role in Höganäs's growth on the PM market and in increasing the volume of mixes sold.

The award jury cited Larsson's "outstanding technical market support work and her successful development and qualification of PM powders in their motivation." Larsson has been with the company for thirty years, beginning in product development, followed by roles in sales and technical marketing. "I feel surprised, moved and honoured to win the prize in Ulf Engström's name, our true powder pioneer. And that makes me feel proud," she stated during the prize ceremony.

"During her many years at Höganäs, Caroline has given outstanding technical market support to Japan, the USA during the time of Höganäs's start-up in North America, and Europe," the jury wrote. "With her deep knowledge and customer focus, she has contributed to many customers' success."

www.hoganas.com

Caroline Larsson received the 2018 Ulf Engström Award. From L-R: Hans Söderhjelm, Caroline Larsson, Fredrik Emilson and Ulf Engström (Courtesy Höganäs AB)

SMS Group to supply main melting units for voestalpine special steel plant

voestalpine reports that it has commissioned SMS Group, Düsseldorf, Germany, to supply the main melting units for its new special steel plant in Kapfenberg, Austria. Construction of the plant, which voestalpine states will be 'the world's most advanced special steel plant,' began with an official groundbreaking ceremony in April 2018.

The contract covers the provision of the plant's electric arc furnace, converter and secondary metallurgical systems. SMS Group will be responsible for the engineering, process technology, and start-up of the fully automated melting system, which will begin production in 2021. Key partners for the subsequent process systems, such as the entire casting area, and for the construction of the hall are expected to be commissioned in the next few months.

voestalpine is set to invest up to €350 million in the new special steel plant, intended to replace the existing voestalpine Böhler Edelstahl GmbH & Co KG plant in Kapfenberg. Once operational, the plant will reportedly produce around 205,000 tons of high-performance steels annually for the international automotive, aviation, oil and gas industries.

Franz Rotter, Member of the Management Board of voestalpine AG and Head of the High Performance Metals Division, stated, "Awarding the contract for the supply of the main melting units, which represent around one third of the total investment volume, lays the technological basis for the new special steel plant. The SMS Group will contribute its comprehensive know-how to this project, both in the metallurgical systems and in the areas of digitalisation and automation."

In addition to the electric arc furnace, in which ultra-pure scrap and alloys are melted into liquid special steels at temperatures of up to 9,000°C, the SMS Group will also supply after-treatment systems. All systems will be powered by electricity from renewable sources.

voestalpine stated that it expects the technology at the new plant to set new standards worldwide in terms of digitalisation, with a sensor and electronic system enabling the entire production process to be managed from a central control station. voestalpine Böhler Edelstahl and SMS Group will set up their own training centre for employees in Kapfenberg, where all production areas will be simulated virtually.

www.voestalpine.com

International Conference on Powder Metallurgy in Asia heads to India in 2019

The 5th International Conference on Powder Metallurgy in Asia (APMA 2019) will be held at the JW Marriot Hotel in Pune, India, from February 18–21, 2019. The event will be hosted by the Powder Metallurgy Association of India (PMAI) and will welcome delegates from Asia and around the world.

APMA 2019 will be India's largest ever conference on Powder Metallurgy and particulate materials, and is expected to attract over 500 delegates. The conference will showcase the capabilities of the PM industry through technical papers offering updates on research, industry developments and trends across the PM supply chain.

In the exhibit hall, suppliers to and users of press & sinter PM, Metal Injection Moulding, Powder Injection Moulding and Additive Manufacturing will demonstrate their goods and services to the PM industry, with many exhibiting in India for the first time. PMAI stated that it also hopes to secure the attendance of a number of OEM buyers and influencers.

A call for papers has been issued and abstract submissions will close on September 30, 2018. Delegate registration is available via the conference website.

www.apma2019.com

Powder Metallurgy and Additive Manufacturing of Titanium Conference issues Call for Presentations

The 2019 Powder Metallurgy and Additive Manufacturing of Titanium Conference (PMTi2019) has issued a Call for Papers for presentation at its first USA-based event. The conference, which has previously been held in Australia, New Zealand, Germany and China, will be held at the University of Utah, Salt Lake City, Utah, USA, from September 24–27, 2019.

The Metal Powder Industries Federation (MPIF) will sponsor the conference and invites the submission of abstracts on the topics of powder production, compaction and shaping, Metal Injection Moulding (MIM), Additive Manufacturing, sintering, mechanical properties, microstructure vs property relationships, PM Ti alloys including TiAl, PM Bio Ti materials, modelling and applications.

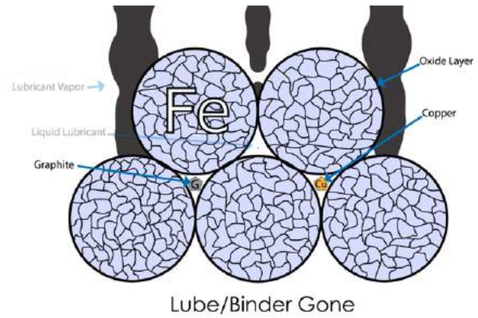
Abstracts are due by April 15, 2019. The MPIF stated that all abstracts will be judged on technical merit and should emphasise results and conclusions in addition to what is new about the work. All manuscripts will be included in the post-conference proceedings.

www.PMTi2019.org

TAT Technologies video offers simplified understanding of sintering for PM

TAT Technologies has released a video which aims to explain the sintering process used in Powder Metallurgy. Aimed to help viewers visualise the journey taken by a PM part from one end to the other of a typical sintering furnace, the two-minute video shows the physical, mechanical and metallurgical transformations undertaken by Fe-Cu-Carbon-Lube green PM parts in a two-hour sintering cycle.

The video is available to view for free via YouTube and offers a simple visual reference for the internal processes that take place when PM material is sintered cleanly and efficiently.



TAT Technologies' new video is designed to offer a simplified understanding of the sintering process (Courtesy TAT Technologies)

TAT Technologies runs a series of popular sintering courses from its training centre in St. Mary's, Pennsylvania, USA. The courses, 'Preparation for Better Sintering' and 'Sintering – Ferrous PM', are aimed at employees in the PM industry who want to learn more about the necessary fundamentals of delubing and sintering. Both offer hands-on training and have common objectives.

The company has announced that the next dates for its sintering courses will be October 16–19, 2018 (Preparation for Better Sintering), and October 22–25, 2018 (Sintering — Ferrous PM).

www.tat-tech.com

CREMER Thermoprozessanlagen receives Fachmetall's PM Qualification Award

CREMER Thermoprozessanlagen GmbH, Düren, Germany, has received the Fachmetall PM Qualification Award 2018 from Fachmetall GmbH, Radevormwald, Germany, a metallurgical laboratory specialising in investigations of Powder Metallurgy and wrought materials. The award is said to recognise CREMER for 'outstanding services to the global Powder Metallurgy industry,' and was accompanied by a certificate and a commemorative sculpture.

Ingo Cremer (centre) accepts Fachmetall's PM Qualification Award from Holger Davin (left) and Georg Schlieper (right) (Courtesy Fachmetall GmbH)

CREMER is a manufacturer of steam treatment and sintering furnaces for Powder Metallurgy applications. The company's MIM-Master, a continuous sintering furnace for Metal Injection Moulding (MIM) based on the walking-beam technique, has played a key role in success of MIM technology over the past 25 years.

Holger Davin, Managing Director of Fachmetall, presented the award to Ingo Cremer, Managing Director of CREMER Thermoprozessanlagen, during the company's annual awards presentation. With the Fachmetall PM Qualification Award and QM Context Award, Fachmetall stated that it aims at drawing the attention of the public to companies with excellent Powder Metallurgy and Quality Management activities.

www.cremer-polyfour.de
www.fachmetall.de

Ricardo collaborates with Toyota on second fuel cell truck

At the recent Center for Automotive Research (CAR) Management Briefing Seminars in Michigan, USA, Toyota Motor Corporation unveiled the second iteration of its Project Portal hydrogen fuel cell electric Class 8 truck.

The group revealed its first 'Alpha' demonstrator vehicle for the project in 2017, and the new 'Beta' iteration is said to significantly exceed its capabilities, increasing the estimated range to more than 300 miles per fill. The Beta truck is also said to enhance versatility and manoeuvrability with the addition of a sleeper cab and a fuel cabinet combination that increases cab space without increasing wheelbase.

For both the Beta and its predecessor Alpha vehicle, global engineering consultancy Ricardo, headquartered in Shoreham-by-Sea, UK, assisted Toyota with a wide range of engineering functions. These included systems integration and packaging for the fuel cells, power electronics, hydrogen tanks, cooling systems, batteries, electric motors and transmission.

Many of the ancillary systems traditionally driven by the combustion engine were also electrified, including the air compressor, power steering and HVAC system, the controls of which required integration into the vehicle's J1939 CAN BUS. Both the Alpha and Beta vehicles were constructed by Ricardo at the workshops of its Detroit Technology Campus in Belleville, Michigan, USA.

With a gross combined weight capacity of 80,000 lbs, the 670+ horsepower Alpha truck produced 1325 pound-feet of torque from two Mirai fuel cell stacks and 12 kWh of battery. The Project Portal Beta is said to maintain these torque and horsepower numbers.

"Our goal with the first truck was to see if it could be accomplished, and we did that," commented Craig Scott, Senior Manager for Toyota's North American Electrified Vehicle & Technologies Office. "This time we're looking at commercial viability. We want to help make a difference - a significant difference when it comes to the air quality not only in the LA area, but across the U.S. and around the globe."

Chris Brockbank, VP of Vehicle Engineering at Ricardo, stated, "The Ricardo team is pleased to have been able to continue our successful collaboration with Toyota on the very important Project Portal heavy duty zero emission fuel cell electric truck demonstration project."

www.ricardo.com
www.toyota.com

Renault to invest more than €1 billion in electric vehicles

Groupe Renault, headquartered in Boulogne-Billancourt, France, has stated that it will accelerate the deployment of its 'Drive The Future' strategic plan by investing more than €1 billion in the development and production of electric vehicles in France.

Drawing on its alliance with Nissan and Mitsubishi, the group reported that it will introduce a new electric platform at its facility in Douai, creating a second Renault electric vehicle production site. The company also announced plans to double ZOE production capacity at its Flins site, the only ZOE production facility globally, as well as launching a new ZOE model.

Renault will triple production of electric motors at its Cleon facility, and introduce a new generation electric motor in 2021. Investment was announced at its site in Maubeuge for the production of the next generation of the Kangoo vehicle, including an electric version of the vehicle, the Kangoo Z.E.

"The acceleration of our investments in France for electric vehicles will increase the competitiveness and attractiveness of our French industrial sites," stated Carlos Ghosn, Chairman and CEO of Renault. "Within the framework of its Drive the Future strategic plan and with the alliance, Groupe Renault is giving itself the means to maintain its leadership in the electric vehicle market and to continue to develop new sustainable mobility solutions for all."

The Renault, Nissan and Mitsubishi alliance is reported to be the combined world leader in electric vehicles, with Groupe Renault stating that it is leading electric vehicle development in Europe. In 2017, Renault posted 38% growth in electric vehicle sales in Europe, with a 44% increase in ZOE registrations and a 23.8% share of the electric vehicle market.

The group has previously stated that it plans to recruit 5,000 employees on permanent contracts in France between 2017 and 2019, and that it will spend €235 million on training over the same period. Renault stated that its plants are adapting to meet the new challenges of the automotive sector, and that it intends to continue the modernisation and digitalisation of its network to ensure a high level of activity at its sites.

www.group.renault.com

MAHLE developing electric motors for hybrid and electric vehicles

MAHLE Group, headquartered in Stuttgart, Germany, reports that it is developing new high-voltage traction motors for fully electrified vehicles (EVs), as well as 48 volt drive motors for new-generation hybrids. The group, which is said to have components in half of the vehicles produced annually worldwide, manufactures high-voltage and low-voltage traction motors for full-sized vehicles, as well as for off-road two-wheel and four-wheel-drive leisure vehicles.

J D Kehoe, Director of Product Development, Filtration and Engine Peripherals for MAHLE Filter Systems in North America, stated that greater internal combustion engine (ICE) downsizing, 48 volt hybridisation, and electric traction motors are all affecting powertrain development. "Downsized internal combustion engines, with higher compression, advanced combustion, high boost and electrified turbocharger actuation will be part of the automotive landscape for decades to come."

"Smaller engines, for example, are expected to deliver 300 horsepower and 30 miles per gallon, with a third less displacement," Kehoe stated, also noting that 48 volt electrical systems are gaining acceptance. MAHLE has also developed electrified HVAC systems and electric auxiliary components such as electric oil coolers and hydraulic pumps. Even electrified riding mowers and material handling equipment have become more common, he added.

MAHLE's 48 volt drive systems are supplied with integrated electronics to govern a typical output of 14 kW (19 hp) and have been demonstrated on passenger vehicles such as the SMART. EVs such as the Chevrolet Bolt, Nissan Leaf or Tesla, have achieved high market profiles, though actual sales remain at 2-3% percent of global deliveries, Kehoe continued. Analyst Alix Partners estimates that by 2023, more than 205 electric models will have entered the market.

MAHLE's high-voltage traction motors for automobiles employ Imbedded Permanent Magnet (IPM) technology. The motors are liquid-cooled and are governed by liquid-cooled controllers. Operating at voltages from 200-400 volts, the power delivered by each motor is up to 100 kW (134 hp) depending on the vehicle's design. Higher-voltage motors, in the 400–800 volt range, offer up to 96% efficiency and peak power output up to 180 kW, or 240 hp.

www.mahle.com

Clarion Sintered Metals recognised with continuous quality award

Clarion Sintered Metals specialises in high-volume production of PM parts for automotive, industrial and agricultural applications (Courtesy Clarion Sintered Metals)

Powder Metallurgy parts manufacturer Clarion Sintered Metals, Ridgway, Pennsylvania, has been recognised by the SRI Quality System Registrar with the President's Award for Commitment. According to the SRI, this award honours companies which have held continuous registration with the Quality System Registrar for twenty or more years.

"This is a great accomplishment for our employees and for our company," stated Dave Bosnik, Vice President of Operations at Clarion Sintered Metals. "Our customers recognise us as a leader in continuous improvement. The award and certification are validation of our commitment to quality."

In addition to this award, Clarion announced that it has recently received certification to the automotive industry's new quality standard, IATF 16949:2016, in addition to recertification under the ISO 9001:2015. The company has two manufacturing facilities in Ridgway, both of which were previously certified to technical specification ISO/TS 16949:2009, which the revised IATF standard replaces.

Established in 1984, Clarion Sintered Metals is one of the largest independently owned Powder Metallurgy parts producers in the world. Specialising in high-volume ferrous-based manufacturing, the company offers a range of design solutions for automotive, industrial and agricultural applications.

www.clarionsintered.com

EPMA reports success of its 2018 Powder Metallurgy Summer School

The European Powder Metallurgy Association (EPMA) held its eighteenth Powder Metallurgy Summer School in Vienna, Austria, July 2-6, 2018, at TU Wien. The five-day programme was hosted and coordinated by Dr Christian Gierl-Mayer, TU Wien, Austria, and Dr Marco Actis-Grande, Politecnico di Torino, Italy.

The programme was delivered by a range of specialists from both industry and academia, whose expertise reflected many key topics currently being employed in today's Powder Metallurgy industry. The course began with an introduction to materials science followed by an introduction to Power Metallurgy. Presentations were then given on metal powder manufacturing, shaping technologies, sintering, and post sintering operations.

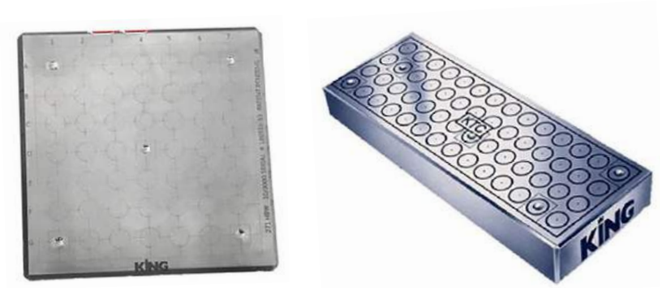
The properties of PM parts were discussed, along with an overview of Metal Injection Moulding and Additive Manufacturing processes. Modelling and a presentation reviewing phase diagrams were followed by a full day of practical work, where Dr Bob Moon and Dr Brian James discussed a number of case studies, organised group problem solving sessions, and conducted hands-on lab work. The last two days included presentations on furnace technologies, hardmetals, light metals and magnets, as well as a detailed look at low alloy steels, special steels and high temperature materials. There was also a tour to Lithoz.

The EPMA Summer Schools are particularly designed for young graduate designers, engineers and scientists drawn from a wide range of disciplines such as materials science, design, engineering, manufacturing or metallurgy. The course is open to graduates, preferably under the age of thirty-five, who have received their degrees from a European university. The EPMA reported that a total of sixty delegates attended this year's Summer School.

www.epma.com

The Summer School included hands-on lab work (Courtesy EPMA)

King highlights test block considerations in hardness testing



A number of factors should be considered when choosing the right test block (Courtesy King Tester Corporation)

King Tester Corporation, headquartered in Phoenixville, Pennsylvania, USA, is a leading manufacturer and distributor of Brinell and Rockwell testers, supplying customers in the aerospace, defense, manufacturing, oil and gas, and heat treating industries. A recent article posted on the company's website highlights the importance of choosing the right test block when performing hardness testing, and identifies the factors to consider in making the correct choice.

It is stated that many people operate under a misconception that they must use a test block equivalent in hardness to the parts or samples they are testing. However, King claims this is not the case. While it is wise to choose a test block within a reasonable range of the same hardness you do not need to match the hardness exactly, it is stated.

The test block is used to indirectly verify the force being applied by the tester is equivalent to the calibrated force of the tester. This is done by using the tester to apply force to a known metal hardness (the test block). The result is then compared to the master indentations on the test block to determine if the tester is applying accurate pressure.

The article discusses a number of key factors to consider. King states that the test block should be within a reasonable range of the hardness of the material to be tested, but it does not need to be exact. The company recommends a test block +/- 50 HBW from the parts target hardness. Conformance with ASTM standards is also said to be an important factor. This means the test block has a limited number of indentation opportunities and may only use the designated test surface, as specified in ASTM E10

King Tester offers ASTM E10 and ISO-17025 certified test blocks in both 2 × 6 and 4 × 4 sizes in a wide range of hardnesses. A patented alphanumeric grid system allows users to log and track daily verifications.

www.kingtester.com

Cincinnati expanding sales team as it enters new markets

Cincinnati Incorporated (CI), Harrison, Ohio, USA, has appointed Eric Blasiman and Nick Thielmann as Sales Engineers for the Midwest US region. Blasiman, who is based at CI's corporate headquarters in Harrison, will be responsible for Northwest Ohio and Southeast Michigan, whilst Thielmann, based in Milwaukee, will cover Wisconsin, Northern Illinois, and Northern Michigan.

Blasiman, a graduate from the University of Toledo, has experience in system design, account management and customer needs analysis. He has previously held design positions with MJ Engineering and Consulting and Kaufman Engineered Systems. "I'm excited to be part of such a fantastic team at CI," he commented. "The opportunity to help our customers sustain and grow utilising CI equipment's comprehensive capabilities is an exciting challenge. I'm looking forward to being part of this process."

Thielmann has experience in electro-mechanical software engineering, industrial IoT systems and account management. He is a graduate of the University of Wisconsin-Madison and previously held product management positions with both ECHO Labs, LLC and Myron Innovations. "I am sincerely privileged to join an organisation so remarkably passionate about its customers, employees and products," said Thielmann. "I'm looking forward to helping fabricators implement the competitive advantages that CI's equipment provides."

Rakesh Kumar, VP of Sales, Service and Marketing for CI, stated, "While CI was already servicing this territory, we wanted to further increase our resources to better serve our customers. Increasing our presence in this area allows us to advance our direct sales approach and deliver on customer expectations."

Cincinnati Incorporated manufactures a range of mechanical and hybrid Powder Metallurgy compacting presses, as well as providing laser cutting and automation technology and other metal fabrication solutions throughout North America.

www.e-ci.com

Air Products introduces new gas density sensor for sintering furnaces

Air Products, Lehigh Valley, Pennsylvania, USA, introduced its new gas density sensor for sintering furnaces during POWDERMET2018, the International Conference on Powder Metallurgy & Particulate Materials, June 17-20, in San Antonio, Texas, USA. The new sensor has been designed to measure the concentration of hydrogen in sintering furnaces that use a nitrogen-hydrogen blend as the hot zone atmosphere.

Continuous measurement and control of the sintering furnace atmosphere is increasingly important in helping metals processors improve quality control, reduce costs and comply with regulatory requirements. During a technical session at POWDERMET, Air Products' Dr Liang He presented a paper titled 'Hot Zone Nitrogen-Hydrogen Atmosphere Monitoring with Gas Density Sensor'.

Dr He discussed the features and benefits of the company's novel gas density sensor, including beta test results taken from continuously measuring the atmosphere in an industrial sintering furnace, for better production process control and consistent product quality.

As well as providing gases, equipment and technology solutions, Air Products offers services for a variety of processes, including powder production, sintering, heat treating, inerting and Additive Manufacturing. In addition to its headquarters in Lehigh, the company also operates laboratories in Allentown, Pennsylvania, for metal processing research and application development, as well as testing for simulating, troubleshooting and optimising customer operations.

www.airproducts.com/mp

Plansee's Digital Days introduce young students to modern manufacturing technology

Plansee held its first Digital Days course, organised in collaboration with Makerspace, at the Chamber of Commerce in Reutte, Austria, July 9–13, 2018. Attended by students aged 15–18, the programme sought to introduce young learners to digitisation and technology across five days of workshops with the theme, 'Let yourself be inspired by modern technology.'

A student presents his Digital Days creation during the event

Topics covered during the week included Additive Manufacturing, CAD, prototyping, laser cutting, robotics and augmented reality. On one day, attendees had the opportunity to present their projects and experiments to teachers and representatives of the Reutte Chamber of Commerce, as well as their parents and family, at a small closing event.

The course organisers reported a high level of enthusiasm from both students and trainers. A second week of Digital Days, attended by twenty-one students aged 12–14, was held at the beginning of September 2018.

www.digital-days.at

IOM³ announces Dr Colin Church as new Chief Executive

Following the announcement that current Chief Executive, Dr Bernie Rickinson, will retire from the UK's Institute of Materials, Minerals and Mining (IOM³) at the end of 2018, the trustees of the institute have announced the recruitment of Dr Colin Church as its new Chief Executive. Dr Church, currently Chief Executive of the Chartered Institution of Wastes Management (CIWM), is expected to take up the position towards the end of 2018 to ensure a smooth handover.

Dr Church holds a PhD in Organic Chemistry and has been Chief Executive of CIWM since 2016. He is also Chair of the Circular Economy Task Force, a Trustee of the CHEM Trust, and has been a member of the Newcastle Waste Commission. Previously, he served as Director, Environmental Quality in the Department for the Environment, Food and Rural Affairs (Defra). He is said to have been responsible for encouraging the government's support for waste infrastructure development, and to have led Defra on climate change mitigation. He has also previously served as a non-executive director of WRAP, the waste reduction and resource efficiency body, and worked as Director, National Climate Change in the Department for Energy and Climate Change (DECC) where he is said to have overseen the setting of the fourth UK carbon budget, implementation of the second and negotiation of the third phase of the EU Emissions Trading System, and the introduction of the Carbon Reduction Commitment.

In 2010-11, he jointly led a successful effort to reduce central government carbon emissions by 10% in twelve months, and was a non-executive director of the Carbon Trust, the carbon reduction and resource efficiency body.

www.iom3.org

Porite Group: A Powder Metallurgy company built on the success of self-lubricating bearings

Established in 1952, Porite Group has a long history of innovation, supplying Powder Metallurgy components to the automotive, power tool, consumer electronics and electrical appliance industries, among many others. Over the years the company has seen rapid expansion, not only in Japan, but at other key locations in Asia and the USA. Dr Yoshinobu Takeda visited Porite Japan on behalf of *PM Review*, and in this article provides a unique view of the company, its products and its key people.

Japan's Porite Group is a leading global producer of oil impregnated sintered bearings, manufacturing these and a wide range of other PM components from its facilities in Asia and the USA (Fig. 1). Headquartered in Saitama-Ken, Japan, the company reported consolidated turnover of around €385 million in 2017 and lists some 4,150 employees across the group.

The company, formerly Tokyo Oil-less Metal Industrial Co., Ltd, was established in 1952 in Saitama Prefecture, Japan, by Tatsunosuke Kikuchi. Today, Porite has manufacturing facilities located in Omiya and Kumagaya, Japan. Two further facilities can be found in Taiwan, with Porite Taiwan Co., Ltd. having sites in Toufen and Chu-Nan. In China, Porite Yangzhou Industrial Co Ltd and Porite (Chen-Zhou) Powder Metallurgy Products Co Ltd both manufacture sintered components. Further production sites are located at Porite Singapore Ltd, Porite Malaysia Sdn Bhd, Porite India Private Ltd and Porite Jefferson Corp in Missouri, USA. Warehouses and sales offices can also be found in Hong Kong, the USA, France and Germany.

Prior to founding the company, Kikuchi worked for a leading Japanese mining company, Kuhara Mining (becoming Nippon Mining in 1929, now a wholly-owned subsidiary of JXTG Holdings). At that time, Kuhara Mining was affiliated with Hitachi Ltd, and for some time Kikuchi worked as a Development Engineer for Hitachi, where he is said to have made numerous

Fig. 1 Self-lubricating bearings have been key to the success of Porite Group

Fig. 2 A selection of the sintered components currently produced at Porite

valuable inventions and gained the nickname 'Edison in Asia'.

In 1934, Kikuchi was assigned to work as the Plant Manager at Dungun Mine, an iron ore mine in Malaysia. Here he gained valuable experience of company management, as well as suffering from a bout of malaria. While working in Dungun, he also encountered Japanese-speaking Taiwanese merchant, Sou. Together, Kikuchi and Sou would later found the Porite Taiwan partnership.

In 1946, following the conclusion of the Second World War, Kikuchi returned to Japan where he found employment with a PM bearing company belonging to Nikko Mining. This was Kikuchi's first encounter with PM bearing manufacture and, although he foresaw the market potential of the product, he found that improvements could be made in the process. One of his patented inventions, granted in 1951, was an effective manufacturing method for electrolytic copper powder which eliminates the need for reduction annealing. This invention greatly contributed to the growth of the Japanese PM Industry and was later recognised with an award from the Japan Institute of Invention and Innovation in 1960.

The birth of Porite

In 1952, Kikuchi established Tokyo Oil-less Metal Industrial Co., Ltd, and began to manufacture and sell bronze alloy bearings. Thanks to the rapid growth of the Japanese electronics and white goods industry, as well as his innovative ideas, the company quickly gained a reputation for performance and quality. In 1956, his brother-in-law, Isamu Kikuchi, joined the company, driven by a strong interest in manufacturing and particularly in Powder Metallurgy.

In 1993 the company changed its name to Porite. A word created from 'Por' for porous and 'ite' as in minerals and products.

Expansion overseas

Building on the success of the company, Kikuchi began looking to establish overseas manufacturing sites. Led by Sou, a sales office was opened in Taiwan in 1962 and Porite (then still known as Tokyo Oil-less Metal Industrial Co. Ltd.) began marketing its products to Taiwanese industries. In 1967, following encouragement from Taiwan's government, Porite established its first Taiwanese manufacturing plant, becoming the company's first overseas subsidiary.

Now CEO of Porite Taiwan, Chiu-Lung Chu, joined the company after a chance meeting with Kikuchi. One evening, while eating in a restaurant close to Porite Taiwan's plant, Kikuchi encountered an intelligent young man leading a fierce discussion with his senior colleagues. Kikuchi had a keen eye for talent and he persuaded the man to join Porite the very next day. The young man was Chu, and, after joining the company, he worked for two years at Porite Japan, studying PM technology and Japanese managerial methods. He would later prove his talent and has led Porite Taiwan to great success.

A global brand

Porite has continued to grow over the years, establishing further manufacturing facilities in Japan, China, Malaysia, India and the USA. The growth of the company, its successful development and subsequent globalisation, is largely due to Kikuchi and the involvement of his brother-in-law, Isamu Kikuchi (currently Director and Executive Adviser at Porite Corporation); his son, Masanori Kikuchi (now Chairman of Porite Corporation); and Chiu-Lung Chu (CEO of Porite Taiwan). As a result of Porite's success, all three Kikuchis have been decorated with the Japanese Government's Order of the Rising Sun for their significant contribution to the local economy and their industry.

Fig. 3 Porite manufactures a wide range of sintered self-lubricating bearings for numerous applications

Bearing development drives further growth

Today, Porite Group's product lines include oilless (self-lubricating) bearings, machine parts, metal injection moulded (MIM) parts, interconnectors for solid oxide fuel cells (SOFCs), components from Soft Magnetic Composites (SMC) and many more. Among them, oilless bearings are still the most important products for Porite.

In order to meet market demands, Porite has incorporated efficient mass production processes through technical innovations and material developments. The company has developed a number of materials for its bearings, starting with Zn containing bronze in 1964, Fe-Pb alloy in 1968, Fe-Zn alloy (YBF) and bronze with Fe (BCF) in 1980. Outside of these material developments, the company has also engineered new designs. One such product was the Nakanige (translated as 'undercut in the middle') bearing in 1984.

Nakanige bearings give the concentricity of upper and lower twin bearings a higher degree of precision, as the twin bearings are actually a single bearing. As a result, assembly cost is eliminated, reducing the production cost for motors using

JPMA PM Awards presented to Porite 2016 - 2006	
2016	Sintered bearing with dimple on inner surface for high-efficiency motor
2015	Bearing for linear vibration actuator to be used in wearable device
2014	Heat resistant sintered oilless bearing for valve switching motor
2013	Sintered bearing for battery cooling fan motor, used for HEV and EV
2012	Low-noise oil-impregnated bearing for a laptop fan
2011	Oil-impregnated sintered bearing for ultra high-speed motor 48,000 rpm
2010	Sintered bearing with superior wear resistance for high load & long-life
2009	Sintered oil impregnated bearing material for fan motor having low cost and long life
2008	Stop ring with flange at the top and bottom for fan motor
2007	Low cost oil-impregnated bearing with superior low & high temperature properties for motors in automobiles
2006	Sintered bearing for high rotation speed range of over 40,000 rpm

Table 1 Porite has been recognised by the JPMA for its development of sintered bearings since 2006

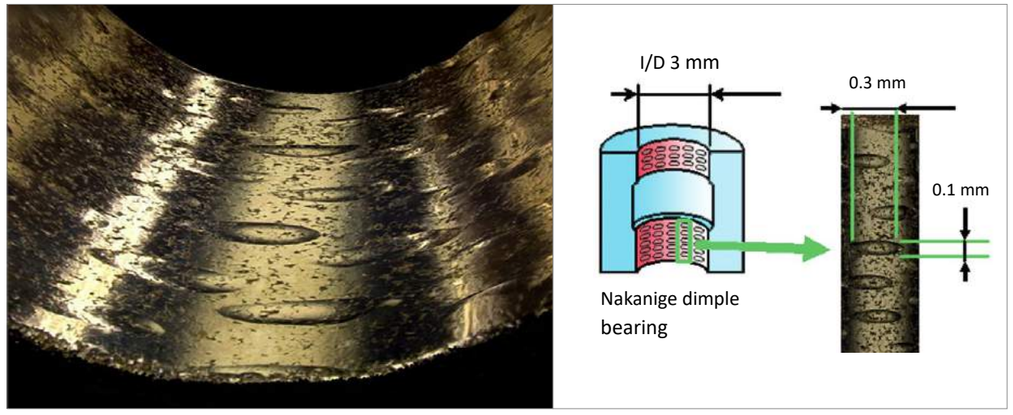


Fig. 4 This award-winning bearing features microscopic dimples on its inner surface

this type of bearing. The Nakanige bearing design was achieved using Porite's proprietary post-sintering process and was a key component in Panasonic's power driver, used on the Challenger spacecraft in 1984.

Table 1 shows examples of Porite bearings which have received JPMA awards since 2006. The list clearly demonstrates Porite's commitment to R&D, highlighting a programme of ongoing bearing development. The latest award-winning bearing is shown in Fig. 4, where the microscopic dimples on its inner diameter can be seen. Using this design, the friction coefficient was reduced by 40% in a rotational range between 200–4500 rpm, while maintaining a tight bore tolerance of 3 μm.

Product development is conducted in close partnership with Porite's customers, as well as at the company's own testing and evaluation facilities. Bearing performance is typically shown with the PV value (MPa m/min), radial crushing strength, friction coefficient, temperature range, load bearing performance, bearing life, noise, etc. Performance depends on material, pore structure and dimensional tolerance, as well as the impregnated oil. Each application must meet a combination of performance targets matching to its specific service conditions. Porite has also co-developed customised oils (PSL, PVL, PML, PSR and POR) for use with its bearings.

Porite Taiwan's facility, located in Tou-Fen Tseng, Miaoli County, is dedicated to the production of a range of micro bearings. This factory alone has a monthly production capacity of up to 200 million parts.

Fig. 5 PM micro gears with a module of 0.1

A move to component part production

In 1970, Porite began to develop machine components. In 1971, it became a distributor for automotive engine and shock absorber components. It continued to expand its material line, adding brass for relay components, stainless steel components and aluminium pulleys for office machines.

Dimensional tolerance

Along with material development, Porite has significantly improved the dimensional tolerance of various components. In 1995, a gear with a module of 0.2 was developed using the company's customised fine powder and high-precision compaction tools. Further development resulted in a component with a gear module of 0.1 in 2007 (Fig. 5). In 1996, Porite developed its first gear meeting Japan Gear Manufacturers Association (JGMA) class 1 specifications for use in printers. Following the company's investment in injection moulding machines in 1999, Porite also produced a plastic injection moulded gear with JGMA class 1 for motors.

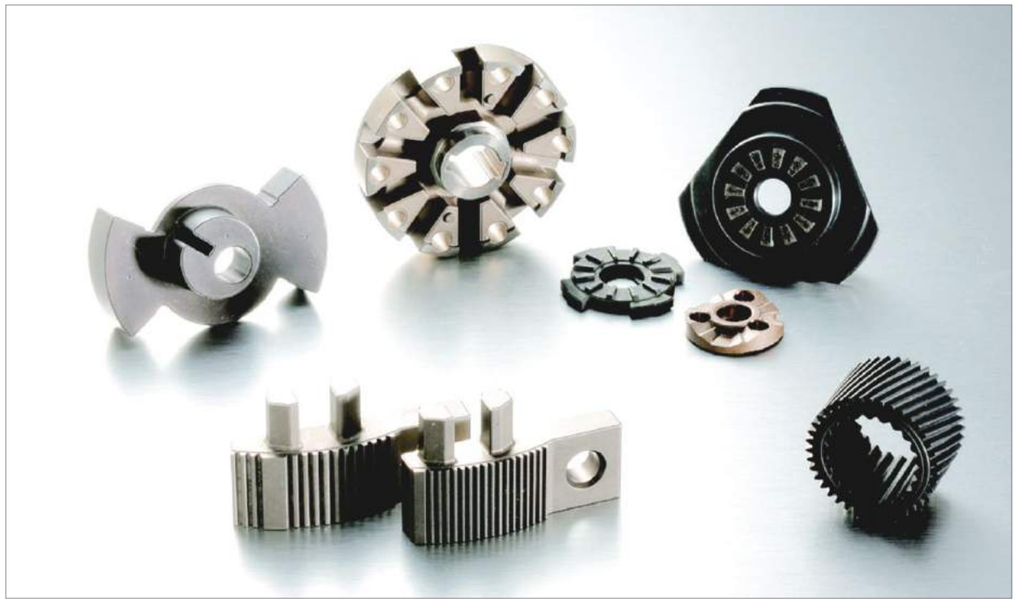


Fig. 6 A selection of Porite's JPMA Award-winning automotive components

Metal Injection Moulding and micro machine parts

It was seen as a natural next step for Porite to enter the Metal Injection Moulding business, as the company was familiar with the market needs and equipped with the technology for both PM and plastic injection moulding. In 1999, it began commercial production of drum coupling components for office machines. MIM production was established at Porite Taiwan and Porite Japan began a focus on micro machine parts.

In 2000, a second plant which provided 4000 m^2 floor space was established in Kumagaya for the production of sintered components for the automotive, robotics and technology markets. Since then, many automotive components have been manufactured by Porite, with a number of them receiving JPMA awards (Fig. 6).

A broad range of components

While Porite Japan has been differentiating itself through a move to small machine parts, Porite Taiwan and Porite China have been developing and producing a wider range of parts, including those for automotive applications such as VVT components, synchroniser hubs, timing pulleys, oil pump rotors, planetary carriers, clutch hubs, primary driven gears for motorcycles, EPS components, etc. In the non-automotive sector, components are produced for agricultural machinery, sewing machines,

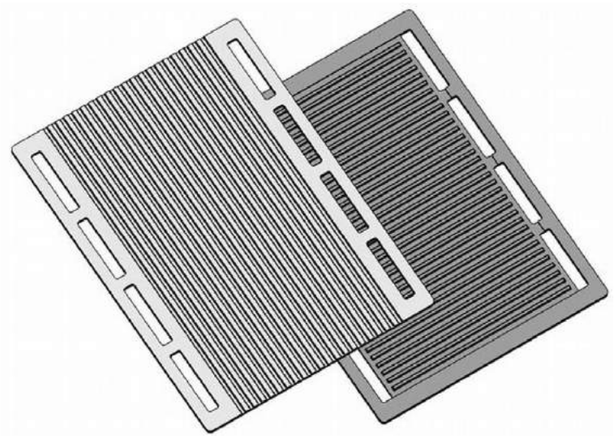


Fig. 7 SOFC interconnectors are manufactured by Porite

Fig. 8 Sintered components manufactured at Porite Taiwan now account for 45% of the group's total production

	Bearings	Mechanical parts	Metal Injection Moulding
Porite Japan	✓	✓	✓
Porite Taiwan	✓	✓	✓
Porite China	✓	✓	
Porite Singapore	✓	✓	
Porite USA		✓	
Porite Malaysia	✓		
Porite India		✓	

Table 2 Manufacturing product lines at Porite subsidiaries

power tools, woodworking, office machines, HVAC and others. As a result, both Porite Taiwan and Porite China have established themselves as major PM companies in their own right.

Another important product for Porite Taiwan is the manufacture of solid oxide fuel cell interconnectors (Fig. 7). Made of a Cr alloy having excellent corrosion resistance, these connectors can prove challenging to manufacture.

Developments in production equipment

Porite has a history of innovation not only in material and component development but also in production processes. In 1965, Isamu Kikuchi led the development of a sizing process stage for manufacturing bearings. By modifying an existing stamping presses, the new sizing press removed the need for final machining.

In the late 1960s, Porite was using manual compaction presses with a capacity of around 500 pcs/hour. To increase this capacity, Tatsunosuke Kikuchi successfully developed an automated compaction press built from a collection of various motors and parts from manual presses. The automated compaction press he developed resulted in a production capacity four times greater than that of the manual press.

Smaller components

With consumer markets moving towards ever smaller products, Porite recognised that the future lay in the miniaturisation of motors and shafts. In 1987, Masanori Kikuchi began the SX-P project, designed to secure Porite's future through the development of miniature bearings for small motors (outer/inner diameters are 1.0/0.5 mm). The project included the development of compaction presses, sizing presses, material handling systems, inspection equipment and high-precision compaction and sizing tools.

In 1988, the company successfully developed its SOMA-2 compaction press and, in 1993, the FUNA-2 sizing press was developed and entered use. Furthermore, a multi-step press, having two upper and three lower levels, was co-developed with a press company for the purpose of making integrated bearings with housings. A compact sintering furnace, TAKE3200, was also developed to meet the company's specific needs.

Multi-level compaction presses

Porite also introduced multi-level compaction presses from third party press makers for the production of intricate components. In 1987, the company installed its first 200 t multi-level press and, in 1989, a 60 t press was introduced. In 1993, the company installed its first CNC 200 t hydraulic compaction press.

High-temperature sintering

A high-temperature sintering furnace with a rapid cooling system was introduced in 1989, and warm compaction equipment installed in 1990. In 2008, a carbonitriding furnace was introduced to minimise the company's outsourcing of heat treatment.

Ongoing investment

Innovation and investment across the group keeps Porite at the forefront of the Powder Metallurgy industry. Today, Porite Taiwan has a greater capacity than at Porite Japan, and in fact the Taiwanese subsidiary now contributes around 45% of the total production of the Porite Group (Fig. 8). It is not only the leader of Taiwan's Powder Metallurgy industry, but one of the leading manufacturers in the world. Modern CNC presses and induction hardening furnaces have been imported from Germany, and both Porite Taiwan and Porite China are well-equipped with modern automation systems and modern machinery.

Future plant design

In Summer 2018, Porite Japan announced plans for an IoT (Internet of Things)-style plant for the manufacturing of helical drive pulleys for EPS. The plant comprises two compaction presses, one sintering furnace and four finishing machines, as well as an automated inspection line and robotised packaging line. Once evaluated, this plant concept is expected to be introduced at other sites within the group.

Fig. 9 PM processed amber in luxury watch faces

Commitment to research and development

For every manufacturing company, R&D is key to growth. As the continued successful development of new products and production technology has shown, Porite is home to an extremely capable R&D department. However, in addition to internal R&D, the company also runs collaboration projects with academia and other companies. Boosted by governmental subsidies, these projects have resulted in the understanding and development of some challenging applications. Examples of research areas in which official reports have been published include: optimisation of filling, die wall lubrication, bearings made of metal glass powder and high-precision compaction methods.

According to a patent search at the National Center for Industrial Property Information and Training (J-Plat Pat), sixty patents have been filed under Porite's name. Among them, forty-six patents were related to bearings and fourteen were related to various unique materials, manufacturing methods etc. One patent filed under Porite's name is for amber manufacturing using natural amber powders. This novel development was the result of a project following the Great East Earthquake and Tsunami of 2011, in collaboration with Iwate University and Kuji Amber KK. As part of the project, Porite exploited their PM technology for the compaction and sintering of amber powder (Fig. 9).

Former President Ma, Chu and Kikuchi at Porite Taiwan's 50th anniversary

Fifty year anniversary celebrations at Porite Taiwan

Porite Taiwan marked its 50th anniversary in 2018 with a celebration attended by over six hundred guests, including the former president of the Republic of China (Taiwan), Ma Ying-jeou, cementing Portite Taiwan's reputation as one of the most important manufacturing companies in the country.

Environmental responsibility

Porite is committed to meeting environmental regulations, actively reducing waste and moving towards zero environmental pollution. The company's latest plant in Kumagaya employs photovoltaic power generation, 250 kW SOFCs, and uses liquefied hydrogen/nitrogen for sintering (Fig. 10). Due to its active approach towards environmental protection, the company has received Green-partner certification from its customers.

A global strategy and global workforce

According to Isamu Kikuchi, Porite's global strategy has been based on the question: "What is the best way to supply the products the customer needs, at their location, and at this point in time?" Following this strategy has led to the opening of Porite's plants in Taiwan, Singapore (1979), Yangzhou China (1992), Malaysia (1999), USA (2002), Thailand (2012; closed due to flooding) and India (2015). Porite has sales offices in France, the USA and Hong Kong.

Fig. 10 A 250 kWh SOFC power system installed at Porites Kumagaya plant

Of course, many factors influence the location of new facilities, especially when these are to be in a different country. For example, when selecting Singapore as its second overseas plant, Porite had three other candidate countries in mind: Brazil, Korea and Pakistan. One of the main reasons for choosing Singapore was the strong support and encouragement of its government. Porite was given permission for the plant's construction within seven days, as well as receiving pioneer status, with five years of tax benefit privileges.

In such a globalised company, technology and information sharing and internal communication are of crucial importance. Porite's employees are often given the opportunity to work at other plants within the group, not only gaining experience of other methods, but also of other cultures. Across the Porite Group, 70% of its employees speak Chinese as their first language, but English is used as a common language for cross-group communications.

The group also holds internal meetings, at which its global subsidiaries share their latest developments and experiences. Tatsunosuke Kikuchi believes in the importance of enabling every employee, irrespective of culture or language, to understand the company's policy, plan and direction. This has more value, he says, than the losses resulting from delays in production due to upper management explaining directly; a belief that has been inherited by subsequent senior management. In 2013, Porite also introduced SAP ERP, a cloud-based enterprise resource planning tool providing a total management system for the group.

Future prospects

The value of sales at Porite Japan, compared with the value of sales for all members of the Japan Powder Metallurgy Association (JPMA) in the past fifteen years, is shown in Fig. 15. This comparison reveals that Porite Japan has grown at a relatively faster rate than the total JPMA membership. "Our business depends on Japanese industries like automotive, home appliances and business machines," stated Isamu Kikuchi. "As PM technology seems to be levelling off, we need to focus on how to sell our products to meet new market demands." This statement seems to reflect a growing need to respond to rapid market changes in the industry, such as the electrification of vehicles, autonomous driving and Additive Manufacturing, which may offer both challenges and opportunities to the PM industry. "We cannot expect growth in the Japanese market however; the growth will be elsewhere in Asia, including India," he added. "Therefore, Porite needs to be more international." As a group, the company already employs a wide and diverse range of employees. With the Kikuchi's company motto in mind, 'Sincerity and technology are the foundation of our company and we all take pride in them,' Isamu Kikuchi believes that the company must now exploit its competence and keep growing in the global market.

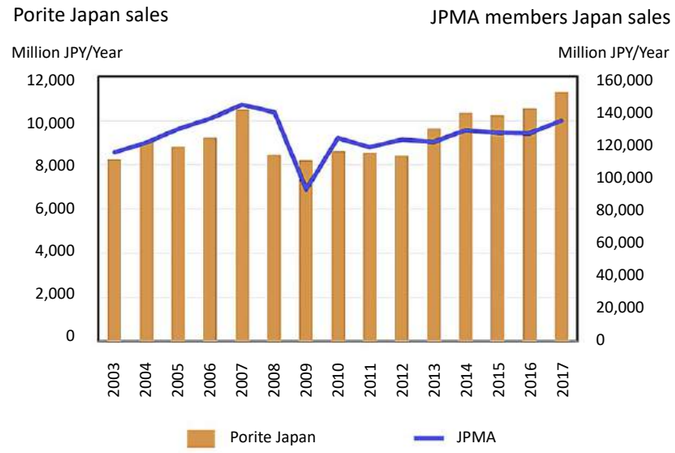


Fig. 11 Sales for Porite Japan compared with all JPMA members (Courtesy JPMA)

Acknowledgements

The author gratefully thanks Isamu and Hirobumi Kikuchi (Vice President) and Porite Japan for providing valuable historical information, data, photos and the interview.

Author

Dr Yoshinobu Takeda
International PM Consultant.
A member of JPMA, JSPM, EPMA, APMI and international committee member of ISO TC-119.
Email: ilikepmtakeda@yahoo.co.jp

Sputtering targets: The advantages of Powder Metallurgy in the production process

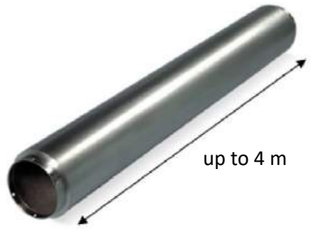
Though production of sputtering targets could be considered a niche application, Powder Metallurgy processes are widely used for the manufacture of a significant range of different coating source materials. In this article, Plansee SE's Jörg Winkler and Christian Linke review the major materials and applications of sputtered and arc-deposited thin films, describe important material and product characteristics of a sputtering target to achieve a stable coating process, and highlight the specific advantages of PM.

Sputter deposition and arc evaporation belong to the group of Physical Vapour Deposition (PVD) technologies. PVD coating processes are widely used for the vacuum deposition of functional thin films, ranging from a few nanometers up to several micrometers in thickness, in a multitude of applications. In these processes the source material is provided as a solid plate, disc or tube, called a sputtering target or arc cathode, which is consumed during the coating process. For ease of comprehension, when referring to the coating source we will only use the terms 'sputtering target', or just 'target' in this article, but most of the discussion also applies to arc cathodes.

Depending on the substrates or parts to be coated, different coating equipment with sputtering targets or arc cathodes in various sizes and shapes is used. R&D deposition equipment often relies on 50–100 mm disc-shaped targets with a thickness of 4–8 mm (Fig. 1); mass production coaters typically require rectangular targets with 1–3.8 m in length, 150–250 mm in width and 10–20 mm thickness. For high-throughput systems, rotary targets of 1–4 m in length are commonly used. Coating sources are available from almost

Fig. 1 Plansee's PVD application laboratory performs sputtering in near-real life conditions

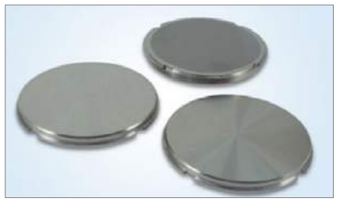
Large-size Mo planar target for the flat panel display industry (pressing & sintering, hot rolling)



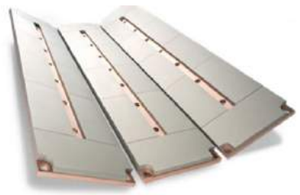
Cr rotary target for architectural glass coating (thermal spraying)

Ultra-high purity W targets for the semiconductor industry (hot pressing or hot isostatic pressing)

AIX arc cathodes for tool coating application (pressing & forging)



TiSi targets for hard coating applications (spark plasma sintering)



Ceramic TiB_2 target bonded on a copper cooling plate (vacuum hot pressing)

Fig. 2 Example of various sputtering target and arc cathode designs, shapes, and sizes for various applications, made by powder metallurgical processes

all inorganic materials, metals, alloys, intermetallics, ceramics and composite materials. Examples of various sputtering target and arc cathode designs can be seen in Fig. 2.

The sputter deposition process

The operating principle of a sputtering process with a planar target is shown in Fig. 3. The sputtering target is generally mounted on a water-cooled backing plate in a vacuum chamber. The substrate to be coated is placed at a distance of 60–120 mm face-to-face with the target. Argon (Ar) gas is introduced into the chamber up to a typical working gas pressure around 5×10^{-3} mbar (0.5 Pa) and a positive voltage of 300–500 V is applied to the target. A plasma discharge ignites in the chamber, consisting of positively charged Ar ions, electrons, and non-ionised Ar. Due to the electric field, the positive Ar ions are accelerated towards the negatively charged cathode, i.e. the sputtering target.

The sputter process can be compared to billiards. The incoming Ar ion hits the surface of the target and its kinetic energy is transferred to other atoms, comparable to the cue ball hitting a rack of coloured balls. Some target atoms gain enough energy to be ejected from the surface (this process is called sputtering), travel some distance through mostly empty vacuum, and as they condense on the substrate surface, atom by atom, a thin film is formed [1, 2].

The magnetron sputtering process is quite inefficient; depending on the target material, sputtering gas and voltage, only 0.2–2 target atoms are evaporated per impinging Ar ion (with ~400 eV kinetic energy) [3]. More than 90% of the electric power is converted into heat, therefore the target must be cooled efficiently. It is either mechanically clamped, glued (conductive epoxy resin), or soldered with indium ('bonded') on a copper backing plate. A magnetron assembly is located underneath to concentrate the plasma near the target surface and to enhance the sputtering rate.

Sputtering is a very versatile thin film coating process, as almost any material can be deployed. Electrically conductive materials are typically operated with DC (direct current) power, while insulating materials are run in RF (radio frequency alternating current) mode. Using a metal sputtering target, e.g. Ti, and adding oxygen (O_2), nitrogen (N_2), or hydrocarbon gas such as acetylene (C_2H_2) into the working gas will result in the formation of Ti-oxide, Ti-nitride or Ti-carbide thin films, respectively. Besides flat, sheet-type substrates, complex-shaped parts can also be coated efficiently when mounted on a planetary rotatable substrate carrier (e.g. hundreds of cutting tools can be coated in a single batch). Deposition rates (i.e. film growth rates) are typically in the range of 2–200 nm/min, and thickness uniformity can be quite high, depending on the application (± 5–10%).

While material utilisation for planar targets is limited to about 40% due to the uneven material erosion track in magnetron sputtering, almost 80–85% of the material of a rotary target can be used for coating films. In addition, rotary targets can be operated at a higher power, enabling higher deposition rates and shorter coating cycle times, as cooling is more efficient (cooling water flows in the inside of the tubular target). Rotary targets made from brittle materials or materials with higher porosity are generally produced by bonding the material to a metallic supporting tube. Materials with enough strength and ductility are made as monolithic types, not requiring a supporting tube.

One major advantage of sputtering is that it allows the operator to tune the thin film properties, especially residual stress, from tensile to compressive, by adjusting the working gas pressure [4], or applying a negative DC bias potential (about 80 V) to the substrate [5]. High compressive stress is often required in wear-resistant tool coatings. In addition, the deposited films are usually very clean and dense, as the process is performed under vacuum. This is especially critical for electronics applications, and high-quality low-resistivity Cu or Al thin films can only be grown by sputtering [6].

However, the vacuum nature is also one of the most commonly mentioned disadvantages of all PVD processes, as vacuum components (chambers, load-locks, pumps, pressure gauges) are expensive and laborious to maintain. From experience, the higher fix-costs of a PVD process can usually be offset by the high throughput of the system, and variable costs are comparable to a non-vacuum process.

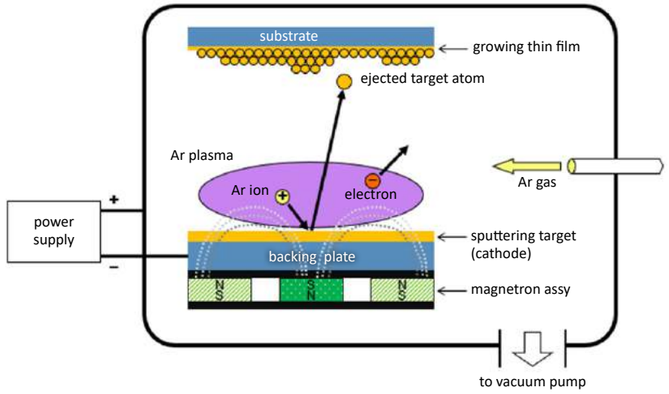


Fig. 3 Operating principle of the sputter deposition process

Applications of sputtered thin films

Functional thin films deposited by a sputtering process are used in numerous applications, including architectural glass, microelectronics, flat panel displays, tool/wear parts/

Large area coating, spectrally selective glazing (low emissivity coatings, anti-reflection coatings)			
Sputtering target material	**Typical target manufacturing method(s)**	**Thin film material (coating)**	**Thin film function**
Ag, Ag-Alloys	VIM-C-W	Ag	reflector layer
Si	TS, C	Si_3N_4, SiO_2	high / low-refractive index layer
SiAl	TS, C	$SiAlO_x$	low-refractive index layer
TiO_x	TS	TiO_2, TiO_xN_y	high-refractive index layer
Ti	C-W	TiO_2, TiO_xN_y	high-refractive index layer
Zn	C	ZnO_2	base coat, transparent conductive oxide
ZnAl-2 wt.%	TS	ZnO_x:AlO_x ("AZO")	transparent conductive layer
ZnO/Al_2O_3 (98/2 wt.%)	P-S, HP, HIP	ZnO_x:AlO_x ("AZO")	transparent conductive layer
NiCr-20 wt.%	VIM-C	$NiCrO_x$	top coat (chemical, mechanical resistant)
Sn	C-W	SnO_2	protective layer, optical interference layer
Cr	TS, HIP	Cr_2O_3, CrO_xN_y	optical interference layer
In_2O_3/SnO_2 (90/10 wt.%)	P-S, HIP	InO_x:SnO_x ("ITO")	transparent conductive layer

*Table 1 Applications of thin films, target and thin film materials, and functions in large area coating, spectrally selective glazing (low emissivity coatings, anti-reflection coatings)**

*For the sake of completeness, target materials not manufactured by PM are included, as indicated in the second column (VIM: vacuum induction melting; EBM: electron beam melting; C: casting; W: cold or hot working; TS: thermal spraying; HP: hot pressing; SPS: spark plasma sintering; HIP: Hot Isostatic Pressing; P: pressing; S: sintering; SF: spray forming); for most applications, thin films are deposited by magnetron sputtering, except for tool & parts coating applications, where cathodic arc evaporation is more prominent.

Microelectronics (integrated circuits, memory, logic, MEMS)			
Sputtering target material	**Typical target manufacturing method(s)**	**Thin film material (coating)**	**Thin film function**
Al	C-W	Al	interconnect
AlCu-0.5...4 wt.%	C-W	AlCu	interconnect
AlSi-1...2 wt.%	C-W	AlSi	interconnect
AlCuSi	C-W	AlCuSi	interconnect
Cu	C-W	Cu	interconnect
Ti	C-W	Ti, TiN_x	diffusion barrier in Al process
Ta	EBM-W	Ta, TaN_x	diffusion barrier in Cu process
W	HP, HIP	W	gate metal
Ni	C-W	Ni	metallisation (front end)
Co	C-W	Co	metallisation (front end), gate
Au	C-W	Au	bond pad metallisation (back end)
AuSn	C-W	AuSn	bond pad metallisation (back end)
NiV-7 wt.%	C-W	NiV	bond pad metallisation (back end)
WTi-10 wt.%	HIP, HP	WTi	diffusion barrier (packaging)
$Pb(Zr_xTi_{1-x})O_3$	P-S, HP, HIP	$Pb(Zr_xTi_{1-x})O_3$ ("PZT")	piezoelectric film (RF filters)
AlSc	C-W, HP, HIP	$AlScN_x$	piezoelectric film (RF filters)
Mo, W	P-S-W, HIP	Mo, W	Bragg reflector (RF filters)
Si	C	Si	Bragg reflector (RF filters)

*Table 1 contd. Applications of thin films, target and thin film materials, and functions in microelectronics (integrated circuits, memory, logic, MEMS)**

Flat panel displays (thin film transistors; TFTs)			
Sputtering target material	**Typical target manufacturing method(s)**	**Thin film material (coating)**	**Thin film function**
Al	C-W	Al	TFT metallisation
AlNd-1 wt.%	SF-W	AlNd	TFT metallisation, less hillock formation
Cu	C-W	Cu	TFT metallisation
Mo	P-S-W, HIP	Mo	adhesion promotion and diffusion barrier
MoX (X = W, Nb, Ti, Ta)	P-S-W, HIP	MoX	adhesion promotion and diffusion barrier
Ti	C-W	Ti	adhesion promotion and diffusion barrier
W	P-S-W	W	adhesion promotion and diffusion barrier
In_2O_3/SnO_2 (90/10 wt.%)	P-S, HIP	InO_x:SnO_x ("ITO")	transparent conductive layer
$InGaZnO_x$	P-S	$InGaZnO_x$ ("IGZO")	semiconductor
Ag, AgX	VIM-C-W	Ag, AgX	OLED anode and reflection layer

*Table 1 contd. Applications of thin films, target and thin film materials, and functions in flat panel displays**

*For the sake of completeness, target materials not manufactured by PM are included, as indicated in the second column (VIM: vacuum induction melting; EBM: electron beam melting; C: casting; W: cold or hot working; TS: thermal spraying; HP: hot pressing; SPS: spark plasma sintering; HIP: Hot Isostatic Pressing; P: pressing; S: sintering; SF: spray forming); for most applications, thin films are deposited by magnetron sputtering, except for tool & parts coating applications, where cathodic arc evaporation is more prominent.

decorative coatings, optical coatings (e.g. eye glasses, precision optics), solar cells, data storage and others (Table 1) [2, 7, 8, 9].

In terms of area and material consumption, architectural window glass is by far the largest and most widespread application, with an annual coated area of more than 1000 million m^2. One glass substrate can be up to 3,300 mm wide and 6,100 mm in length ('Jumbo size'). The sputtering target (mostly rotary) is installed straight across the width of the substrate and is typically some 150–300 mm longer on each side, to ensure high film thickness uniformity (< ±5%). The glazing is coated with a multilayer stack of different materials, combining highly optically reflective materials like Ag with transparent dielectric or electrically conductive metal oxides with high and low refractive indices. The thickness of each individual layer is only in the range of 5-50 nm. The film stack either acts as an anti-reflection coating, or as a so-called spectrally selective coating (low emissivity or 'low-E' coating), being transparent for visible light and reflective for infrared (IR) radiation. Depending on which side of the window glazing this coating is applied to, it will keep a building warm (if applied to the inside), or cool (if applied to the outside). In large area coating, most of the sputtering target materials are either cast or produced by atmospheric plasma spraying of powder directly onto a supporting tube. In the latter case, used targets can also be refurbished after reaching the end of their lifetime [10].

"In terms of area and material consumption, architectural window glass is by far the largest and most widespread application"

Sputtering targets for microelectronic applications are the largest application by revenue, with a market size of almost $700 million per annum [11]. Substrate sizes to be coated are the standardised, common sizes of silicon wafers, i.e. 200 or 300 mm diameter, with the 450 mm process in introduction phase. The diameter of the disc-shaped sputtering target is typically around 1.5 x the wafer diameter. Thin films are only a couple of 10 nm in thickness, and mainly used as interconnects, metallisation or diffusion barriers (Ti- and Ta-Nitride) [7]. The semiconductor industry primarily requires ultra-high purity

Tool, parts, and decorative coatings			
Sputtering target material	**Typical target manufacturing method(s)**	**Thin film material (coating)**	**Thin film function**
TiAl (+ Si, Ta, V, B, Cr, Y,...)	P-W	$(TiAl)N_x$	wear-resistant coating for cutting tools
AlCr (+ Si, Ta, V, ...)	P-W	$(AlCr)N_x$	wear-resistant coating for cutting tools
Cr	HIP	Cr/CrN_x	adhesion layer for DLC, decorative coating
Cr	HIP	CrN_x	high-hardness, low-friction coatings for combustion engine components
WC	HP	WC/C	low-friction layer for tribological applications
TiSi	SPS	$(TiSi)N_x$	wear-resistant coating for cutting tools
C	S	DLC	low-friction, high wear resistant for tribology
CrW	SPS	$(CrW)N_x$	wear-resistant coating for forming tools
TiB_2	HP	TiB_2	cutting tools for aluminium alloys
Ti, Zr	C	TiN_x, ZrN_x	decorative, wear-resistant coatings

*Table 1 contd. Applications of thin films, target and thin film materials, and functions in tool, parts, and decorative coatings**

*For the sake of completeness, target materials not manufactured by PM are included, as indicated in the second column (VIM: vacuum induction melting; EBM: electron beam melting; C: casting; W: cold or hot working; TS: thermal spraying; HP: hot pressing; SPS: spark plasma sintering; HIP: Hot Isostatic Pressing; P: pressing; S: sintering; SF: spray forming); for most applications, thin films are deposited by magnetron sputtering, except for tool & parts coating applications, where cathodic arc evaporation is more prominent.

Precision optical coatings (filters, anti-reflection coatings, mirrors)			
Sputtering target material	**Typical target manufacturing method(s)**	**Thin film material (coating)**	**Thin film function**
Nb	EBM-C-W, HP	Nb_2O_5	anti-reflection coating (high index)
Nb_2O_{5-x}	HP, HIP	Nb_2O_5	anti-reflection coating (high index)
Ti	C-W	TiO_2, TiN	anti-reflection coating (high index)
TiO_x	TS	TiO_2	anti-reflection coating (high index)
Hf	EBM-C-W	HfO_2	anti-reflection coating (high index)
CeO_2	P-S	CeO_2	anti-reflection coating (high index)
Si	C	SiO_2, Si_3N_4	anti-reflection coating (low, high index)
Al	C-W	Al	reflective layer
		Al_2O_3	anti-reflection coating (low index)
ZnO	P-S	ZnO	anti-reflection coating
SnO_2	P-S, HIP	SnO_2	anti-reflection coating
In_2O_3/SnO_2 (90/10 wt.%)	P-S, HIP	$InO_x:SnO_x$ ("ITO")	anti-reflection coating

*Table 1 contd. Applications of thin films, target and thin film materials, and functions in precision optical coatings**

Switchable glass (electrochromic glass, smart glass)			
Sputtering target material	**Typical target manufacturing method(s)**	**Thin film material (coating)**	**Thin film function**
W	TS, P-S	WO_x	electrode layer
WNi	TS, P-S-W	$WNiO_x$	electrode layer
Ni(V)	VIM-C-W	$Ni(V)O_x$	electrode layer
Ta	EBM-W	Ta_2O_5	electrolyte (Li ion conductor)
Li_3PO_4	HP, HIP	LiPON	electrolyte (Li ion conductor)
In_2O_3/SnO_2 (90/10 wt.%)	P-S, HIP	$InO_x:SnO_x$ ("ITO")	transparent conductive layer

*Table 1 contd. Applications of thin films, target and thin film materials, and functions in electrochromic and smart glass**

Thin film batteries (all-solid state, Li-ion)			
Sputtering target material	**Typical target manufacturing method(s)**	**Thin film material (coating)**	**Thin film function**
$LiCoO_2$ (and similar oxides)	HP, HIP, S	$LiCoO_2$	cathode layer
Li_3PO_4, Li_3PO_4:graphite	HP, HIP	LiPON	electrolyte layer
Li	C-W	Li	anode layer

*Table 1 contd. Applications of thin films, target and thin film materials, and functions in thin film batteries**

*For the sake of completeness, target materials not manufactured by PM are included, as indicated in the second column (VIM: vacuum induction melting; EBM: electron beam melting; C: casting; W: cold or hot working; TS: thermal spraying; HP: hot pressing; SPS: spark plasma sintering; HIP: Hot Isostatic Pressing; P: pressing; S: sintering; SF: spray forming); for most applications, thin films are deposited by magnetron sputtering, except for tool & parts coating applications, where cathodic arc evaporation is more prominent.

metal targets like Ta (4N), Ti (5N), Cu (>6N) or AlCu (>5N), all of which are produced by casting; the most prominent PM materials are WTi (5N) and W (>4N), typically produced by vacuum hot pressing and/or Hot Isostatic Pressing at temperatures well above 1400°C and dwell times of up to ten hours, to achieve high density but avoid excessive grain growth [12].

In terms of the number of parts being coated, tribological and oxidation resistant coatings are the most important category. Most of the coatings are ceramic materials, including nitrides, oxides, carbides and borides of transition metals, and diamond-like carbon (DLC) in a thickness range of some hundreds of nanometers up to some micrometers. Typically, the thin films are used to increase the hardness, thermal stability, oxidation/corrosion resistance and chemical inertness of a component or part. Millions of high-speed steel or cemented carbide-based cutting tools (indexable inserts, end mills, drill bits, etc) are coated annually to improve their cutting performance and to prolong their lifetime [13]. With rising customer awareness and policy regulations calling for emission reduction and to reduce fuel consumption in passenger cars, the need for low-friction, wear-resistant tribological coatings and thermal barrier coatings in the automotive industry is increasing; parts to be

Photovoltaics (thin film solar cells)			
Sputtering target material	**Typical target manufacturing method(s)**	**Thin film material (coating)**	**Thin film function**
CuGa 20...30 wt.%	C-W, HIP	$Cu(In,Ga)Se_2$	absorber layer in CIGS solar cell
CuInGa	HIP	$Cu(In,Ga)Se_2$	absorber layer in CIGS solar cell
Mo	P-S-W	Mo	back electrode layer in CIGS
$Mo:Na_2MoO_4$	HP, HIP	Mo:Na	sodium doping layer
ZnAl-2 wt.%	TS	$ZnO_x:AlO_x$	transparent conductive layer ("AZO")
ZnO/Al_2O_3 (98/2 wt.%)	HP, HIP	$ZnO_x:AlO_x$	transparent conductive layer ("AZO")
Sn	C-W	SnO_2	transparent conductive layer in CdTe
NiV-7 wt.%	C-W	NiV	back contact in CdTe solar cell
Cr	HIP	Cr	barrier coating on metallic substrates
ZnTe, ZnS	HP, HIP	ZnTe, ZnS	window layer in CdTe solar cell
Si	TS, C	Si_3N_4	barrier coating (on glass substrates)

*Table 1 contd. Applications of thin films, target and thin film materials, and functions in photovoltaics (thin film solar cells)**

Data storage (hard disc drives, optical recording media)			
Sputtering target material	**Typical target manufacturing method(s)**	**Thin film material (coating)**	**Thin film function**
Co-Fe, Co-Ni, Co-Ni-Cr	VIM-C-W, HIP, HP	Co-Fe, Co-Ni, Co-Ni-Cr	magnetic recording media
Fe-Ni, Fe-Tb		Fe-Ni, Fe-Tb	magnetic recording media
Co-Cr, Co-Cr-Ta, Co-Cr-Ta-Pt		Co-Cr, Co-Cr-Ta, Co-Cr-Ta-Pt	ferromagnetic film (recording media)
Tb-Fe-Co, Tb-Fe-Co-Cr		Tb-Fe-Co, Tb-Fe-Co-Cr	magneto-optical recording media
Gd-Fe-Co, Dy-Fe-Co		Gd-Fe-Co, Dy-Fe-Co	magneto-optical recording media

*Table 1 concluded. Applications of thin films, target and thin film materials, and functions in hard disc drives, optical recording media**

*For the sake of completeness, target materials not manufactured by PM are included, as indicated in the second column (VIM: vacuum induction melting; EBM: electron beam melting; C: casting; W: cold or hot working; TS: thermal spraying; HP: hot pressing; SPS: spark plasma sintering; HIP: Hot Isostatic Pressing; P: pressing; S: sintering; SF: spray forming); for most applications, thin films are deposited by magnetron sputtering, except for tool & parts coating applications, where cathodic arc evaporation is more prominent.

Element	Target 1 µg/g	Target 2 µg/g	Ratio
Si	4	2	2
P	2	0.7	2.9
S	0.5	0.4	1.3
Cr	24	12	2
K	26	11	2.4
Ca	13	8	1.6
Fe	21	18	1.2
Al	3	7	0.4
Ni	7.5	4.6	1.6
Cu	4.9	5.9	0.8

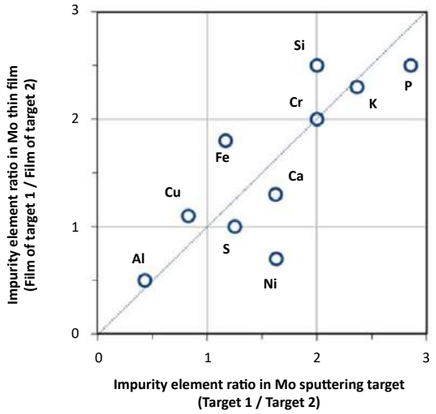


Fig. 4 Comparison of chemical impurities in two molybdenum targets, as measured by GDMS (glow discharge mass spectrometry), and impurity element ratios of respective thin films, as measured by SIMS (secondary ion mass spectrometry). Only elements well above the detection limits of both analysis methods are shown

coated include engine components (piston pins, piston rings), valve train components (valves, camshafts), transmission components (bevel and sun gears, etc.) and fuel system components (plungers, solenoids, needles) [14, 15].

"PM processes offer the crucial advantage of the parts produced exhibiting consistent, predictable and homogeneous microstructure..."

Powder Metallurgy processes

Most of the well-known advantages and characteristics of Powder Metallurgy are not fully utilised in the manufacture of sputtering targets or arc cathodes. As shown in Fig. 2, the shape of the coating source is far from complex. Only for materials with high hardness or brittleness (intermetallics, ceramics), being difficult to machine, is the near-net shape capability of PM embraced. In addition, the compacted parts do not require great precision, narrow tolerances or a high-quality surface finish, as some final machining operations (milling, grinding and polishing) are generally necessary to achieve the specified flatness and surface roughness (often Ra < 10 µm). So why use Powder Metallurgy at all?

For most applications, homogeneous coating thickness is essential; within a coating run, large substrate areas must be coated with minimum thickness tolerances; from run to run, the thin film thickness is not allowed to drift, throughout the entire target lifetime. To attain high thickness uniformity, a homogeneous microstructure of the target material is of paramount importance. The plates or tubes should be free from through-thickness gradients of chemical composition, phase composition or crystallographic texture; these features should also be consistent across different material lots.

Powder Metallurgy processes offer the crucial advantage of the parts produced exhibiting consistent, predictable and homogeneous microstructure. In contrast to melting and casting, where materials are always heated above the melting point, PM enables the tuning of material characteristics like phase composition, segregations, grain size and physical properties (density) in a wide range. An as-cast microstructure, with its different solidification zones, or complex phases in the case of alloys, is unsuitable for a sputtering process; castings are usually subjected to subsequent thermomechanical processing (cold or hot working, annealing) for grain refinement and homogenisation.

Material compositions specific to certain applications or customers can be readily produced by mixing various powders, for example, complex multi-element compositions (alloys, composites) with stoichiometries not accessible by traditional (liquid) metallurgical processes at all. In addition, PM process equipment such as blenders or sintering and hot-pressing furnaces are available in various sizes, and thus even low-volume batches with customer-specific material compositions can be produced cost-effectively.

Ceramic coatings are versatile and required in many applications, as shown in Table 1. A fully-reactive PVD process (using Ar working gas in combination with O_2, N_2, or C-containing gases such as acetylene) is often not desirable, due to complex process control and hysteresis effects [2]. Consequently, powder metallurgically produced ceramic targets or arc cathodes (oxides, nitrides, carbides, borides) are sought more frequently.

More detailed application examples highlighting the advantages of Powder Metallurgy are included in the following section.

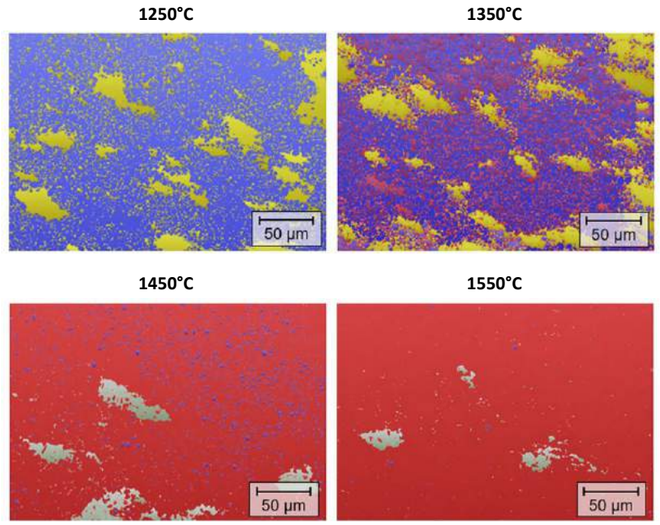
Sputtering target material properties and performance

While in the early days of sputtering the target was perceived as a simple plate of metal, this has changed. The target design and its metallurgical properties can significantly influence the stability, reproducibility and performance of a PVD coating process, as well as the properties of the deposited thin films. In this section the most important properties of a target will be described, i.e. chemical purity, microstructure (phase composition, grain size, texture) and density.

Chemical purity

The required chemical purity of the sputtering target material heavily depends on the application, with microelectronics demanding the highest purity levels of up to 99.9999% (6N). In general, impurity elements stemming from the target will also be incorporated in the thin film. In Fig. 4 this is shown for two molybdenum targets exhibiting different concentrations of trace elements. Thin films were deposited from both targets and the chemical composition of the coatings was analysed by SIMS (secondary ion mass spectrometry). Due to the lack of an appropriate calibration standard, it was not possible to obtain absolute concentration values. Therefore, relative concentration ratios of selected chemical elements in the coatings are compared. For example, if the Cr impurity level of Target 1 is double the Cr impurity level of Target 2, a similar concentration ratio was also found in the thin films deposited from these targets. This relationship is approximately linear, but additional effects like impurity element-specific sputtering yield [3] and angular emission profile [16, 17] will lead to deviations for some chemical elements.

Low oxygen impurity levels are typically required for deposition of metal films and are particularly critical for metal targets which are strong oxide formers (Ti, Al, Nb, Ta, Cr, Mo). High oxygen content leads to particle and droplet formation during the PVD process, resulting in in-film defects and significant yield loss intolerable for semiconductor or flat panel display applications. Similarly, high oxygen impurity content in $Ti_{0.5}Al_{0.5}$ targets causes a remarkable decrease in hardness from 35 to 20 GPa in reactively deposited $TiAlN_x$ hardcoatings, by altering the growth orientation and morphology of these coatings [18]. Limiting the oxygen concentration to an acceptably low level can present a certain challenge for PM processes. For example, oxygen levels in PM-grade hot pressed Nb or Ta are typically higher by two orders of magnitude, compared to e-beam melted material. On the other hand, sintering in high vacuum or reducing atmosphere (dry hydrogen), or addition of oxygen getters (Ca, Mg), can effectively reduce the oxygen content in sintered material. For instance, the oxygen content of Mo, hydrogen sintered at a temperature above 1800°C, is below 12 ppm [19].



Phase composition (area fraction in BSE image)				
Hot press temp.	Ti	Ti-rich (β Ti,W)	W-rich (β Ti,W)	W
1250°C	0%	31%	0%	69%
1350°C	0%	22%	30%	48%
1450°C	3%	0%	92%	5%
1550°C	2%	0%	98%	0%

Fig. 5 Microstructure of multiple-phase WTi-10 wt.% alloy as a function of hot-pressing temperature at constant dwell time. Four phases were observed: Ti (green), a Ti-rich (βTi, W) phase (yellow), a W-rich (βTi, W) phase (red) and a W (blue). The area fractions of the individual phases were obtained by image analysis of BSE (backscattered electrons) images.

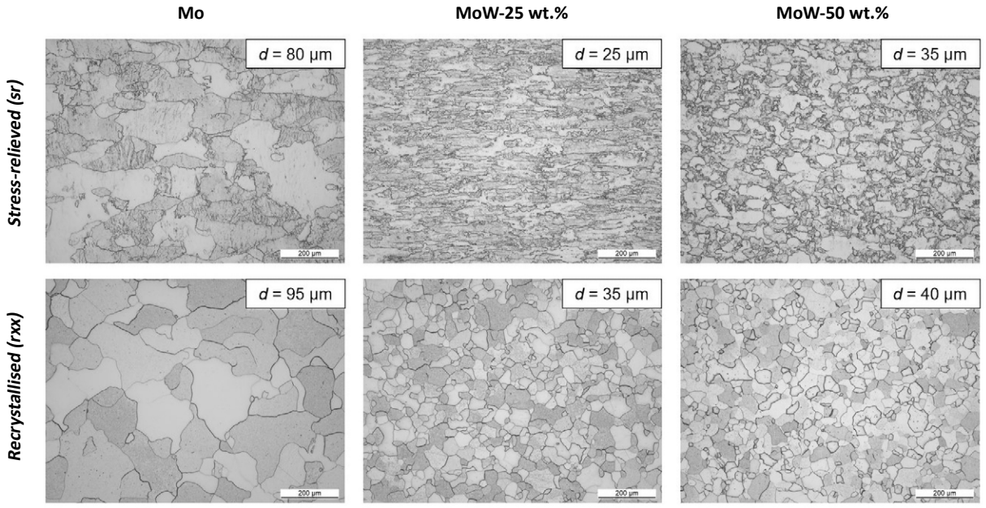


Fig. 6 Microstructures of Mo, MoW25, and MoW50 sputtering targets in stress-relieved (upper row) and recrystallised (lower row) condition. The samples represent the plane section (parallel to sheet plane) of the rolled material. Rolling direction is the same for all samples (left-right). Magnification is 100:1 for all samples, inset gives the mean grain size d, as measured by ASTM E112.

Microstructure: Phase composition

In multi-element sputtering targets the chemical composition and phase distribution within the material are key parameters and PM processes enable extensive freedom of design in tailoring the target microstructure. Firstly, PM enables chemical compositions which may not be accessible by casting processes at all, for example due to large differences in melting temperatures of the constituting elements (e.g. TiAl, AlCr, WTi, CuGa, CuIn). Additionally, in PM processes like sintering, hot pressing, or HIPing, the process temperature can be lower than the melting points of all, or only selected elements or compounds. Consequently, it is possible to customise the phase composition of the target by deliberately limiting the process temperature (in combination with the time at temperature) and to control the formation of intermetallic compounds, precipitates or segregations.

The phase composition of multi-element materials is known to affect the particle performance of the target. For example, WTi-10 wt.% alloy, a commonly used diffusion barrier material, can be prepared by mixing Ti and W powders with appropriate particle sizes and size distributions, and compaction by hot-pressing. Adjusting the hot pressing temperature allows tuning of the phase composition in a wide range (Fig. 5).

At the lowest hot pressing temperature (1250°C) the material consists of a W matrix (blue) with a Ti-rich (βTi, W) second phase (yellow), formed by interdiffusion. At 1350° an additional W-rich (βTi, W) phase is detected (red) and poor particle performance of such multiple phase target material was reported [20]. A further increase in hot pressing temperature to 1450°C results in a remarkable change in phase composition, with a W-rich (βTi, W) matrix (red), some residual W (blue) and Ti precipitates (green); an additional increase in temperature to 1550°C leads to a further increase of the W-rich (βTi, W) phase, approaching a single-phase structure, which was reported to be least prone to particle formation during the sputtering process.

Microstructure: Texture

The importance of the sputtering target's crystallographic texture, i.e. the grain orientation distribution, cannot be overstated, though this is often overlooked or neglected in practice. Therefore, we want to elaborate on this microstructural feature in more detail.

Metal and ceramic sputtering targets are predominantly polycrystalline. The sputtering rate of a material is strongly dependent on the orientation distribution function of the individual crystallites. For planar Tantalum targets, Wickersham *et al.* found the sputtering yield to increase by a factor of two as the predominant grain orientation changed from (111) to (011) planes parallel to the sputtering surface. The sputtering yield correlates with the atomic packing density in the uppermost atomic layer of the target surface and is proportional to the thin film deposition rate [21]. Consequently, to ensure a stable deposition rate and minimise coating thickness variations during the target lifetime, the target plate's through-thickness uniformity of the crystallographic texture is of paramount importance.

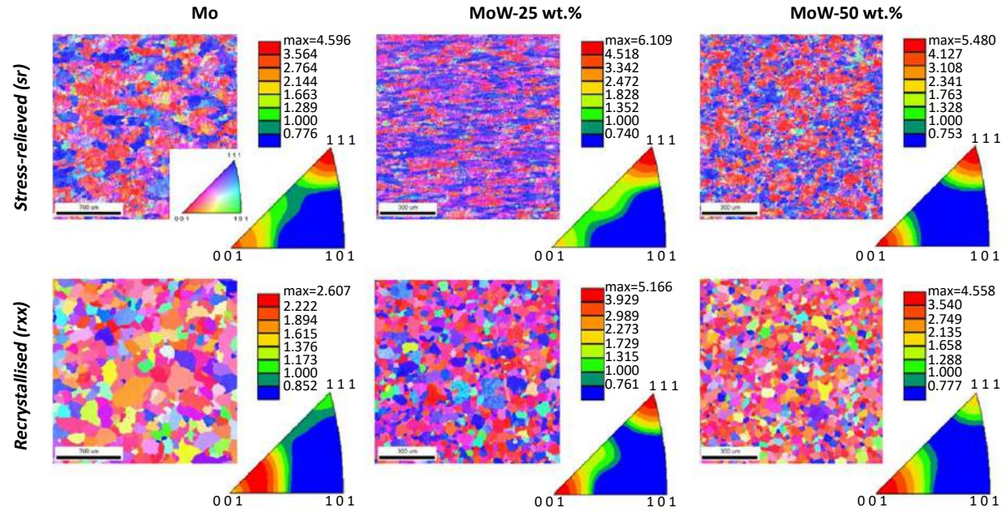


Fig. 7 Grain orientation mapping (colour code map only shown of stress-relieved Mo, same for all samples) and inverse pole figures for the normal direction (i.e. the sputtering surface) of Mo, MoW25, and MoW50 targets in stress-relieved (upper row) and recrystallised (lower row) condition. The strength of texture is indicated by the colour bar graph; a higher max value indicates a more pronounced texture

In addition, the target texture has to be consistent from batch to batch, after a material has been qualified and released for a certain coating process by the customer. Usually no changes of the thermomechanical processes can be made by the manufacturer without prior notice to the end-user. If deviation from a locked-in process of record (POR) is required, the target material usually has to be requalified. Even a supposedly minor process change may have a significant influence.

For example, a variation of the process conditions during the final annealing step of cold isostatically pressed, hydrogen-sintered, hot-rolled Mo and molybdenum-tungsten alloys (MoW-25 wt.% and MoW-50 wt.%) results in a different grain size and grain orientation (texture) of the plates [22], altering the deposition rate of the sputtering targets and consequently the film thickness of the deposited coatings [23]. The microstructures of the three materials are shown in Fig. 6. The as-deformed (hot rolled and stress-relieved) condition is shown in the upper row, while the lower row shows the samples after an additional recrystallisation annealing treatment.

Molybdenum and tungsten form a solid solution. In the stress-relieved condition all samples exhibit slightly elongated grains in the longitudinal direction resultant from hot rolling. After recrystallisation, the microstructure changes to a more equiaxed grain structure for all materials. The mean grain size of both MoW alloys is smaller than for pure Mo by almost a factor of two. Electron backscatter diffraction (EBSD) analyses of the target samples also reveal a change in crystal orientation distribution due recrystallisation (Fig. 7).

All three stress-relieved materials exhibit a preferential orientation of (111) planes in normal direction to the surface, whereas a smaller number of grains show a (100) orientation. Upon recrystallisation the amount of (100) orientated grains increases, those of (111) decreases, and the overall intensity of the grain orientation weakens.

The (111) oriented grains exhibit the lowest atomic packing density in bcc molybdenum; their sputtering yield is only 0.98 atoms/ion. In contrast, (100) grains have a higher packing density and higher sputtering yield of 1.29 atoms/ion. (101) oriented grains would be the fastest sputtering ones (1.68 atoms/ion) [24], but are almost non-existent in all samples. Consequently, differences in deposition rate are to be expected in the polycrystalline Mo and Mo alloy materials with different texture.

The sputtering performance and deposition rate of all six materials was assessed at Plansee in the

> *" If deviation from a locked-in process of record (POR) is required, the target material usually has to be requalified..."*

Target material	Deposition rate (nm/min)		
	400 W	600 W	800 W
Mo, *sr*	96	142	192
Mo, *rxx*	98	145	197
Delta (rxx-sr)	*1.6%*	*1.8%*	*2.4%*
MoW25, *sr*	97	143	192
MoW25, *rxx*	100	148	199
Delta (rxx-sr)	*2.8%*	*3.5%*	*3.4%*
MoW50, *sr*	88	131	175
MoW50, *rxx*	95	141	188
Delta (rxx-sr)	*6.8%*	*7.1%*	*7.4%*

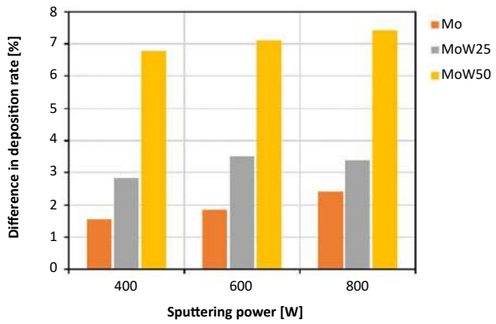


Fig. 8 Comparison deposition rate and relative difference of deposition rate for Mo, MoW25 and MoW50 sputtering targets when changing the microstructure from the stress-relieved (sr) to the recrystallised (rxx) condition.

in-house R&D sputtering deposition system, using planar sputtering targets (100 mm in diameter and 8 mm in thickness). The deposition rate at three different DC power levels is shown in Fig. 8.

All recrystallised target materials exhibit significantly higher deposition rates than the stress-relieved ones. The largest variation (> 7%) was observed for MoW50 at the highest power setting. As discussed above, this is mainly due to the different texture. For the recrystallised material the share of faster sputtering (100) oriented grains increases at the expense of slow-sputtering (111) crystallites. The difference in deposition rate also increases with increasing W content. This may be attributed to two effects:

1. Both MoW alloys exhibit a more pronounced texture than Mo (their max values in the inverse pole figure mappings are almost doubled);
2. Recrystallised MoW50 has a higher share of fast-sputtering (111) oriented grains than MoW25.

For applications such as semiconductors, flat panel displays and large area coatings, the film thickness uniformity has to be precisely controlled, and deviations must typically be kept below ±5-10%. In these applications, thickness differences of 10 nm and less have a significant impact and, as shown above, such differences can be caused by seemingly minor manufacturing process modifications, affecting the sputtering target's microstructure.

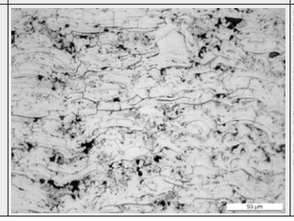
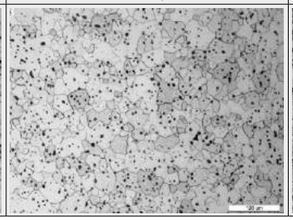
Properties	Manufacturing process		
	Thermal spraying (APS)	Hot Isostatic Pressing (HIP)	Pressing, H_2 sintering, hot working
Relative density	87%	97%	99.5%
Oxygen content	0.25 wt.%	0.03 wt.%	0.005 wt.%
Microstructure	layered grains, voids and oxides	equiaxed grains, residual pores	deformed grains, no pores or voids
Light optical micrograph			

Table 2 Properties and metallographic cross sections of Mo rotary sputtering targets manufactured by different powder metallurgical processes (APS: atmospheric plasma spraying).

Microstructure: Density

Sputtering target density (residual porosity) also has a significant influence on its performance. Voids are known to be potential particle sources [25]. During sputtering, continuous erosion along the grain boundaries will eventually separate individual grains from the bulk material, which may potentially drop onto the substrate. In addition, lower target density might cause poor thin film performance. Chi-Fung Lo et al observed an increase in electrical resistivity of sputtered W films from 14 to 26 μΩcm (+86%) when the relative density of the W target decreased from 99.5% to 82.5% [20].

In general, the relative density of a target should be as high as possible, at least > 95%, and obviously the manufacturing process has a major influence. In Table 2 some physical and microstructural properties of molybdenum rotary targets, made by three different PM process routes, are compared.

Pressed, sintered and hot worked molybdenum is characterised by a dense microstructure with low oxygen content; HIPed Mo exhibits some residual porosity with an oxygen content an order of magnitude higher, compared to pressed & sintered material. The lowest density and purity is obtained with thermal spraying (APS).

Droplet formation is associated with occurrence of an electrical discharge (arc) in the deposition system. Sputtering tests were performed with all three materials by continually ramping up the specific power (8 → 33 kW/m at constant rate) and counting the arcs. The lower density thermally sprayed and HIPed targets were prone to arcing and particle formation at specific power levels of 21 and 16 kW/m, respectively, while arcing was only observed at 33 kW/m for sintered & hot worked Mo (note: 33 kW/m is a very high power level). In addition, the sintered and hot worked Mo produced very few arcs during the total test period of 2.5 hours (arc frequency: 3.8 Arcs/hour), while the less dense targets showed a much higher frequency of electrical discharges.

Pronounced differences were observed in the deposited coatings as well. Thin films sputtered from the sintered & hot worked target had a homogeneous, defect-free surface with low electrical resistivity (15.1 μΩcm; Fig. 10) and the typical rice grain shape microstructure. In contrast, the thin films deposited from the APS target had a higher number of in-film defects and particles, as well as higher electrical resistivity (25.5 μΩcm), probably a direct result of the higher impurity content and lower density of the sprayed target material [26].

Technology trends

Sputter and arc deposition processes have been in commercial use for decades; in fact, the universal genius Thomas Edison applied for a patent as far back as 1900, claiming the deposition process of a gold seed layer on his phonograph wax master cylinders [27]. The thin film coatings market is steadily growing, and consequently, this is attracting many new suppliers to the market, leading to enhanced competition. Usually, target manufacturers seek to protect their intellectual property by applying for patents for either the target material (composition or microstructure), its manufacturing process, its application in a deposi-

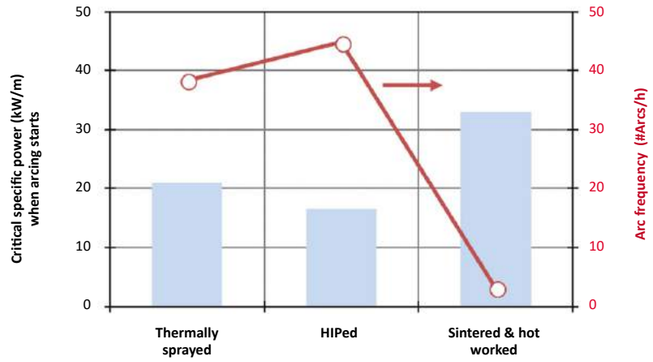


Fig. 9 Comparison of arc frequency and critical specific power levels for initiating arcs during DC sputtering of different molybdenum rotary sputtering targets (Ø152 x 600 mm).

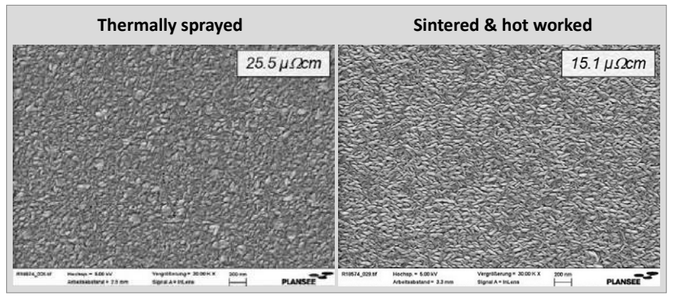


Fig. 10 SEM pictures (30.000 X) of the surface of sputtered thin films sputtered from thermally sprayed (left) and sintered & hot worked (right) Mo targets. Substrate: soda-lime glass; film thickness: ~500 nm; electrical resistivty measured by four-point probe.

Trends in thin film and PVD technologies	Trends in PM processing of sputtering targets
• technologies to increase target utilisation (planar → rotary; magnetron retrofits) • increase deposition rate (efficient target cooling and bonding technologies) • tightening particle performance requirements • novel driving modes (e.g. high-power impulse magnetron sputtering, HIPIMS) • deposition at room temperature, avoidance of substrate damage from plasma (flexible electronics) • deepening understanding of plasma-target interactions through advanced numerical simulation and analysis tools • increasing competitive pressure from atmospheric deposition processes (ink-jet printing; screen printing)	• growing demand for (low-volume) customer-specific material compositions, with ever increasing complexity • increased utilisation of SPS, HP and HIP processes • microstructure tailored to application requirements (design to cost) • ceramics replacing respective metals • materials or microstructures with improved thermal-shock resistance, low CTE, and high thermal conductivity • refurbishing, recycling

Table 3 Technological trends in thin film and PVD process technologies (left) and Powder Metallurgy materials and processes (right)

tion process, or the derived thin film coatings and device structures. The number and complexity of such patents is increasing, and suppliers must allocate considerable resources to ensure freedom-to-operate. Some key technology trends are summarised in Table 3.

Conclusion

PVD processes such as magnetron sputtering or cathodic arc evaporation are widely used for the vacuum deposition of functional thin films in a multitude of applications, including architectural glass, microelectronics, flat panel displays, tools, wear parts, decorative coatings, optical coatings, solar cells and data storage, among others. The quality of the coating source makes a significant contribution to the stability and reproducibility of the coating process and the performance of the thin films itself.

The most important sputtering target properties are high chemical purity, uniform fine-grained microstructure (phase composition, crystallographic texture), and high density. These features can be attained more easily by powder metallurgical processing: PM materials exhibit homogeneous microstructures, and PM permits the tuning of material characteristics such as phase composition, segregations, grain size and physical properties (density) in a wide range. Similarly, PM enables chemical compositions which may be not accessible by casting processes at all, for example due to large differences in melting temperatures of the constituting elements. It also offers high material utilisation and near-net-shape capability; particularly important for materials which are difficult to machine; and allows for cost-efficient manufacture of low-volume batches with customer-specific material compositions.

Authors

Dr Jörg Winkler
(Head of Development Display & Solar)
Dipl-Ing Christian Linke
(Project Manager)
Plansee SE
Business Unit Coating
Metallwerk-Plansee St. 71
6600 Reutte
Austria

Contact:
joerg.winkler@plansee.com
www.linkedin.com/in/joerg-winkler/
www.plansee.com

Acknowledgements

The authors would like to thank Dr Michael Eidenberger-Schober, Enrico Franzke, Dr Harald Köstenbauer, Dr Judith Köstenbauer, Thomas Leiter, Dominik Lorenz, Dr Peter Polcik, Thomas Scherer, Dr Hennrik Schmidt and Dr Michael O'Sullivan, and the entire team of BU Coating for their kind support.

Plansee SE

Plansee is one of the global leaders in the field of Powder Metallurgy. The privately-owned company manufactures refractory metals and composites from metal powders. Plansee covers all aspects of the production process: the company reduces metal oxide to pure metal powder, which is then compacted, sintered, and processed in various additional forming steps to produce highly resistant materials and products. Plansee is at home in electronics, medical technology, or high-temperature furnaces - wherever traditional materials are stretched beyond their limits.

For the coating industry, Plansee has been a valued, reliable supplier of sputtering targets and arc cathodes for many years. Depending on the customers coating system, the company offers rotary and planar targets in all common sizes. For this, Plansee performs every stage of the production process in-house.

References

[1] K. S. Harsha, Principles of Physical Vapour Deposition of Thin Films, Oxford: Elsevier Ltd., 2006.

[2] D. M. Mattox, Handbook of Physical Vapour Deposition (PVD) Processing, Park Ridge: Noyes Publications, 1998.

[3] N. Laegreid and G. K. Wehner, Sputtering Yields of Metals for Ar+ and Ne+ Ions with Energies from 50 to 600 eV, *J. Appl. Phys.*, Nr. 32, p. 365, 1961.

[4] J. A. Thornton, J. Tabock and D. W. Hoffman, Internal stresses in metallic films deposited by cylindrical magnetron sputtering, *Thin Solid Films*, Bd. 64, pp. 111-119, 1979.

[5] J. Soldán, J. Neidhardt, B. Sartory, R. Kaindl, R. Cerstvy, P. H. Mayrhofer, R. Tessadri, P. Polcik, M. Lechthaler and C. Mitterer, Structure–property relations of arc-evaporated Al–Cr–Si–N coatings, *Surf. Coat. Technol.*, Nr. 15, pp. 3555-3562, 2008.

[6] P. J. Ding, W. A. Lanford, S. Hymes and S. P. Murarka, Oxidation resistant high conductivity copper films, *Appl. Phys. Lett.*, Bd. 64, Nr. 21, p. 2897, 1994.

[7] J. Sarkar, *Sputtering Materials for VLSI and Thin Film Devices*, Oxford: Elsevier, 2014.

[8] K. Pulker, *Coatings on Glass*, Oxford: Elsevier, 1984.

[9] F. W. M. Friz, Coating Materials, in *Optical Interference Coatings*, Berlin, Springer, 2003, pp. 105-130.

[10] C. Michaluk, Spray Rejuvenation of Sputtering Targets. Patent US2013156967.

[11] *It's a Materials World–with Positive Forecast*, [Online]. Available: http://www.semi.org/en/node/56701. [Accessed on 13 July, 2018].

[12] C.-F. Lo, „Method of making high-density, high-purity tungsten sputter targets". Patent US6328927.

[13] A. Inspektor and P. A. Salvador, Architecture of PVD coatings for metalcutting applications: A review, *Surf. & Coat. Technol.*, Bd. 257, pp. 138-153, 2014.

[14] Q. M. Mehran, M. A. Fazal, A. R. Bushroa and S. Rubaiee, A Critical Review on Physical Vapour Deposition Coatings Applied on Different Engine Components, *Crit. Rev. Solid State and Mat. Sci.*, Bd. 43, Nr. 2, pp. 125-175, 2018.

[15] J. Vetter, 60 years of DLC coatings: Historical highlights and technical review of cathodic arc process to synthesize various DLC types, and their evolution for industrial applications, *Surf. Coat. Technol.*, Bd. 257, pp. 213-240, 2014.

[16] J. Neidhardt, S. Mraz, J. M. Schneider, E. Strub, W. Bohne, B. Liedke, W. Möller and C. Mitterer, Experiment and simulation of the compositional evolution of Ti-B thin films deposited by sputtering of a compound target, *J. Appl. Phys.*, Bd. 104, p. 063304, 2008.

[17] M. Rausch, M. Pavlovic, P. Kreiml, M. J. Cordill, J. Winkler and C. Mitterer, Sputter deposition of Mo-based multicomponent thin films from rotatable targets: Experiment and simulation, *Appl. Surf. Sci.*, Bd. 455, pp. 1029-1036, 2018.

[18] H. Riedl, C. M. Koller, F. Munnik, H. Hutter, F. M. Martin, R. Rachbauer, S. Kolozsvári, M. Bartosik and P. H. Mayrhofer, Influence of oxygen impurities on growth morphology, structure and mechanical properties of Ti-Al-N thin films, *Thin Solid Films*, Bd. 603, pp. 39-49, 2016.

[19] K. Babinsky, J. Weidow, W. Knabl, A. Lorich, K. Leitner and S. Primig, Atom probe study of grain boundary segregation in technically pure molybdenum, *Mat. Characterisation*, Bd. 87, pp. 95-103, 2014.

[20] C. F. Lo, P. McDonald, D. Draper and P. Gilman, Influence of Tungsten Sputtering Target Density on Physical Vapour Deposition Thin Film Properties, *J. Electron. Mater.*, Bd. 34, Nr. 12, pp. 1468-1473, 2005.

[21] Z. Zhang, L. Kho and C. E. Wickersham, Effect of grain orientation on tantalum magentron sputtering yield, *J. Vac. Sci. Technol. A*, Bd. 24, p. 1107, 2006.

[22] S. Priemig, H. Leitner, W. Knabl, A. Lorich, H. Clemens and R. Stickler, Textural Evolution during Dynamic Recovery and Static Recrystallization of molybdenum, *Metall. Mater. Trans. A*, Bd. 43A, pp. 4794-4805, 2012.

[23] C. Linke, M. Eidenberger-Schober, H. Köstenbauer, D. Lorenz and J. Winkler, Linking Target Microstructure with its Sputter Performance, in *SVC Tech. Conf. Proceedings*, Providence, RI, USA, 2017.

[24] H. S. Huang, C. H. Chiu, I. T. Hong, H. C. Tung and F. S. Chien, Determining the sputter yields of molybdenum in low-index crystal planes via electron backscattered diffraction, focused ion beam and atomic force microscope, *Mat. Characteriz.*, Bd. 83, pp. 68-73, 2013.

[25] C. F. Lo and P. Gilman, Particle generation in W-Ti deposition, *J. Vac. Sci. Technol. A*, Bd. 17, Nr. 2, pp. 608-610, 1999.

[26] D. Rafaja, H. Köstenbauer, U. Mühle, C. Löffler, M. Schreiber, M. Kathrein and J. Winkler, Effect of the deposition process and substrate temperature on the microstructure defects and electrical conductivity of molybdenum thin films, *Thin Solid Films*, Bd. 528, pp. 42-48, 2012.

[27] T. A. Edison, Process of coating phonograph-records. US Patent 713863, 18 Nov. 1902.

MPIF's 2018 Design Excellence Award winning parts continue to showcase the abilities of metal powder technology

The winners in the 2018 Powder Metallurgy Design Excellence Awards competition, sponsored by the Metal Powder Industries Federation, were announced during the POWDERMET2018 International Conference on Powder Metallurgy and Particulate Materials, San Antonio, Texas, USA, June 17-20, 2018. We present the 'press and sinter' PM components that received either Grand Prizes or Awards of Distinction.

Each year, the Metal Powder Industries Federation (MPIF)'s annual Powder Metallurgy Design Excellence Awards showcase the many and varied applications for Powder Metallurgy components. The industry awards, open to all members of the MPIF, are presented in categories that not only champion automotive applications, but also those components found in hand tools, hardware, aerospace, military, medical and more.

A panel of industry judges evaluates the entries according to a stringent set of criteria and awards Grand Prizes and Awards of Distinction. The winners are said to demonstrate outstanding examples of PM's diversity as a manufacturing technology, highlighting PM's flexibility to push forward new concepts and process controls, and to demonstrate the capabilities offered by the technology.

In total, seven Grand Prizes and twelve Awards of Distinction

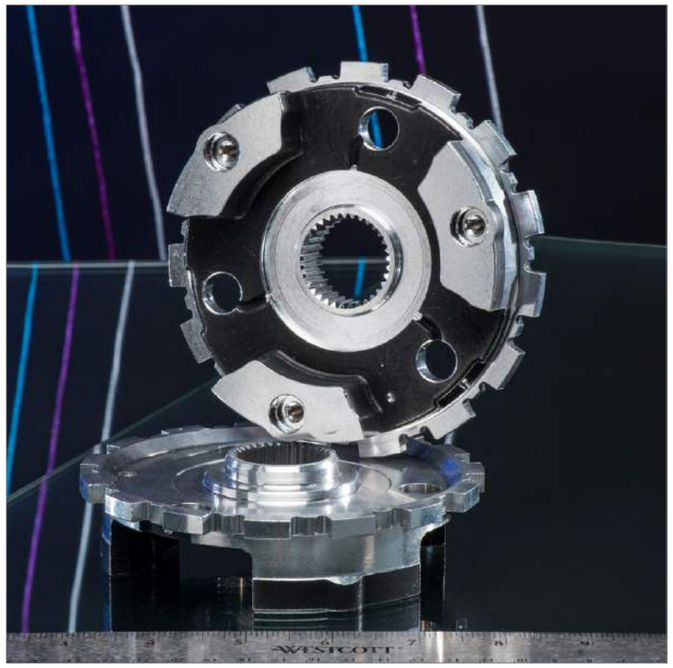


Fig. 1 GKN Powder Metallurgy received the Grand Prize in the Automotive-Transmission category (Courtesy MPIF)

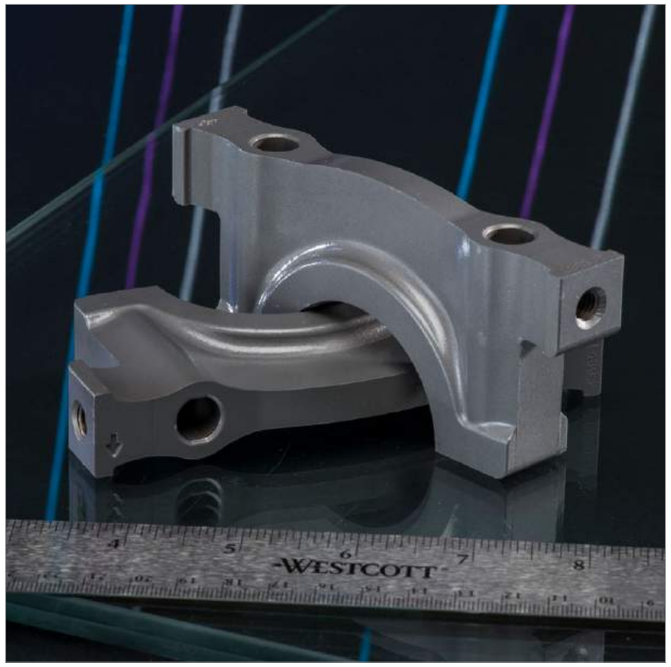


Fig. 2 GKN also received the Grand Prize in the Automotive-Engine category for these main bearing caps (Courtesy MPIF)

Fig. 3 The winner of the Grand Prize in the Hand Tools/Recreation category was FMS Corporation (Courtesy MPIF)

were given in the 2018 competition. Presented here are the 'press and sinter' PM winners. Full details of the MIM award winning components can be found in our sister publication, *PIM International* (Vol. 12, No. 3).

Grand Prizes

Automotive-Transmission: GKN Powder Metallurgy

The Grand Prize in the Automotive-Transmission Category was awarded to GKN Powder Metallurgy for an aluminium PM planetary reaction carrier which it produced for General Motors (Fig. 1). The carrier goes into the all-new GM 9T50 nine-speed transmission, offered in such vehicles as the Chevrolet Malibu and the Equinox crossover.

Made from a unique metalmatrix composite (MMC) aluminium alloy system and mated to an overdrive carrier, this first-of-its-kind two-piece design required extremely tight tolerances.

Automotive-Engine: GKN Powder Metallurgy

The Grand Prize in the Automotive-Engine Category also went to GKN Powder Metallurgy for a copper steel main bearing cap made for FCA US LLC (Fig. 2). The part is used in the 2.0 L all- aluminium turbocharged four-cylinder FCA engine launched in the Alfa Romeo Giulia.

Although PM main bearing caps have dominated engine design for more than two decades, the design of this part is said to break new ground. Requirements for engine weight reduction drove the designers to an 'upside down' sculpted version. This novel design delivers a part that is 23% lighter than previous versions and offers 10% better fatigue strength.

Hand Tools/Recreation: FMS Corporation

The Grand Prize in the Hand Tools/Recreation Category was presented to FMS Corporation Minneapolis, Minnesota, USA, for three sinter-hardened steel parts made for Graco, Inc.: an eccentric gear, a combination gear and a connecting rod that incorporates a bronze bearing (Fig. 3). The parts comprise an assembly that drives a piston pump within a paint sprayer.

The complex eccentric gear, which is compacted using cored holes on one side to balance the moment of inertia around the centre shaft, features AGMA class 6 gear quality. The combination gear is complex, combining a helical gear and a spur gear. The bronze bearing is compacted, sintered and sized in place inside the connecting rod, then oil impregnated. The combination gear and connecting rod are manufactured completely net-shape.

Awards of Distinction

Automotive-Transmission: Stackpole International

An Award of Distinction in the Automotive-Transmission Category was given to Stackpole International, Canada, for a copper-steel rear planetary carrier (Fig. 4). The component is used in a new ten-speed automotive transmission, developed jointly by Ford and General Motors and found in such vehicles as the Ford Mustang and GM Camaro.

The assembly consists of a clutch hub and a spider, which are joined using a novel sinter- brazing concept. The creative design of the ferrous carrier enabled it to win out over an aluminium casting design by delivering lighter weight and superior strength.

Automotive-Engine: AAM Powertrain

An Award of Distinction in the Automotive-Engine Category went to AAM Powertrain, Detroit, Michigan, USA, for a pre-alloyed steel VVT sprocket, which is used in overhead camshaft GM inline three- and four-cylinder engines in cars such as the Buick Encore and Envision, and the

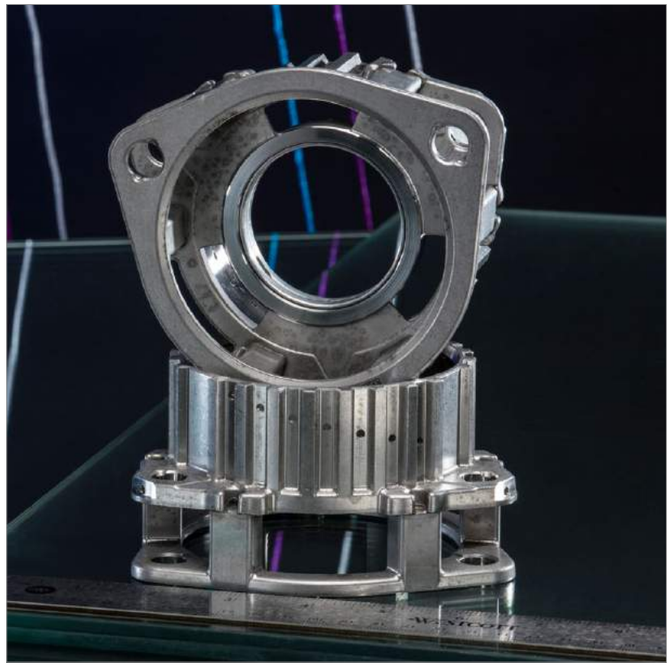


Fig. 4 An Award of Distinction in the Automotive-Transmission category was presented to Stackpole International (Courtesy MPIF)

Fig. 5 AAM Powertrain received the Award of Distinction in the Automotive-Engine category (Courtesy MPIF)

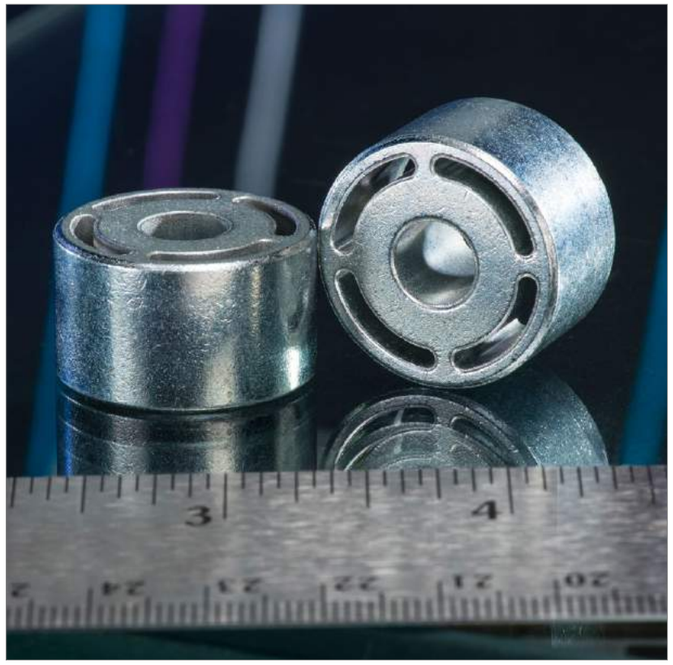


Fig. 6 The Award of Distinction in the Lawn & Garden category was presented to SMC Powder Metallurgy (Courtesy MPIF)

Fig. 7 A second Award of Distinction in the Lawn & Garden sector was presented to MPP (Courtesy MPIF)

Chevrolet Cruze and Malibu, among others (Fig. 5). The six pitch inverted tooth was specifically selected to address concerns with NVH-noise, vibration, and harshness-as well as with durability and rotating mass. The part demands very consistent powder filling to achieve the extremely tight tolerances required.

Lawn & Garden/Off-Highway: SMC Powder Metallurgy Inc

An Award of Distinction in the Lawn & Garden/Off-Highway Category was given to SMC Powder Metallurgy Inc., St. Mary's, Pennsylvania, USA, for a copper-steel spacer used in a tilt steering mechanism as a pivot on an ATV/SSV application (Fig. 6). The part is over-moulded with plastic and sees very little stress in the application. A collaborative design engineering effort converted the machined wrought part into a successful over-moulding process delivered at a competitive cost.

Lawn & Garden/Off-Highway: MPP

Another Award of Distinction in the Lawn & Garden/Off-Highway Category went to MPP, Westfield, Indiana, USA, for a heat-treated nickel-steel clutch housing made for Hilliard Company (Fig. 7). The part goes into a differential unit used in such applications as lawn/garden tractors and recreational vehicles. The high-density, high-surface-area part is symmetrical, with high hubs on each end, which are critically required to be equal in density.

Hardware/Appliance: ASCO Sintering Co.

An Award of Distinction in the Hardware/Appliance Category went to ASCO Sintering Co., Commerce, California, USA, for a stainless-steel radius-adjust head (Fig. 8). The part goes into commercial water sprinklers where it is used to adjust the water pattern. The part's complex shape, with a deep-cored hole opposing a deep feature, was achieved by complex tool design and press control. Significant savings were realised in both tooling costs and production rates. The part is pressed to net shape with only resin impregnating and nickel plating as secondary operations.

Hardware/Appliance: FMS Corporation

Another Award of Distinction in the Hardware/Appliance Category was given to FMS Corporation, Minneapolis, Minnesota, USA, for a stainless steel spindle used in a shower valve assembly, linking the handle to the cold-and-hot-water mixing valve (Fig. 9). To avoid impractical tooling to form a step from the gear root diameter to the sealing diameter, the part is designed as a two-part assembly: a gear and a spindle that are first compacted and sintered, then assembled using automated equipment and re-sintered to bond the two parts together.

www.mpif.org

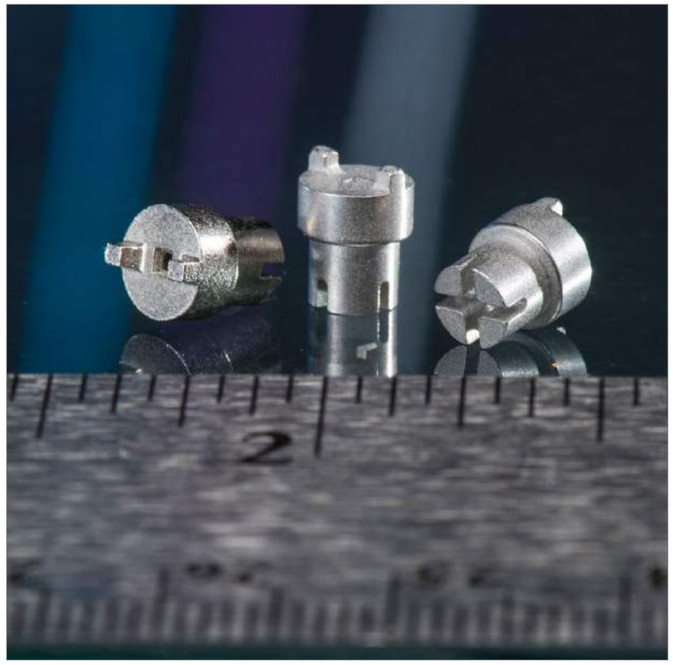


Fig. 8 An Award of Distinction in the Hardware/Appliance category went to ASCO Sintering Co (Courtesy MPIF)

Discover more award winning Powder Metallurgy parts

Award presentations made by the Metal Powder Industries Federation (MPIF), the European Powder Metallurgy Association (EPMA) and the Japan Powder Metallurgy Association (JPMA) are featured online at www.pm-review.com.

The awards clearly demonstrate Powder Metallurgy's versatility and cost competitiveness, and include ferrous, non-ferrous and Metal Injection Moulded (MIM) products made around the world for a variety of end-user industries.

www.pm-review.com

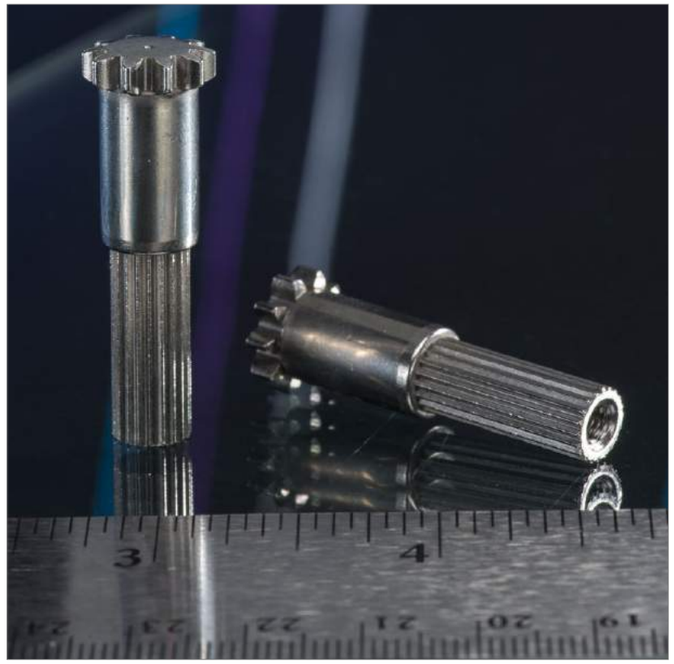


Fig. 9 A further Award of Distinction in the Hardware/Appliance category was presented to FMS Corporation for this stainless steel spindle (Courtesy MPIF)

POWDERMET2018: High complexity and high density forming continue to drive PM growth

A technical session at the POWDERMET2018 conference, organised by MPIF (Metal Powder Industries Federation) and held in San Antonio, Texas, June 17-20, 2018, focused on the two factors that are the main drivers for new PM structural part applications; namely, ever-increasing shape complexity and the attainment of higher formed density levels, as an enabler for enhanced product performance levels. Dr David Whittaker reviews two key presentations on this topic.

Recent innovations in cold axial die compaction technologies

In a paper from Guillermo Polo (Osterwalder AG, Switzerland), the author described the developments in PM compaction press technology that are assisting the PM industry in pursuing more complex and accurate shapes in a price-competitive manner.

A powder compaction press can be classified based on its performance, a combination of factors such as accuracy, repeatability, speed, reliability or the ability to produce complex shapes, that create added value for the user. Current axial compaction press technologies can be classified, as in Fig. 1, as low, medium or high-performance, from mechanical or non-full-CNC hydraulic presses, to CNC hydraulic presses and culminating in servo-CNC electrical presses with additional features, such as side forming.

The increasing performance of pressing equipment has enabled an evolution of shape complexity and Fig. 2 demonstrates the continuous adaption of presses to the demands of products. During the past decade, the use of electrically powered systems to drive axial compaction presses has spread across all geographical PM markets and such systems have become a popular alternative to traditional mechanical and hydraulic drives. For high-end applications, direct drive technologies (DDT) are now used for the main drives on powder compaction presses, in the range up to around 700 kN compacting force. The DDT is based on a hollow

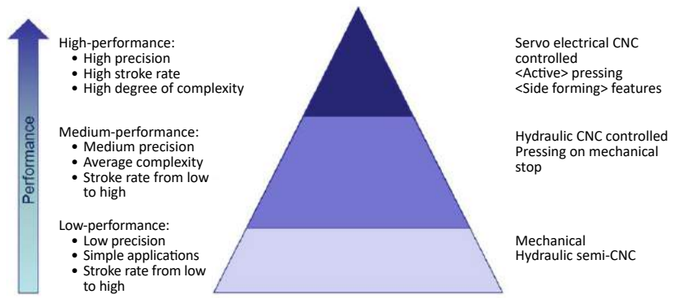


Fig. 1 Classification of powder compaction presses according to performance [1]

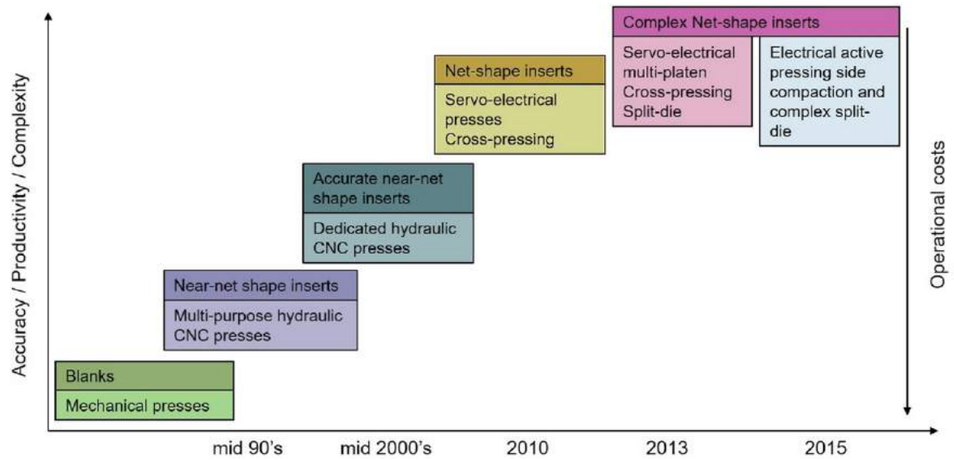


Fig. 2 How compaction pressed have adapted to cope with higher complexity [1]

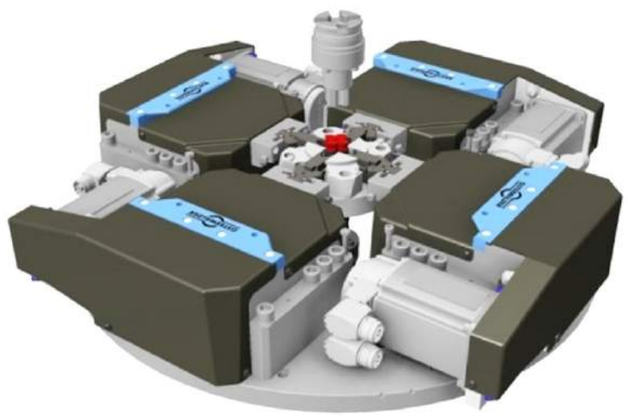


Fig. 3 Four side compaction modules arranged to produce a part with a full split die [1]

	Upper punch - Pressing position [mm]	Die - Pressing position [mm]	Part height [mm]	Part weight [g]	Compacting force [kN]
Nominal	4.853	7.558	5.015	6.118	14.0
Tolerance	± 0.001	± 0.001	± 0.03	± 0.06	± 2
Mean value	4.8527	7.5575	5.0153	6.1179	13.89
MAX - MIN	0.0012	0.0006	0.020	0.053	1.12

Table 1 Results of performance test on a 160 kN electrical press with DDT drives [1]

shaft servo motor connected to a ball-recirculating spindle locked by a nut. The nut has a high-precision guiding system to guarantee accuracy and alignment.

The author reported on a performance test on a 160 kN compaction press with DDT drives. The results demonstrated a positioning accuracy of 0.0012 mm for the upper punch, 0.02 mm for the total part height and 0.053 g for the total part weight (Table 1).

Nowadays, servo-electrical drive technologies are also applied to side-forming devices. A typical system consists of independent side-forming modules that can be arranged freely over the die platen. Each module uses an individual drive, servo-assisted and CNC-controlled, with its own positioning high-resolution linear scale and force monitoring (Fig. 3).

Extremely complex shapes can be produced using this innovative technology, without using mechanical stops on the side forming punches (active pressing). A performance study on a part based on a full split die with 4 side punches was carried out to verify these units. The results, in terms of accuracy, are displayed in Fig. 4. The minimal kick-back effect and undershooting can be seen in Fig. 5.

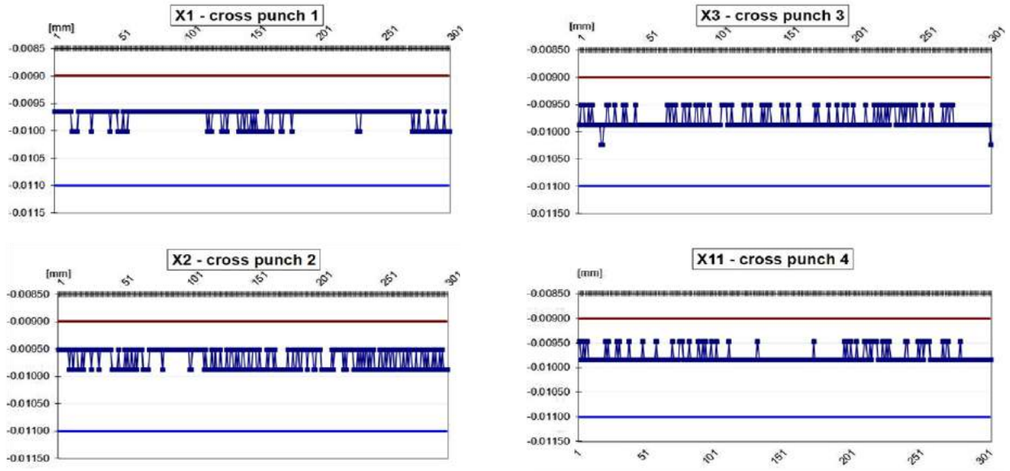


Fig. 4 Results of performance test with full split-die part (4 sliders) [1]

A servo-electrical drive, attached to the lower ram of the press, has been developed for the production of threads and other helical profile shapes. This drive consists of a DDT motor spindle with a special bearing design to withstand the axial forces (Fig. 6). This system is capable of performing axial movements with rotation in both directions. The movements (axial and rotation) are synchronised with the movement of the die. Rotational movement is closed-loop controlled by a precision rotary encoder that guarantees the correct angle every time during the press cycle. The torque on the rotational drive can be monitored and displayed in the HMI (Human Machine Interface) for trouble-shooting and process surveillance.

Until recently, electrically driven presses were restricted to around 700 kN for multi-level equipment and 1500 kN for single level. The reason for this has been claimed to be a cost-benefit limiting factor in up-scaling motors for high force applications.

A possible route to overcoming this limitation is through the use of a hybrid electrical-hydraulic concept: the main axes are electrically driven, whereas the additional upper and lower punches, including the core-pin, are CNC hydraulically driven.

The main electrical drives provide a drastic reduction in energy consumption, as well as high positioning accuracy, full reliability, reduced maintenance requirements and low operating costs. The hydraulic additional axes make the equipment very flexible and compact, and keep development and investment costs at acceptable levels.

Due to the upper electrical ram, the general speed of the press can be increased. Initial field tests on a 2000 kN multi-platen press of this type showed that a medium-sized synchroniser hub, usually produced at 13-14 strokes/min on an equivalent CNC hydraulic press, can be pressed at speeds over 16 parts/min. Also, the upper ram and die had a positioning accuracy and repeatability of +/- 0.002 mm, significantly better than the +/- 0.01 mm of an equivalent CNC hydraulic press. Also, a much better thermal stability and hence a shorter process set-up time is foreseen.

Another innovation is the use of linear guides for the main and addi-

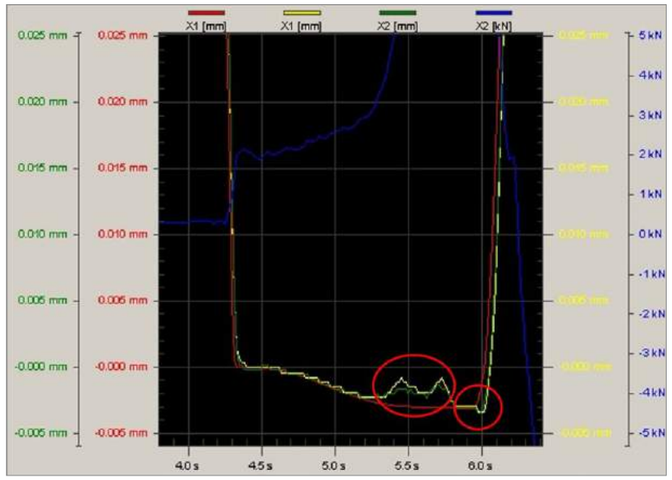


Fig. 5 Minimal kick-back effect and undershooting during decompression [1]

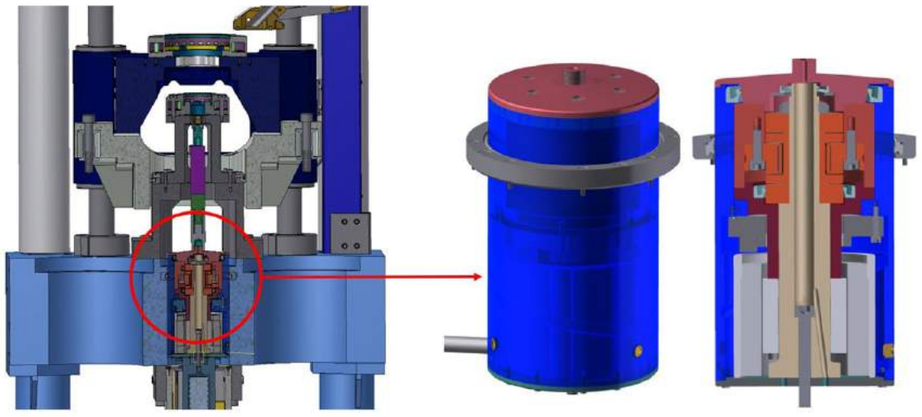


Fig. 6 DDT drive with axial and rotational capabilities for the production of threads [1]

tional platens, instead of the typical guiding columns. The linear guides are attached to a high rigid wall in the back of the press and provide platen stiffness in the same range as guiding columns, but with improved accessibility. The mechanical stops for the additional axes have a motor-driven press position adjustment stroke of 12 mm, automatically controlled through parameters in the HMI software.

The typical distribution of energy requirements of a full hydraulic press shows that more than 70% of the consumption is in the upper ram. The design of current and future multi-level presses with electrical drives may have to take this into consideration. By replacing only the main cylinders for electrical drives, energy consumption can be drastically reduced, from an average of 50-70 kWh to 10-20 kWh.

As a proof of concept, a synchroniser hub (1500 kN force, three lower punches, two upper punches, total height 18.5 mm) was produced on a full hydraulic press at 12 parts/min with 62 kWh and on a hybrid electrical-hydraulic press at 14.7 parts/min with 10.5 kWh. Also, the combination of main drives with a servo-controlled pump for the additional axes reduces the consumption in the stand-by mode to only 2 kWh.

The architecture of the press, combined with the twin DDT system for the die and the compact hydraulic unit for the additional axis, enable a reduction in pick-up height of the equipment (distance between floor level and die platen in the withdrawal position. This is reduced to 1800 mm in the configuration with four lower levels, meaning that the equipment does not need a pit for installation, but a simple platform 600 to 800 mm tall.

The author concluded that over the last ten years, the production equipment for axial die compacting has experienced a substantial technological evolution, mainly linked to the development of CNC controlled electrical drives that tend to replace the hydraulic cylinders widely used until now. For the production of more complex shapes, alternatives to pure axial compaction have been developed, such as side forming and drives that combine axial with rotational forming. The size of electrical-driven powder compacting presses has been steadily growing and it was stated that, as the electrical presses have clear technological and economic advantages against the full hydraulic versions, this upscaling will surely continue.

Fig. 7 The new 200 ton electrical multi-level press from Osterwalder

	Warm compaction	Warm die compaction	Warm compaction	Warm die compaction	Warm die compaction
	ANCORDENSE™	AncorMax® D	ANCORDENSE™ 450	AncorMax® 200	AncorMax® 225
Market introduction	1994	2002	2006	2006	2012
Lubricant % (typical)	0.6	0.55	0.3 - 0.5	0.40	0.2 - 0.3
Powder heating	Yes	No	Yes	No	No
Powder temperature	120 - 140°C	Not required	135 - 165°C	Not required	Not required
Die heating	Required	Required	Required	Required	Required
Part temperature	130 - 150°C	60 - 70°C	140 - 175°C	80 - 105°C	90 - 112°C
Density increase over 0.75% AcraWax at 700 MPa compaction	0.12 g/cm³	0.10 g/cm³	0.15 g/cm³	0.12 g/cm³	0.15 g/cm³
Green Strength at 700 MPa (ref - 0.75% AcraWax - 13 MPa)	25 MPa	20 MPa	30 MPa	25 MPa	35 MPa
Ejection force at 830 MPa compaction	17 MPa	26 MPa	15 MPa	27 MPa	17 MPa
Part height limitation	Standard PM limits	20 mm	Standard PM limits	30 mm	30 mm

Table 2 Higher density compaction processes capabilities [2]

Methods of achieving higher density in powder metal parts by single press and single sinter

A second paper, from Kalathur S Narasimhan (P2P Technologies, USA), turned the attention to the issue of high-density forming. The point was made that the growth of PM structural part applications, particularly in the automotive sector, has been and remains closely linked to the ability to process parts to high density. Fig. 8 shows the effect of increasing density on the strength of a PM part for three different material compositions and other benefits of increasing density were identified as improved ductility and higher fatigue endurance.

The paper then discussed methods of improving density. Firstly, the longest established methods in this context were identified as double press-double sinter (DPDS), copper infiltration and powder forging. Although each of these methods has proved successful in achieving increased density, they all have drawbacks that have limited their application.

For DPDS, the costs associated with this process are significant. After pre-sintering, the dimension of the part is different from the original die size and, hence, a separate tool is necessary for the second compaction. Two furnaces are required; one for pre-sintering and the second for the final sintering. Press utilisation time is increased, or a need exists for a second press. Most importantly, work in process inventory increases.

The limitation of copper infiltration is that isolated pores that are not interconnected do not become filled with Cu and large pores are not infiltrated. Generally, subsequent infiltration of a sintered part delivers

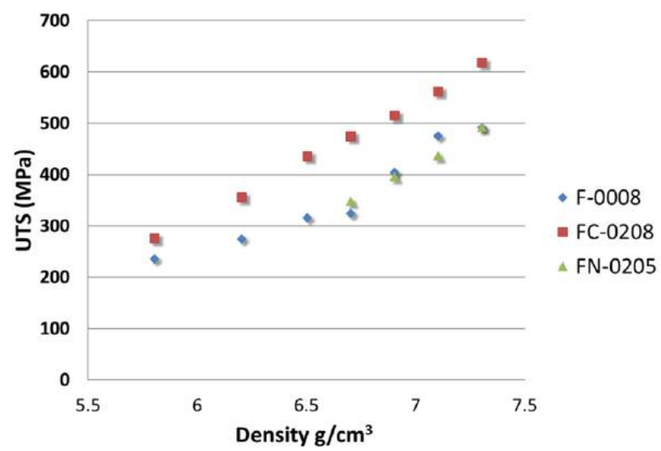


Fig. 8 Effect of density on ultimate tensile strength of common powder grades used for making PM parts [2]

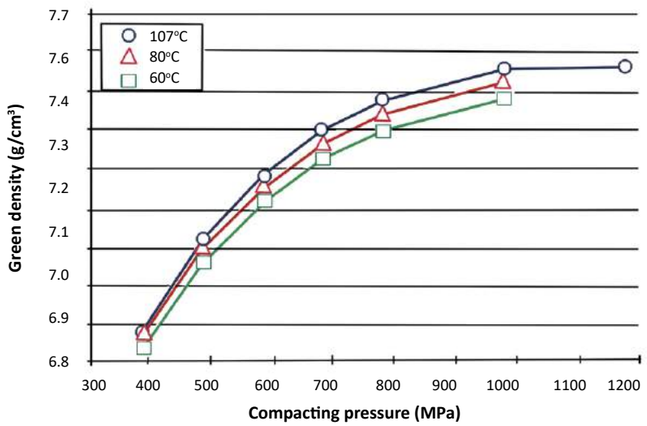


Fig. 9 Compressibility curves for AncorMax 225, FLN2-4400 at various die temperatures [2]

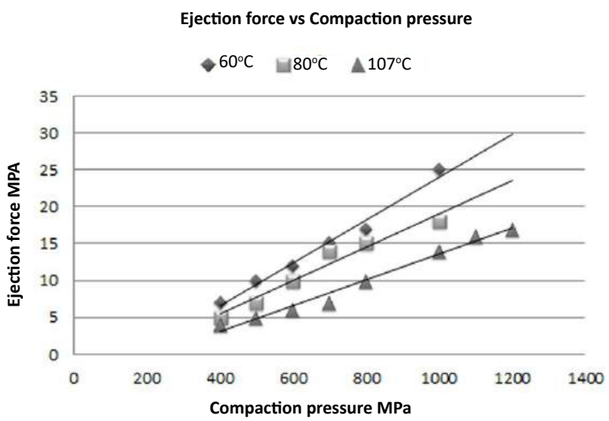


Fig. 10 Ejection force required on AncorMax 225 FLN2-4400 mix compacts pressed at various die temperatures [2]

Ancorsteel® 1000B				
Sieve distrubution (w/o)				
Micrometers	+250	-250 / +150	-150 / +45	-45
U.S. Standard Mesh	(+60)	(-60 / +100)	(-100 / +325)	(-325)
	Trace	12	67	21
Ancorsteel® 1000C				
Sieve distrubution (w/o)				
Micrometers	+250	-250 / +150	-150 / +45	-45
U.S. Standard Mesh	(+60)	(-60 / +100)	(-100 / +325)	(-325)
	Trace	17	70	13

Table 3 Atomised iron powder fractions by sieve size [2]

higher strength than single step infiltration; hence sintering followed by infiltration is preferred. Due to the growth associated with Cu, higher carbon content is used to control the dimensional change. This higher carbon leads to reduced impact strength.

Although a number of PM parts are produced through the powder forging process route, including connecting rods and automotive transmission components, powder forging is a capital-intensive process.

More cost-effective means of achieving higher density have therefore been pursued over the past couple of decades or so. In the 1990s, it was discovered that, when compaction of powders is carried out at elevated temperatures (up to ~300°C), the density of the compacted part was higher than without heating; the higher the temperature, the higher the density. However, at temperatures above ~250°C, oxidation of the powder becomes an issue and so material grades were developed that allowed 'warm compaction' at 160°C or below.

For instance, Hoeganaes Corporation introduced various products that enabled compaction at 140°C (ANCORDENSE™, 60°C (AncorMax® D),92°C (AncorMax® 200),160°C (ANCORDENSE™ 450),107°C (AncorMax® 225). Each of these products used different types of binders and lubricants that operate at maximum efficiency at the specified temperature to enable compaction to achieve density and ejection of the part.

A comparison of the various high-density processes is given in Table 2. The aim was to lower the lubricant to as low a level as possible without affecting the ejection pressure of the compact from the die after compaction.

Warm compaction that requires both powder and die heating has maximum flexibility, but field experience has indicated that powder heating is very inconvenient for most parts makers, although the process is still widely used globally.

	Lube Wt.%	Powder type	Green density (g/cm³)	Sintered density (g/cm³)	TRS (MPa)	D.C (%)	Hardness HRA
Compaction at 600 MPa	0.6	Full distribution	7.16	7.17	936	0.09	43
Compaction at 600 MPa	0.2	+325 mesh (44 µm)	7.27	7.26	1004	0.16	45
Compaction at 600 MPa	0.4	+325 mesh (44 µm)	7.24	7.23	974	0.12	44
Compaction at 600 MPa	0.6	+325 mesh (44 µm)	7.17	7.19	913	0.12	43
Compaction at 800 MPa	0.6	Full distribution	7.26	7.30	1002	0.13	46
Compaction at 800 MPa	0.2	+325 mesh (44 µm)	7.42	7.44	1162	0.20	48
Compaction at 800 MPa	0.4	+325 mesh (44 µm)	7.36	7.37	1073	0.17	47
Compaction at 800 MPa	0.6	+325 mesh (44 µm)	7.28	7.31	1007	0.14	46

Table 4 Ancorsteel 1000B (full distribution and +325 mesh screened powder) with 2% nickel + 0.6% graphite, compacted at 600 MPa and 800 MPa at ambient temperature, sintered at 1120°C in $90N_2/10H_2$ atmosphere and normally cooled [2]

The development of non-powder heating technology (Warm Die Compaction) was therefore welcomed. This process relies on the heat transfer from the heated die to the powder during compaction. The powder away from the die wall may not be at the desired temperature if the mass is increased significantly, hence a limitation of part height and weight of 30 mm or 1 kg, respectively.

The major effort over the years has been to reduce the lubricant to a minimum. AncorMax 225 achieved this objective with a lubricant content as low as 0.25%.

In 2002, Toyota Motor Corporation introduced a technology that combined Warm Die Compaction with higher compaction pressures. In this technology, the admixed lubricant level was held at a low level (0.25 wt.%), die wall lubrication was applied and compaction was carried out at 140°C. At high compaction pressures of above 1000 MPa, ejection forces decrease and continued increase in compaction pressure is possible, with very good high density being achieved. The

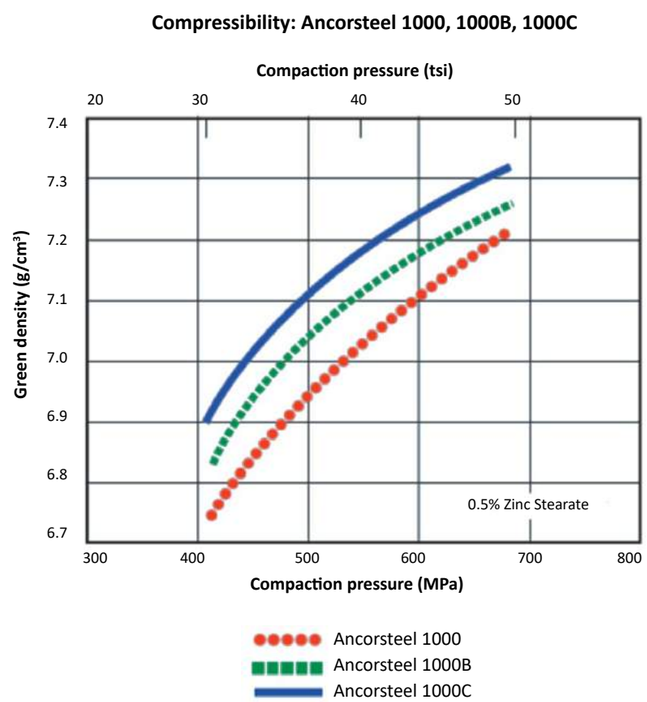


Fig. 11 Compressibility of atomised iron powders with sieve fractions shown in Table 3. Note that Ancorsteel 1000C has lower fines (-44 µm) compared with Ancorsteel 1000B and has higher density [2]

Relative cost	PM process
1	Single press and sinter
1.65	Double press and double sinter
1.5 to 1.8	Cu infiltration
1.9 to 2.0	Powder forging
1.4	Warm compaction
1.2 to 1.3	Warm Die compaction
1.1 to 1.2	+325 Compaction
unknown	High tonnage compaction with warm die wall lubrication
unknown	UTRON, Combustion compaction

Table 5 Rough estimates of relative costs of PM higher density processes [2]

effects of higher compaction pressure are demonstrated in Figs. 9 and 10. The ejection force, which is an indication of good lubricity in the mix, is shown in Fig. 10.

The paper concluded with the presentation of the author's proposal for a modification of the base iron powder to increase density. This proposal was based on the recognition that information in Hoeganaes Corporation data sheets (Table 3) on the particle size distributions of the most commonly used iron powder grades, Ancorsteel® 1000B and Ancorsteel® 1000C, indicated that Ancorsteel® 1000C had a lower amount of -325 mesh (44 µm) powder and yielded a higher density level (Fig. 11). Lowering the -325 mesh (44 µm) fraction increases density, possibly because of the interference of the fine powders with particle-particle contacts.

It was postulated that, since the surface area of the powder is decreased by removing the -325 mesh (44 µm) fines, it should be possible to use a lesser amount of lubricant and achieve higher density. Decreasing the lubricant is not likely to affect ejection of compacted parts, as the surface area is reduced by using +325 mesh powder and, hence, reduced lubricant will still provide lubricity.

A set of trials was therefore conducted comparing full distribution Ancorsteel® 1000B powder with 0.6% lubricant and screened +325 mesh powder with 0.4 and 0.2% lubricant in terms of green and sintered density. The results are shown in Table 4, which illustrates the benefit of lowered lubricant level on density. A lower lubricant level is possible by reducing the fines. Based on part complexity and surface area, the lubricant levels need to be adjusted.

Microstructure evaluation showed no laminations cracks at the reduced lubricant level of 0.2% and the pore distribution was uniform. It was claimed that all of the higher density processes discussed in the paper should also benefit from using +325 mesh powder instead of full distribution powder. It was, however, pointed out that in order to adopt the proposed development, atomisation technology development is necessary in order to minimise -325 mesh fractions in the currently available atomised iron powders, as screening 20% of the powder fraction to obtain +325 mesh is not a cost-effective approach.

Finally, Table 5 compared the relative costs of the various process options and the projected cost of the new technology proposed.

References

[1] Recent innovations on cold axial die compaction technologies, Guillermo Polo. As presented at POWDERMET2018 International Conference on Powder Metallurgy & Particulate Materials, San Antonio, Texas, USA, from June 17–20, 2018, and published in the proceedings by the Metal Powder Industries Federation (MPIF).

[2] A brief overview of high density processes, Kalathur S. Narasimhan. As presented at POWDERMET2018 International Conference on Powder Metallurgy & Particulate Materials, San Antonio, Texas, USA, from June 17–20, 2018, and published in the proceedings by the Metal Powder Industries Federation (MPIF).

Author

Dr David Whittaker
Tel: +44 1902 338498
Email: whittakerd4@gmail.com

Proceedings

Advances in Powder Metallurgy & Particulate Materials—2018, the proceedings of the technical sessions, poster program and special interest programs (where applicable), is published in digital format by the MPIF. These proceedings are provided to full-conference registrants free of charge or they can be purchased from the MPIF's Publications Department.

www.mpif.org

POWDERMET2019

POWDERMET2019, the International Conference on Powder Metallurgy & Particulate Materials, will take place in Phoenix, Arizona, from June 23–26, 2019.

www.powdermet2019.org

industry events

2018

Euro PM2018 Congress & Exhibition
October 14-18, Bilbao, Spain
www.europm2018.com

formnext
November 13-16, Frankfurt, Germany
www.formnext.com

Hagen Symposium 2018
November 29-30, Hagen, Germany
www.pulvermetallurgie.com

POWDERMET2019
June 23-26, Phoenix, USA
www.powdermet2019.org

PMTi 2019
September 24-27, Salt Lake City, USA
www.pmti2019.org

2019

APMA 2019
February 19-21, Pune, India
www.apma2019.com

MIM2019
February 25-27, Orlando, USA
www.mim2019.org

Asiamold - 3D Printing Asia 2019
March 10-12, Guangzhou, China
www.asiamold-china.com

PM China 2019
March 25-27, Shanghai, China
www.pmexchina.com

RAPID + TCT 2019
May 20-23, Detroit, USA
www.rapid3devent.com

AMPM2019
June 23-26, Phoenix, USA
www.ampm2019.org

Pick up your free copy at PM related events worldwide

Powder Metallurgy Review magazine is exhibiting at and/or being distributed at events highlighted with the *Powder Metallurgy Review* cover image

Event listings and media partners

If you would like to see your Powder Metallurgy related event listed in this magazine and on our websites, please contact Paul Whittaker, email: paul@inovar-communications.com

We welcome enquiries regarding media partnerships and are always interested to discuss opportunities to cooperate with event organisers and associations worldwide.

Advertisers' index

Shaping the future together

The powder metal industry faces a rapidly changing business environment. To stay ahead, we work closely together with customers and partners to improve processes, secure competitiveness and develop the next generation of applications. We are shaping the future – together

To discover more about Höganäs powder metal solutions, please visit our website or contact your nearest sales representative.

Inspire industry to make more with less. **www.hoganas.com**

Höganäs