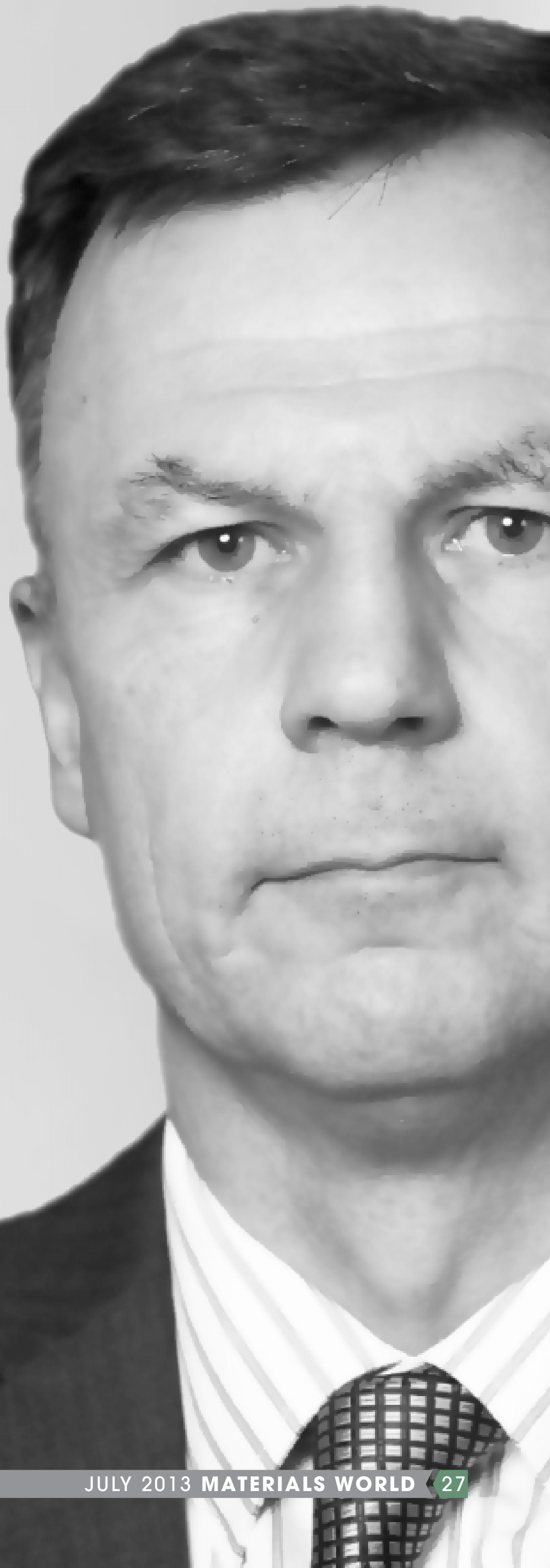
Q&A

High-performance ceramic powders play a crucial role in everything from coatings for turbine engines and land-based power generation to ceramic parts for prosthetics and sensor technology. Paul Newbatt from nano-ceramic powder manufacturer Innovnano tells Melanie Rutherford about recent R&D in thermal barrier coatings technology and how the company has taken nanotechnology to an industrial scale.



Tell me a bit about your background in the industry.

I've been in the commercial side of technology for more than 25 years, mostly with international organisations, working in business development, communications and building sales teams. I studied chemistry at Brunel University, UK, and stayed on to do research work in transition metal oxide chemistry for a few years. I then moved into industry, to apply that knowledge – including thermal analysis, rheology and viscometry – in the instrumentation market. I got involved in powder technology in 2002, working with metal powders and nanotechnology in one of the centres set up by the Department of Trade and Industry (DTI – now the TSB). Innovnano recruited me to help it commercialise its nanostructured ceramic powders. My role is to effectively take them to market, which we've been doing over the last 18 months.

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What attracted you to join Innovnano?

For me, the main attraction is its capacity to employ nanotechnology on an industrial scale. The company has taken nanotechnology out of the test tube and developed a new process – EDS – to produce industrial-scale quantities of nanostructured materials. The site where I am based in Coimbra, Portugal, currently manufactures 100 tonnes in one production module and there's room to expand that as demand increases. Furthermore, the nanostructured powders produced by the EDS process, which involves high temperatures and pressures followed by rapid quenching, have interesting applications in a wide variety of advanced technologies, an example being thermal barrier coatings for the aerospace industry. Working with an enabling technology like EDS in such cutting-edge sectors is an exciting time.

What makes a good thermal barrier coating?

Obviously it's got to have a high temperature resistance capability, but if a ceramic powder is also homogeneous then you get a very stable coating with good continuity. What you don't want is variation in the powder feedstock, as that will translate into variations in the coating. If you've got good, low thermal diffusivity then you can use thinner, lower mass coatings. Not only are there cost benefits associated with using less material, but also mechanical benefits, as you can effectively reduce the weight of the insulated moving part, avoiding the issues associated with centrifugal force, for example, on a turbine blade. Controlling and defining the median particle size of the powder is therefore an important requirement, in order to get the desired coating structure and ensure strong adhesion to the substrate. Excitingly, the combination of nanostructured powders and an emerging process called suspension plasma spray (SPS), enables industry to 'design' the appropriate coating for end applications. In particular, nanostructured feedstock and SPS, can be used to obtain a columnar structured coating. Coatings with a columnar morphology are highly desired by the aerospace industry for use as a thermal barrier coating (TBC), as they offer high strain tolerance and high thermal insulation, ensuring maximum protection from the engine's extreme temperatures.

Tell me about this SPS technique

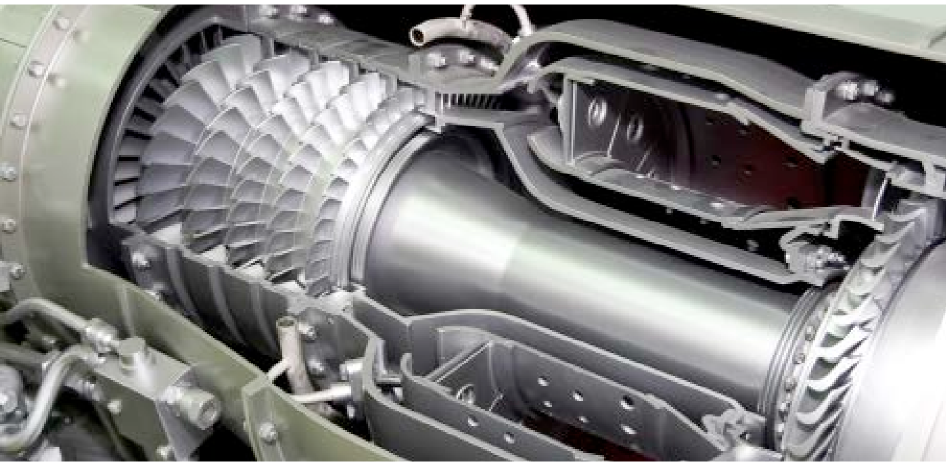
Suspension Plasma Spray (SPS) is a relatively new, and still developing, technique that injects a suspension feedstock (powder suspended in a solvent), rather than the conventional solid-based feedstock, into the plasma spray for deposition as a coating. Innovnano uses nanostructured ceramic powders in an ethanol-based suspension, which, when applied by SPS, gives a high quality end coating, although alternative solvents can be used. As a method, SPS holds several important benefits. These include its reduced capital outlay, high deposition efficiency and its flexibility - SPS can be used to produce multiple coating structures (depending on the desired properties of the end-application). Furthermore, a key advantage with Innovnano's powder for SPS is that it doesn't use other chemical dispersants when in suspension, keeping the chemistry simple – after all, manufacturers want a powder suspension that is easy to handle and simple to use. Nanostructured feedstock for SPS has been shown to exhibit a fundamental advantage, and can achieve coatings with increased durability, in turn reducing the need for service intervention. As such we are working closely with SPS torch manufacturers and clients to further exploit the benefits of nanostructured powder-based suspensions in conjunction with this promising technique.

How does SPS compare to similar techniques?

SPS coatings compare favourably with those produced by electron beam – physical vapour deposition (EB-PVD), which is a well tried-and-tested process that the aerospace industry, among others, has been using for years. I think what attracts coating specialists to SPS is the potential it provides for enabling top quality coatings but at a substantially lower capital equipment expenditure and footprint. SPS also offers a significant increase in process efficiency in terms of getting the powder onto the substrate and, as a higher percentage of powder is deposited on to the target compared to EB-PVD, SPS effectively minimises waste and process costs. Another positive attribute of SPS over EB-PVD, is that it does not require a direct-line-of-sight deposition mode. This means that when coating complex shapes with hidden curves or internal surfaces, users of SPS do not have to manipulate the substrate to ensure that internal surfaces are in the line-of-sight of the evaporated material. An alternative popular coating technique is air plasma spray (APS). Compared to this method, SPS is able to retain the nanostructure, from the feedstock, in the deposited coating due to its less aggressive technique. This is a great improvement as retaining the nanostructure enhances the overall performance of the coating. Unlike APS, SPS can also be tailored to a broader range of coating structures for given application requirements: from the 'splat-type' coating to the previously mentioned columnar coatings prevalent on turbine blades.

What temperatures can these coatings withstand?

There's probably no one answer as it's so application dependent. For aerospace manufacturers who want TBCs to withstand the extreme temperatures (around 1,400°C) found in engines, the dense, columnar structure coating produced using the SPS technique



with a nano-powder feedstock is a good solution. However, they are constantly looking to drive temperatures up. If you can run an engine hotter, then you can run it more efficiently. You require less fuel and there are fewer CO_2 emission issues – companies are being driven by government legislation in that direction as well, so this is an additional bonus.

What are the factors limiting this target?

It's a combination of the material and the process used to lay it down. Our EDS process lends itself to the production of some of the emerging ceramic powders that are sought after for SPS. Ultimately, it's about finding materials, adapting those materials within suspensions, and working with spray torch companies to develop the conditions to produce good nanostructured materials.

Which industries will benefit from these materials and techniques?

Aerospace and land-based power generation are the two premium ends of the market. Then you're getting into marine engines and automotive, and more industrial areas such as hot zones, boiler technology and piping systems.

Are you seeing demand from other industries?

Absolutely – our ceramic powders can be used in biomedical applications such as prostheses, connectors and implants, as well as solid oxide fuel cells in sensor technology. Perhaps even in the photocatalytics area the use of SPS will be important for applying the 'smart' surfaces seen in modern, interactive devices.

Is there greater demand from any particular industry?

As more people are travelling, the demand for air travel is growing – emerging countries are setting the pace here. If there's a demand for travel there's a demand for aircraft, and that means a demand for new, better performing engines, cleaner energy technology, and a requirement for keeping those engines in A1 condition. The more weight there is on a rotating turbine blade engine, the higher the centrifugal force, and you want to keep that to a minimum. So a thinner – even incrementally thinner – barrier coating is an advantage, bringing down the weight and reducing the centrifugal force, which in turn reduces wear.

What are the current trends in the coatings industry?

SPS is emerging fast as industrial leaders are continuously looking for alternative coating methods that can cut down on operational costs. Another expanding area is alternative and sustainable energy. We have been collaborating with academic institutes to help with this R&D phase, and have developed and produced sputter coating targets, made from nanostructured aluminium zinc oxide to create ultra-thin films and transparent conducting oxides for photovoltaic applications, and the results are excellent. Industry is increasingly looking for a replacement for some of the more conventional transistor conducting oxides – indium tin oxide is used a lot, but it's getting scarcer and more expensive. Materials such as aluminium zinc oxide are a cheaper, more readily available, and equally transparent and electrically conducting substitute.

How important is it for academia and industry to work together?

I don't think you can survive in an industrial, high-technology environment these days without having a good network of partner organisations, whether academic or from a commercial environment. We have a good network of close relationships with industry and academia that we draw upon to pool experience and expertise. We work closely with specialists from Portugal and the Iberian Peninsula, as well as the USA, the UK and Germany.

What does the future hold for the coatings industry?

I would like to pose that challenge to the reader – the next development in ceramic powders comes from them. Where next? Our EDS process is so adaptable that it lends itself to the production of complex mixed oxide ceramic systems and we are always looking for that 'industry pull' to go on to the next products. The next tranche of nanostructured ceramic powders is only limited by the imagination of industry.

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