Technical ceramics: Perfecting the process

Demand for technical ceramics has remained relatively stable over the last few years, but increasingly detailed customer specifications for these materials mean that manufacturers are having to become more flexible in their product designs. *Kasia Patel, North American Editor,* examines some of the new developments in manufacturing techniques.

Technical ceramics is a growing sector and the highly specialised nature of these products mean that specifications for their design and performance characteristics are constantly evolving, requiring companies to develop new processing techniques and materials to satisfy customers and remain competitive.

UK-based Morgan Advanced Materials has increased its focus on niche applications, having recently announced an expanded offering of zirconia in brazed assemblies, in addition to digital modelling capabilities for other brazed applications.

The company told **IM** that demand has been growing, not in terms of product volumes, but in the form of a shift in material requirements, with customers expecting more from the performance of their products.

"You would typically use ceramics brazed assemblies in high performance environments where performance is critical," Oliver Ridd, international sales and new business development manager at Morgan, told **IM**. "You can make these assemblies out of lots of other feedthrough but they wouldn't be brazed, they'd be joined by other methods – with glass and plastics as well. But typically, when you've got higher temperatures, higher pressures, or high voltage requirements, you would need to use ceramic. That's where the increase in demand is coming from."

Brazing is used to connect materials such as metals and ceramics to create new components. Other methods include shrink fitting and gluing, however, according to Morgan, these are not always the most relevant options for components with complex geometries destined to be used in harsh environments.

One of the benefits touted by Morgan of using ceramic-to-metal brazing, particularly with zirconia, is the outcome of robust and resilient joints, creating better strength and hermeticity (water- and air-tightness).

The company added that brazing of zirconia allows for greater flexibility when dealing with complex geometries. Brazed assemblies normally utilise alumina as a base material, however zirconia is Morgan's new product offering.

Zirconia is highly resistant and exhibits high fracture toughness, making it suitable for use in components exposed to wear and corrosion, such as in the petrochemical and industrial sectors. It is widely used as a refractory material, as well as in insulation, abrasives and enamels.

Typical applications for Morgan's brazed assemblies include gas detectors, microscopes, nuclear detectors and sensors and engine management for the aerospace sector.

"With regards to the digital modelling, we have a few sites around the world that are manufacturing brazed assemblies. What we would like to have is a cohesive expression, rather than just at one particular site," Ridd said.

As well as adding zirconia to its brazed assembly portfolio, Morgan has also developed digital modelling for technical ceramic production, which allows the company to be more flexible in responding to customer requirements, in addition to benefiting from the cost savings offered by digital modelling with prototyping, which bypasses the need to test the product by manufacturing it first – this does away with engineering and raw material costs, while speeding up the timescale of developing a product.

"One of the most important factors is around the brazed joint, the part where the ceramic and the metal come together. If you get that wrong, they can break mechanically, they can break under temperature, or, if they are supposed to be vacuum type, this also needs to be tested," Ridd told **IM**. "The modelling we typically do is thermal modelling to show how the joints will behave under temperature, so during brazing and during application as well."

While some companies are still experimenting with the development of new products using trial and error, according to Morgan, the availability of more powerful computers means there has been a shift to doing more with digital modelling. From the company's point of view, it is a time and cost saver, but also gives it an edge by enabling it to produce an almost entirely bespoke product to customer requirements.

Ceramic matrix composites

According to a recent report on the technical ceramics industry by business research group, Markets and Markets, the technical ceramics sector will be worth more than $7.6bn by 2019, recording annual growth of 6.49% from 2014.

The report identified Asia-Pacific as the largest market for technical ceramics and said that ceramic matrix composites (CMCs) were likely to be the fastest growing product segment.

"CMCs allow original equipment manufacturers OEMs to customise light-weight and high-temperature resisting composites for various end industries, such as electronics, automotive, aerospace and military and defence," the Markets and Markets report stated.

CMCs comprise a ceramic matrix reinforced by a refractory fibre, made of a material such as silicon carbide (SiC). These composites offer low density, high hardness and superior thermal and chemical resistance and can be tailored to end use applications. To date, CMCs have been mainly used in internal engine components, exhaust systems and other "hot-zone" structures as lightweight replacements for metallic superalloys.

Although engineers have been researching the potential of CMCs for nearly two and a half decades, commercial successes for these materials have been largely confined to missile structures, radomes and exhaust systems for fighter jets. Nevertheless, this area continues to receive investment with the aim of achieving large scale manufacturing of CMCs, which at present can only be produced in relatively small volumes.

CMCs are typically made using fabrication processes, such as chemical vapour or liquid phase infiltration, hot press sintering techniques and polymer infiltration and pyrolysis (PIP).

Magnetic separation developments to boost Chinese ceramic minerals

Albert Li

China's Ganzhou SLon Magnetic Separator Ltd has launched a vertical ring and pulsating high gradient magnetic separator for various non-metallic processing applications, which it hopes will help Chinese ceramic mineral producers access higher value markets.

Feldspar from Yichun, in Jiangxi province, is abundantly available and has a whiteness of between 25 and 45 degrees. After the company's de-ironing and purification process, whiteness can reach up to 60-70 degrees, creating a high quality ceramic source material.

Laian county is also rich in feldspar, although owing to its high iron content, the material has traditionally been unsuitable as a quality ceramic source material. Now that the county has 10 processing facilities, feldspar ore with an iron oxide (Fe_2O_3) content of 1.48% can be processed to 0.8mm. This material is then fed into a magnetic separator, resulting in a non-magnetic product with an iron content of 0.26%, which satisfies industry requirements in both the ceramics and glass sectors.

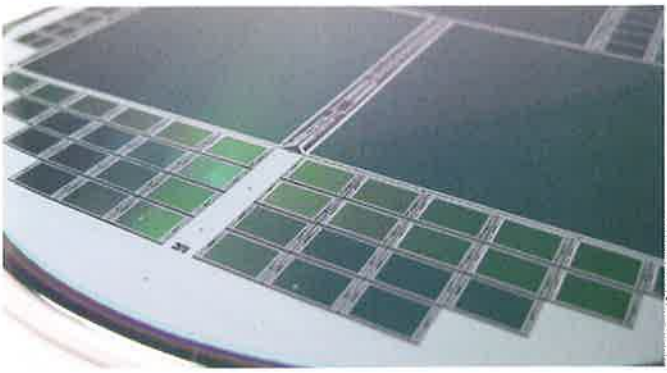
This processing technique is also being used by companies in Hengyang, Shenyang, Hubei and Chuxiong provinces in China.

Quartz sand mined in Hanzhong and Shaanxi provinces has a low economic value in the glass industry, owing to its high iron content. Low-iron/titanium material is sought after in high-tech glass applications, however. Looking to cater to this opportunity to upgrade Chinese ores is Taiwan Glass Hanzhong Silica Sand Co., a mining and processing business which produces quartz sand for the glass industry. The company has a production capacity of 200,000 tpa and since it began using magnetic separation in 2008, the Fe_2O_3 content in its quartz has fallen from 0.35% to 0.06%, reaching the quality standards required for glass applications.

Quartz from Fengyang in Anhui province has traditionally been easily processed into material with an Fe_2O_3 content of 0.01-0.02% using a simple process of crushing, grinding and de-ironing via permanent magnets, de-sliming and grading.

However, in recent years, this simple technique has been unable to yield material that satisfies the rising standards of end users. As a result, 70 local companies have started using magnetic separators to produce quartz with an Fe_2O_3 content of less than 0.008%, with a fine yield rate above 95%, increasing the value of the quartz sand several times over.

Silica processing company, Dongyuan County Jianji Mining Co. Ltd, which has a capacity of 1.7m tpa dry and wet silica fume production, has also managed to reduce the Fe_2O_3 content in its quartz from 0.08% to less than 0.008% using magnetic separation.



Windell Oskay, via Flickr

Companies that make silicon wafers need high quality ceramic feedthroughs for their machines, according to Morgan.

Digital modelling also removes the element of risk. In critical applications, such as in the oil and gas industry or the medical sector, knowing in advance how a product will perform in a high stress situation before it is actually used is an extra assurance that the final result will meet the standards required by the particular application.

Asia: demand due to more than urbanisation

In the ceramics field, Asia represents a huge end market for products driven by urbanisation, which typically increases consumption of tiles and other ceramic household items. But it is also increasingly becoming a place to sell processing technology required to manufacture sanitaryware and whiteware, as quality becomes more important.

Another trend in technical ceramics technology is the provision of high quality, niche materials for medical applications, as the healthcare system in Asia, particularly China, is overhauled.

"That's not just brazed assemblies but also metallised products, so we produce some alumina parts that aren't brazed, but which go into similar products, such as x-ray equipment. With the improvement in healthcare in China and other Asian countries, such as India and India, we're starting to see increased demand for high quality products," Ridd told **IM**.

These are not implantable products, but rather items such as feedthroughs for equipment like CT scanners, MRI scanners, x-ray technology and oncology equipment.

The semiconductor market has also been driving ceramics demand. While this end market initially created uses for ceramics, like feedthroughs in semiconductors, demand as a whole has started to flatten off now, according to Morgan, but the sector still presents an opportunity for growth in the development of upgraded products and processes.

"It used to be very cyclical, where new products were suddenly being discovered – iPads, phones – but now we've got so much of that equipment already, what's happening in the semiconductor market is the development of new, better, higher-performing versions of what we already have," Ridd told **IM**.

Commander, US 7th Fleet

Growth in the healthcare industry in Asia is driving demand for technical ceramics, encouraging companies to come up with more efficient and risk-free production processes.

"Actual demand in the semiconductor market has evened out a lot and the market is much more interesting for us. We've now seen, in semiconductor processing equipment, companies that make silicon wafers needing high voltage and high quality feedthroughs for their machines," he added.

Processing: The sum of its parts

With many technology companies experiencing a decline in demand, Morgan has chosen to focus on niches that its competitors might not address, rather than concentrating on mass production of glass feedthroughs, for example, which are cheap and easy to produce, but need to be made in very high volumes.

"We go for the higher quality, more difficult to make, challenging application products that always use ceramic. So, while the total market available to us is smaller, they are more profitable for Morgan and higher quality for the customer," Ridd told **IM**.

The processing of niche technical ceramics is not without its challenges. When it comes to brazing, Morgan emphasises the need to focus on modelling and designing joints properly in order to make the most of the technology and the materials used. With vacuum furnaces, constant investment in equipment required to make high quality ceramics.

However Ridd noted that, no matter how advanced the technology, good quality raw materials are a must. "If you try and make a brazed assembly with fantastic metal and fantastic brazing but you've got a really bad ceramic, it won't ever be a good product, so the underlying ceramic is critical," he said.

99% bespoke

At a time when keeping supply chain costs down is a growing priority, many companies are content to make do with existing technology and production methods. In Morgan's case, new technology developments are born from requests to improve existing processes, rather than the identification of product gaps in technical ceramics.

"It's much more a case of working with customers, rather than the consumers saying to

Processing ceramics in Iran

The lifting of economic sanctions against Iran has created opportunities for ceramics producers in the country. India is one of the fastest growing consumers of ceramic minerals, such as kaolin, and despite a thriving domestic industry, 6-15% of the kaolin consumed in India is imported from the UK, Germany, China and Iran annually.

According to Dr Alireza Ganji, advisor to the Industrial Soils Committee at the Iran Mine House (IMH), the country has a large ceramic production capacity, ranking fourth in the world in terms of ceramic tile output in 2014, producing over 450m square metres of tile. A large amount of ceramics produced in the country are consumed domestically — in 2014, internal market demand for ceramic raw materials totalled around 10m tonnes, driven by the tile, sanitaryware, tableware and other ceramics industries.

However, Ganji told **IM** that ceramics manufacturers want highly processed or refined raw materials, and domestic processing of ceramic minerals currently leaves much to be desired.

"At present, there are a few Iranian ceramic raw materials producers which are able to process and refine their minerals for ceramics and so they do not have the capacity to supply these industries from the view points of quantity and quality," he said.

"Furthermore, Iranian ceramic raw materials producers need to produce high grade raw materials at low prices in order to enter and compete in regional and international markets," he added.

Further investment is needed in processing technology in Iran, where companies have good mining knowledge but lack sophisticated beneficiation capacity. The removal of sanctions, coupled with business-hungry international engineering companies looking to get into Iran, mean that the country is likely to quickly catch up and be able to offer ceramic materials of international quality within a relatively short time.

Some important requirements outlined by consumers of Iranian ceramic raw materials include processing techniques. Such as:

- The ball clay refining process;
- Processing and refining of kaolin;
- Processing of different types of ceramic clays;
- Processing of feldspars;
- Applying and installing new technologies in processing of ceramic raw materials (ceramic minerals);
- Innovation in mining of ceramic raw materials mines;
- Foreign investment in ceramic raw materials mines and potential by leading companies of developed countries.

us they are desperate for something which nobody makes," Ridd told **IM**. "Normally we come up with something new that will give customers better performance, a longer lifetime, or works better at high temperature. It's a mutual relationship rather than being driven really hard by customers."

This is not to say that Morgan isn't focused on staying ahead of its competitors. "That's where developing and being able to braze with new materials, such as zirconia, and other changes are really important for us, because it means we're able to offer something really different that we weren't offering before," Ridd said.

As a result, around 99% of what Morgan's brazing arm produces is bespoke, with only one product line that produces standard, "off the shelf" smaller brazed items. Everything else is developed with the end customer's name on it.

Another benefit to focusing on niche technologies is less exposure to price volatility which has, in recent years, defined much of the ceramics market.

Don Klas, Global CEO Advanced Materials and Manufacturing at Morgan Advanced Ceramics, said that the diversity of products used as raw materials by Morgan makes 2016 difficult to predict, however many of Morgan's end markets are far less connected to GDP growth and market instability than bulk-produced ceramics products are.

Fang HSIEH

Demand for uniform, mass-produced, high quality ceramics in emerging economies is driving ceramic mineral producers in countries like China, India and Iran to upgrade local processing technology in order to supply these markets.

"For 2016, in specific areas, especially technical ceramics, we're seeing good possibilities," Klas told **IM**. "However, we are seeing some strong headwinds in semiconductor markets, electronics, and in general, the price of oil is playing havoc with some of our markets right now."

"There are some muddy waters ahead for 2016, but in areas such as the medical sector and very niche aspects of the electronics industry, we expect growth," he added. "Beyond that, is hard to predict what's going to happen more broadly."