bulletin | cover story

Ceramics in Australia: Raw and advanced materials drive Land Down Under's global reach

From technical ceramics to nuclear and solar R&D, Australia's sector is more than a zircon in the rough.

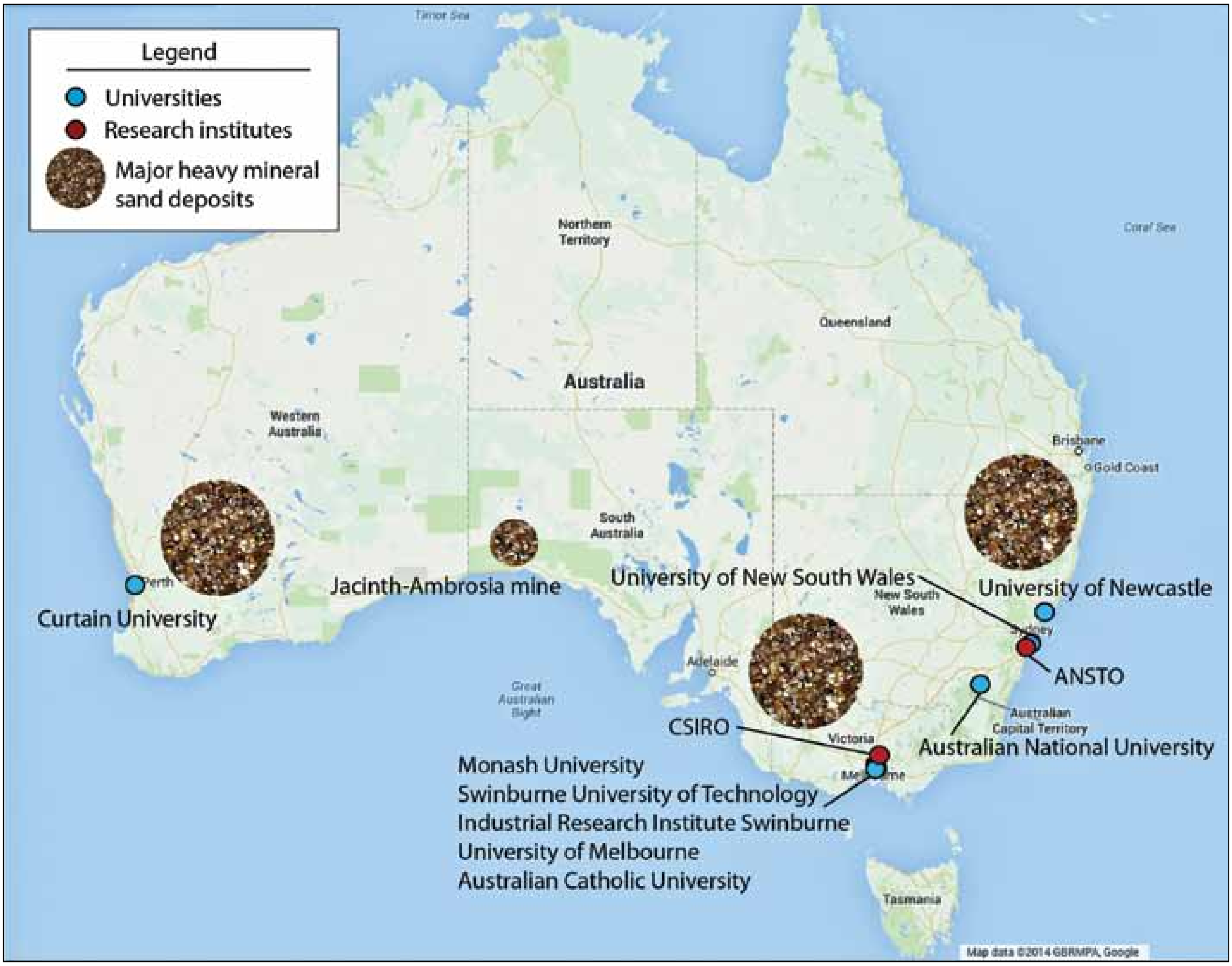
By Alex Talavera and Randy B. Hecht

A ceramic anode-supported fuel cell—composed of a yttria-doped zirconia (YSZ) anode support, nickel oxide anode, YSZ thin electrolyte membrane, and strontium-doped lanthanum manganite cathode—manufactured by Ceramic Fuel Cells Ltd. (Noble Park, Victoria).

Take one island continent rich in natural resources, academic strength, and economic muscle. Add a relatively small population that is concentrated in a handful of metropolitan areas and dispersed across a vast terrain. Throw into the mix a distance from global markets that can make foreign trade daunting—Melbourne is more than twice as many miles from Los Angeles (7,931) as it is from the South Pole (3,614). ("Nearby" is a relative term in this land—from the capital city, Canberra, it is 1,449 miles to Wellington, New Zealand; 3,353 to Jakarta, Indonesia; and 4,920 to Tokyo, Japan.) Combine all these factors and you begin to get a sense of the opportunities and challenges that come together in the Australian ceramic sector.

Wealth of minerals available

For example, Australia is the source of 37% of the world's supply of zircon. World production in 2012 was approximately 1.3 million tons, according to Iluka, the world's largest producer of this mineral sand. In its "Mineral Sands Industry Fact Book,"the Australian company notes, "In the majority of mineral sands deposits, zircon is produced in lower quantities than titanium dioxide. The historical average ratio between the two



Geographic locations of major universities, research institutes, and primary mineral sand deposits in Australia.

mined product streams is in the range of 1:4 to 1:5. Iluka's Jacinth–Ambrosia mine in South Australia is the exception, with zircon accounting for approximately 50% of the assemblage of valuable heavy mineral." Approximately 50% of zircon is used in the ceramics sector, the company says, and demand for it is heavily concentrated in China (41%), Europe (25%), and Asia–Pacific (18%), whereas North America accounts for only 8% of global demand.[1]

Rare earths are another area of natural resource activity. The government agency Geoscience Australia estimates that the country's rare earths, reported as rare-earth oxides (REO), as of December 31, 2012, "amounted to 3.19 million tons (Mt) of economic demonstrated resources (EDR), 0.42 Mt of paramarginal resources, and 31.14 Mt of submarginal resources."

About 67% of Australia's accessible EDR comprises reserves as defined under the Joint Ore Reserve Committee (JORC) code." Of this, "33% of the EDR comprises published JORC code compliant measured and indicated resources in operating mines, deposits being developed for mining, and in deposits that have published scoping/feasibility studies with positive results. There is a further 16.13 Mt REO in the inferred resources category."[2]

The agency adds, "Using available information, Geoscience Australia estimates that Australia's monazite resources are around 7.8 Mt. Assuming the REO content of monazite to be about 60%, the heavy mineral deposits could hold a resource of around 4.68 Mt contained REO. Currently, extraction of rare-earth elements from monazite is not viable because of the cost associated with disposal of thorium and uranium present in the monazite."

The Australia Nuclear Science and Technology Organisation (ANSTO), which is part of the country's Department of Industry, has been involved in rare-earth processing, analysis, and development for more than 20 years. Its ANSTO Minerals department processing capabilities extend from "rare earths that contain major economic minerals, such as monazite, bastnasite, and xenotime," to "rare earths from accessory, more complex mineral phases, such as apatite, zirconium/niobium minerals, and other less frequently exploited minerals." In addition, it has developed "conceptual studies to introduce new technology into existing mineral processing flow sheets" and been involved in "solvent extraction technologies used for production of separated rare-earth products."[3]

Back-and-forth commercial transactions

But the ceramic sector's materials requirements and the parameters of Australia's domestic market can lead to commercial transactions that move across borders and back again. A case in point is the high-purity aluminum oxide and high-purity zirconia that are the principal raw materials used by Ceramic Oxide Fabricators, whose single biggest product is the $SIRO_2$ oxygen sensor. "None of those materials are refined to the high purity that we need in Australia, so we import most of our raw materials, because the market for these high-purity oxides in Australia is too small to justify refining them here," says Alan Walker, manager.

The company has a long-standing relationship with two suppliers in Japan, which also is the destination for some of its exported finished products. "The great majority of our sales are exports," Walker says. "We import raw materials from Japan, turn them into finished ceramics, and some of those finished ceramic products we export back to Japan."

Similarly, the company resells "various parts and materials that we can't or don't make here in Australia because the domestic market is too small," he adds. "In the United States, we have some companies who supply specialty insulation. The market in Australia for them is not particularly big, but we have had a very long-standing relationship with those suppliers." Its ties to the U.S. also include relationships with Oak Ridge National Laboratory, NASA, and Caltech. "To an engineer, those places are the pinnacle, and we're tremendously proud of the fact that even though it's only a very small part of what we do, that those very highly regarded organizations sometimes come to us."

Working with customers

Because Ceramic Oxide Fabricators' customers are for the most part in mature industries, such as automotive, "a lot of the changes that they adopt tend to be incremental rather than revolutionary," Walker says. For that reason, the company's focus is on increasing the accuracy and extending the life of its sensors. Fifteen years ago, their lifetime could be six months to one year. Today, a span of one year to 18 months is more common, and R&D efforts are targeting opportunities to enhance that aspect of performance. Areas of investigation include novel materials for and new configurations of oxygen sensors. "The intention would be to provide more precise control of combustion to improve fuel efficiency."

Like the size of the market, limited awareness of ceramic capabilities can pose additional constraints on the

The overachievers down under

Steady growth and a stable economy make Australia a market worth watching.

By Alex Talavera and Randy B. Hecht

Australia sprawls across 2,988,901.76 square miles, an area slightly smaller than that of the 48 contiguous U.S. states. All that terrain is home to only 22,507,617 people—roughly 8% less than the combined populations of Ohio and Pennsylvania—and a labor force of 11.58 million.

But if the home team is small in numbers, it compensates with economic brawn. The *CIA World Factbook* notes that, as of 2012, Australia has achieved "more than 20 years of continued economic growth, averaging 3.5% a year" and that its economy is characterized by "contained inflation, very low public debt, and a strong and stable financial system." Until recently, its economic virtues also included consistently low unemployment. However, in August, the Australian Bureau of Statistics announced that the seasonally adjusted unemployment rate had risen to 6.4%, the highest in more than a decade.

The country's GDP (purchasing power parity) is $998.3 billion, which makes it the 18th largest in the world and translates to $43,000 per capita. Services generate 68.7% of GDP, followed by industry (27.4%), and agriculture (3.8%). Major industries include mining, industrial, and transportation equipment; food processing; chemicals; and steel. For 2013, the industrial growth rate was 3.2%.

Australia's trading partners are concentrated in the Asia–Pacific region. Leading destinations for the country's exports, which totaled $251.7 billion in 2013, were China, Japan, South Korea, and India. The world's largest net exporter of coal, Australia generates 29% of global coal exports. Its natural resource exports also include bauxite, iron ore, copper, tin, gold, silver, uranium, nickel, tungsten, rare-earth elements, mineral sands, lead, zinc, diamond, natural gas, and petroleum. Additional exported commodities include meat, wool, alumina, wheat, and machinery and transport equipment. The country also is home to 37% of the world's zircon mining, although the mineral sands are mostly exported to trading partners, such as Japan for processing and then reimported into Australia for commercial use.

Imports for 2013 totaled $245.8 billion and included machinery and transport equipment, computers and office machines, telecommunication equipment and parts, crude oil, and petroleum products. Top import trading partners are China, U.S., Japan, Singapore, Germany, Thailand, and South Korea. The U.S.–Australia Free Trade Agreement has been in effect since 2005 and made more than 99% of U.S. manufactured exports to Australia duty-free.

For information about trade or joint venture opportunities in Australia, contact the American Chamber of Commerce in Australia, the U.S. Chamber of Commerce Australia Working Group, or one of the regional Chamber of Commerce offices listed on the Embassy of Australia webpage. The Office of the U.S. Trade Representative maintains online market information about Australia, and the U.S. Commercial Service offers further information through an online library of resources related to doing business in Australia. ■

The kangaroo is the unofficial symbol of Australia.

industry. Morgan Advanced Materials Technical Ceramics exports close to 80% of what it produces in Melbourne, says Stuart Pratt, sales and marketing manager. On the domestic side, it must contend with prevalent "preconceived ideas about ceramic" that have their roots in memories of alumina ceramic as brittle and lacking strength—"so a lot of my work is almost a re-education of some of those ingrained fears that engineers have about ceramics."

"The usage of ceramic in Australia is not particularly high. Australia doesn't have a huge manufacturing base, so we would never survive just making ceramics and selling it in Australia. We have to consider that the world is our customer base and our marketplace," Pratt says.

"That's been a challenge over the years. People say, 'Oh, but you're over on the other side of the world.' And I have to say, in my working life here, that sort of perception has changed dramatically," he adds. That has happened, in part, thanks to another characteristic of the Australian ceramic sector—frequent collaborations by companies, research institutes, and government agencies on materials research, development, and commercialization.

Pratt takes pride in "the fact that Melbourne is the birthplace of toughened zirconia ceramic," which was invented by a team at the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia's national science agency. "This business licensed that technology, licensed the patent for the material, and over the years we've improved it, developed it, and so on. I think a lot of people are surprised that our business was at the very forefront of toughened zirconia ceramic and that we still make, I believe, the best zirconia ceramic in the world."

Like Ceramic Oxide Fabricators, Morgan Advanced Materials Technical Ceramics is heavily invested in enhancing its existing applications—for example, components for severe service valves—and broadening its customer base for those applications. Its business is focused on customized solutions and often develops replacements not for other ceramics, but, rather, metal parts.


Credit: Morgan

Morgan Technical Ceramics manufactures a variety of advanced ceramic products for many applications including replacement of metal parts.

In response to demand from customers in industries such as mining and chemical processing, the company has developed the capability to manufacture larger parts. "Everybody wants to make a process line bigger so that they can get more capacity into it," Pratt says. However, given the "limitations on how big ceramic parts can be made," he does not see this trend continuing indefinitely: "I think we've got up to a level that caters to most applications."

But, as with Ceramic Oxide Fabricators, he is seeing increased demand for extended cycle time. "Twenty years ago, a plant would run for three months. Then it would have a close down and they would replace all the valves, pumps, and wear parts, and then they would run for another three months," he says. "The cost of a shutdown is enormous—not just the cost of the parts that you were having to replace, but the loss of productivity that you get while the plant is shut." Customers, therefore, are seeking the company's help in extending cycle time and reducing downtime.

The same goals apply within the company itself. "From the year dot [the year one] we've had a continuous improvement program," Pratt says. "To this day, we're always looking at more effective ways so that we can get more product out of the same amount of equipment and the same amount of man-hours. That's something that's enshrined in every successful business these days."

Patnerships and sharing intellectual property

Public–private partnerships take on an added layer of complexity when technologies or products emerge from research at ANSTO, the government's nuclear science and technology agency.

"In some cases, technology fusion provides the company with materials and processes that will enable them to take or advance their opportunity in their specific domain," says Gerry Triani, research program leader in Nuclear Materials Science. "What we generally do is, we retain foreground technology in our nuclear space and assign rights to our partners to exploit the technology in their area of application." In some cases, that means that ANSTO ends up owning the patent, but the agency is "keen to seek licensing opportunities."

For example, "I currently hold a U.S. patent in solar, and in that space, we're looking for licensing opportunities with a number of companies, from hardware providers to module manufacturers," he says. "We feel that we shouldn't be the gatekeepers of the intellectual property and that it should be exploited. This IP was generated through our collaborative program in solar through the Cooperative Research Centre for Polymers. We're looking to find licensing opportunities with partners globally to make sure that the IP is available to innovative companies."

ANSTO has a record of success in incubating IP, creating seed companies internally, and then selling those com-

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Credit: ANSTO

ANSTO's synroc hot isostatic pressing technology can reduce radioactive waste volume. Metal cans are loaded with radioactive nuclides and a ceramic powder, and then hot isostatic pressed an encapsulate solid waste for disposal into a respiratory.

panies. One example is Ceramisphere Ltd., a business that was spun off ANSTO's materials chemistry labs and has "developed a generic platform for delivering controlled release of active molecules" for such applications as "anticorrosion and biocidal coating, including delivery of therapeutics and vaccines." Another technology company, Biogill Ltd., works in wastewater treatment using "ANSTO's IP in nanoceramic membranes, which consume nutrients in the wastewater using biomass."

Immobilization of nuclear waste is the primary area of focus at ANSTO's Materials Engineering Institute, which developed titanate ceramics for that purpose and continues to pursue advances in that arena. "We use a technology called hot isostatic pressing, and anything that looks good—whether it's glass, ceramic, or glass-ceramic—we'll press it as a dense solid for nuclear waste immobilization," says Lou Vance, chief scientist at Wasteforms Research. "Because we don't have any high-level waste in Australia, we use this information to develop these sorts of solids for high-level waste immobilization. What we want to do is to partner with engineering companies in other countries that actually have the nuclear waste, where we'd provide advice on the composition of the solids."

Further out on the horizon, "We have this waste from the production of molybdenum-99, a radiopharmaceutical that's used in cancer treatment and diagnosis," Vance says. "We're gearing up in the next two or three years to increase our generation of this material, which produces what is known as intermediate-lev-

Directory of Australian ceramics industry, associations, and institutes

COMPANIES AND COMMERCIAL ENTERPRISES

Note: For links to information about and contact details for ceramic tile companies in Australia, see the Australian Tile Council listing in the **Associations and Research Institutes** section of this directory.

AZoM.com
Suite 24, 90 Mona Vale Road
Warriewood, New South Wales 2102
Phone: +61 2 9999 0070
Fax: +61 2 9999 0071
E-mail: info@azom.com (general inquiries)
Website: www.azom.com

AZoM publicizes news, views, and developments in the materials science community to increase use of advanced materials by the engineering and design community worldwide.

Ceramic Fuel Cells Ltd.
170 Browns Road
Noble Park, Victoria 3174
Phone: +61 3 9554 2300
Fax: +61 3 9790 5600
E-mail: info@cfcl.com.au
Website: www.cfcl.com.au

CFC develops, manufactures, and markets solid oxide fuel cell technology and products developed for small-scale, microcombined heat and power, and distributes generation applications that cogenerate electricity and heat for homes and businesses. The company notes that its technology has achieved "the world's highest electrical efficiency from a small-scale generator (up to 60%)" and "reduces carbon dioxide emissions by more than two-thirds compared to coal-fired electricity generation."

Ceramic Oxide Fabricators
83 Wood Street
Eaglehawk, Victoria 3556
Phone: +61 3 5446 3489/+61 3 5446 8151
Fax: +61 3 5446 1215
E-mail: ceramics@cof.com.au
Website: www.cof.com.au

Ceramic Oxide Fabricators works in the manufacture and distribution of advanced ceramic components for abrasion, corrosion, and electrical resistance; laboratory ware; thermocouple sheaths and insulators; and zirconia-based oxygen sensors. Its business extends to importation and distribution of advanced ceramics. The company's family of products encompasses solid electrolyte oxygen sensors, laboratory crucibles, low-wear clutch parts, wire guides, furnace components, thermocouple components, bearings, water knife nozzles, and radar insulators.

Hitech Materials Pty. Ltd.
60/62 Murray Park Road
Wollongong, New South Wales 2525
Phone: +61 419 991 930
E-mail: info@hitechmaterials.com.au
Website: www.hitechmaterials.com.au

Hitech is an independent, materials engineering consultancy founded in 2008 by Phil Walls, Ph.D., that focuses on improving plant performance and reducing maintenance costs and down time.

Iluka Resources Ltd.
Level 23 140 St. Georges Terrace
Perth, Western Australia 6000
GPO Box U1988
Perth, Western Australia 6845
Phone: +61 8 9360 4700
E-mail contact form: www.iluka.com/products/product-enquiry
Website: www.iluka.com

Iluka's focus is mineral sands product exploration, project development, mining and processing, and marketing. Established 60 years ago in Australia, where most of its production base remains, it has had mining and processing operations in the U.S. for more than 40 years. The company notes that it is "the major producer of zircon globally and a significant producer of the high-grade titanium dioxide products of rutile and synthetic rutile."

Morgan Technical Ceramics Australia Pty. Ltd.
30-36 Birralee Road, Regency Park
Adelaide, South Australia 5010
Phone: +61 8 8243 5300

4 Redwood Drive
Melbourne, Victoria 3168
Phone: +61 3 9550 9144

5-21 Amour Street
Sydney, New South Wales 2212
Phone: +61 2 9772 5600

34 Aerodrome Road
Caboolture, Queensland 4510
Phone: +61 7 5433 7100

el waste—about 5,000 liters a year. We're in the stage of detailed engineering to produce a plant to immobilize this material in a glass-ceramic. This engineering plant is probably our main focus and activity at present."

"That will be the first-of-a-kind plant of the hot isostatic pressing technology for actual nuclear waste," Triani adds. "It will be done in a way that it will be in line with our nuclear medicine production facility, and it will be done remotely, in a hot cell to demonstrate the robustness of this technology."

ANSTO is open to working with U.S. researchers and companies in pursuit of joint ventures, joint research, and commercialization and is in the process of completing a Cooperative Research and Development Agreement (CRADA) with Savannah River Laboratory in the U.S. "The object of this CRADA is to study these waste solids produced by melting versus hot isostatic pressing," Vance says. "In Britain, hot isostatic pressing is the baseline technology now, because we've been collaborating with them for years. We've worked with researchers from Japan and France over the years. But we've never worked with companies to actually engineer a plant to do the job, basically because in all countries the immobilization of nuclear waste, while considered important, is a bit low on funding these days."

Credit: Trelleborg

Trelleborg Engineered Systems (Brisbane, Queensland) manufactures a variety of products, including those related to mining and mineral processing. One example is this cyclone underflow launder for iron ore, which is lined with glue in ceramic mats.

"We leverage our know-how and technology into other areas of classical ceramic application," adds Triani, who is working with U.S. companies—including several start-ups on the west coast—on solar projects. "We are developing our ceramic powders and films for their applications. These connections have

Lot 13 Cutler Road
Jandakot, Western Australia 6064
Phone: **+61 8 9417 9600**
Website: **www.morgantechnicalceramics.com**

Launched in 2003 with the merger of Morgan Advanced Ceramics and Morgan Electro Ceramics, Morgan Technical Ceramics uses ceramics, glass, precious metals, and related materials to develop engineered solutions for clients in the electronics, energy, healthcare, industrial, petrochemical, security and defense, and transport industries.

The scope of its ceramic production capabilities includes compaction pressing, ceramic injection molding, extrusion, isostatic pressing (dry and wet bag), green machining, laser cutting, diamond grinding, metalizing (refractory, thick film, and thin film), and laser marking. It also offers such testing and verification services as CMM (3D measurement), scanning, X-ray thickness, vacuum leak testing, pressure testing, mechanical strength testing, and thermal cycling.

Palmer Technologies Pty. Ltd
PO Box 513
New Farm, Queensland 4005
Phone: **+61 7 3852 4448**
Fax: **+61 7 3852 4934**
E-mail contact form: **www.palmertechgroup.com/contact.php**
Website: **www.palmertechgroup.com**

Palmer is an engineering cosultancy headed by Greg Palmer, Ph.D., that specializes in improving the engineering and reliability of refractory concrete structures.

Shinagawa Refractories Australasia Pty. Ltd.
Head office:
23 Glastonbury Avenue
Unanderra, New South Wales 2526
Phone: **+61 2 4221 1700**
Fax: **+61 2 4221 1795**

Kwinana plant:
1 Beard Street
Naval Base, Kwinana, Western Australia 6165
Phone: **+61 8 9410 8700**
Fax: **+61 8 9410 8799**
E-mail: **info@shinagawa.com.au**
Website: **www.shinagawa.biz**

Shinagawa Refractories Australasia is the successor to Shinagawa Thermal Ceramics, the largest manufacturer and supplier of quality, cutting-edge refractory products and insulating materials in the region. The company markets refractory solutions for all heat-intensive industries in the region, including iron and steel, aluminum and alumina, mineral processing, nonferrous metals, petrochemicals, and power generation, among other sectors. It conducts tests and trials of new and improved materials at an in-house pilot plant, and its research and development activities are enhanced by access to technology from its parent company, Shinagawa Refractories of Japan, and technical exchange agreements with refractory manufacturers worldwide.

Trelleborg Engineered Systems Australia
515 Zillmere
Zillmere, Brisbane, Queensland 4034
Phone: **+61 7 3866 7444**
Fax: **+61 7 3263 4912**

25 Glassford Road, Kewdale
Perth, Western Australia 6105
Phone: **+61 8 9256 6000**
Fax: **+61 8 9353 5990**
E-mail: **tqr.info@trelleborg.com**
Website: **www.trelleborg.com.au**

Trelleborg Engineered Systems offers engineered rubber products for offshore, infrastructure, construction, and marine industries. The company focuses on specialty engineered products, such as acoustic isolation systems, movement supports for structures, specialty water seals, and sheeting for industrial and mining applications. Trelleborg Engineered Systems is part of the worldwide Trelleborg Group, founded in 1905, that specializes in advanced polymers for high-performance industrial environments.

Weir Minerals Australia Ltd.
Level 3, 1 Collins Street
Melbourne, Victoria 3000
Phone: **+61 2 9934 5100**
Fax: **+61 2 9934 5201**
E-mail: **robb.clawson@weirminerals.com**

1 Marden Street
Artarmon, New South Wales 2064
Phone: **+61 2 9934 5100**
Fax: **+61 2 9934 5201**
E-mail: **australiansales@weirminerals.com**
Website: **www.weirminerals.com/weir_minerals_australia.aspx**

Weir provides diverse slurry equipment solutions—including pumps, valves, hydrocyclones, and linings—for mining, transportation, milling, processing, and waste management applications. Weir Group operates about 200 manufacturing come about through an evolution of other technologies that we actually have here at ANSTO, such as sol–gel processing and atomic layer deposition." Examples include perovskite ceramics and piezoelectric ceramics for sonar application.

Looking ahead to the next five to ten years, ANSTO will continue to monitor trends and emerging technologies in the immobilization of nuclear waste, which it regards as an area of continuing market opportunities. "There's quite a bit of interest in countries that house nuclear energy programs," Vance says. "When the plans for those countries are more advanced, we'd be seriously interested in engaging engineering companies to actually do the work. It's a bit odd, actually—in Australia we don't have even a low-level waste dump after all this time, and yet we've been working with academics and the practicalities of nuclear waste for about 35 years."


Credit: U. of Melbourne

Carolina Tallon is a postdoctoral researcher at the University of Melbourne.

Another key driver of future business at ANSTO is expanded production of molybdenum-99, the base material for nuclear medicines used to diagnose cancer, heart disease, and muscular and skeletal conditions. "At the same time, within the nuclear science and technology portfolio, we're also developing inorganic sorbent materials for our next-generation radioisotope medical generators that will be used in positron emission tomography imaging," Triani says. "Our outreach

Directory of Australian ceramics industry, associations, and institutes

and service facilities in more than 70 countries worldwide. Its Artarmon, New South Wales, location is the only fully integrated slurry pump facility in the world.

UNIVERSITIES

Australian Catholic University
The university has campuses in **Ballarat, Brisbane, Canberra, Melbourne, North Sydney**, and **Strathfield**.
Contact details by campus: **www.acu.edu.au/about_acu/our_university/contact**
Website: **www.acu.edu.au**

Australian National University
Canberra, ACT 0200
Phone: **+61 2 6125 5111 (general switchboard)**
Phone: **+61 2 6125 0330 (business and government)**
E-mail: **innovation@anu.edu.au**
Website: **www.anu.edu.au**

Curtin University Australia
Main Campus:
Kent Street, Bentley, Perth, Western Australia 6102
Additional campuses: **Curtin Sydney, Curtin Sarawak, Curtin Singapore**
Jane Coole, Director of External Relations
Phone: **+61 8 9266 1868**
Fax: **+61 8 9266 3175**
E-mail: **jane.coole@curtin.edu.au**
Website: **www.curtin.edu.au**

Monash University
Monash University has campuses in Berwick, Caulfield, Clayton, Parkville, and **Peninsula**. The university also operates a campus in Malaysia, a joint graduate school in China, a learning center in Italy, and a research center in India, and it offers courses at other locations, including Monash South Africa.

Contact details by campus: **www.monash.edu.au/people/contact.html**
Website: **www.monash.edu.au**

Swinburne University of Technology
The university has campuses at **Croydon, Hawthorn, Melbourne, Prahran, Wantirna**, and **Sarawak**.
Contact details by campus: **www.swinburne.edu.au/contacts-campuses/campuses/index.html**
Phone: **+61 3 9214 8000** (main switchboard)
Staff directory: **www.swin.edu.au/directory**
Website: **www.swinburne.edu.au**

Industrial Research Institute Swinburne (IRIS)
Contact: **Sally McArthur, director**
Phone: **+61 3 9214 8452**
E-mail: **smcarthur@swin.edu.au**
Website: **www.swinburne.edu.au/engineering/iris**

As a whole, Swinburne targets research in niche and developing markets and prides itself on its "innovation and excellence in applied research." The university's "research, development, and deployment activities" are concentrated in the areas of future manufacturing, sustainable futures, digital frontiers, personal and societal well-being, and inspirational science and technology.

Within that context, IRIS is the center for manufacturing research at the university and defines its core area of interest as surface science and interface engineering. Areas of inquiry encompass biointerface engineering and analysis, electron microscopy and characterization, laser and plasma deposition technologies, rapid prototyping and manufacturing, and robotics and noncontact inspection. The faculty includes ACerS Fellow Christopher Berndt, who also is an adjunct professor at Stony Brook University in New York and whose research focus is thermal spray technologies.

University of Melbourne
The University has campuses at **Burnley, Creswick, Dookie, Parkville, Shepparton, Southbank**, and **Werribee**.
Directory of contacts for commercial inquiries: **www.commercial.unimelb.edu.au/contact-us**
Chemical and Biomolecular Engineering Department
Phone: **+61 3 8344 7441**
Fax: **+61 3 8344 4153**
E-mail: **eahod-chemeng@unimelb.edu.au**
Website: **www.unimelb.edu.au**

The School of Engineering's Chemical and Biomolecular Engineering Department includes a Ceramics and Minerals Processing Group that works on the development of "fundamental knowledge in suspension rheology, colloid and surface chemistry in order to improve processing of ceramics and minerals." Research interests encompass ceramics processing, minerals processing, and surfaces and modeling.

University of Newcastle
The University has campuses in **Newcastle Callaghan, Newcastle City, Central Coast, Port Macquarie, Singapore**, and **Sydney**.
Contact details by campus: **www.newcastle.edu.au/contact**
Website: **www.newcastle.edu.au**

University of New South Wales
The University has campuses at **Kensington, Paddington**, and **Canberra**.
Contact details by campus: **www.unsw.edu.au/contacts**
Website: **www.unsw.edu.au**

One of the leading research-intensive universities in the Asia–Pacific region, the University of New South Wales is "investing considerable resources in particular areas where we feel we can make a difference" and "identifying emerging problems and opportunities, and moving to meet the challenge." Faculty and researchers work in collaboration with external partners from industry, government, and other organizations to fulfill this mission.

Among the university's areas of research strengths are biomedical sciences; water, environment, and sustainability; next-generation materials and technologies; and ICT, robotics, and devices. Within that frame of reference, research focuses on such areas as nanomaterials, silicon solar cells, superconductors, and building materials.

ASSOCIATIONS AND RESEARCH INSTITUTES

Australian Ceramic Society
Website: **www.austceram.com**

The Australian Ceramic Society is dedicated to "furthering all aspects of ceramics in science, industry, research, trade, and art." Its Federal Council includes representatives from New South Wales, Victoria, and Western Australia, each of which "operates autonomously with its own committee."

projects within the Institute of Materials Engineering also see our researchers working closely with several firms. In one such case, we are working with a U.S.-based SME to develop semiconducting materials for low-cost flexible solar cells." So, although half the planet separates the Australian and U.S. markets geographically, there's a world of opportunity available to U.S. companies that are willing to go the distance to collaborate on ceramic innovations and advances.

References

[1]Iluka, "Mineral sands industry fact book," February 2014.

[2]Geoscience Australia, "Australian atlas of minerals resources, mines, & processing centres," http://www.australianminesatlas.gov.au/aimr/commodity/rare_earths.html#Industry_Developments.

[3]ANSTO, "Rare-earth processing," http://www.ansto.gov.au/BusinessServices/ANSTOMinerals/Capabilities/RareEarthProcessing.

Credit: Monash U.

Monash University has several campuses in Australia, including locations in Berwick, Caulfield, Clayton, Parkville, and Peninsula, and around the world.

In keeping with the Australian industry's strong ties to Japan, the organization cosponsors, along with the Ceramic Society of Japan, an annual Joint Ceramic Award designed to promote bilateral cooperation in the sector. The award covers modest travel and living expenses that allow an annual exchange of one "distinguished ceramicist" from each country to visit the other to complete a short-term research project.

The Society publishes its *Journal of the Australian Ceramic Society* twice a year, and the organization publishes abstracts and complete papers online at www.austceram.com/journal.htm.

Australian Nuclear Science and Technology Organisation

New Illawarra Road
Lucas Heights, New South Wales 2234
Contact: **Gillian Blackburn, Research Management Officer**
Phone: **+61 2 9717 3111**
E-mail: **gillian.blackburn@ansto.gov.au or gib@ansto.gov.au**
Website: **www.ansto.gov.au**

ANSTO is a public research agency that operates under the aegis of the Commonwealth Ministry for Industry. In the area of nuclear safeguards, the organization is committed to "helping train personnel from Pacific Basin countries to manage nuclear materials safely and securely" and "ensuring that countries not experienced in handling nuclear materials keep to international standards and best practice."

The scope of its work encompasses a wide variety of disciplines and areas of concern, including:

- Advising the Australian government on global nuclear issues;
- Providing 85% of nuclear medicines used in Australian hospitals;
- Using nuclear tools to detect past climate change;
- Neutron scattering, which "allows scientists to see what X-rays cannot;"
- Manufacture and supply of radiopharmaceuticals; and
- Delivering services in mining, silicon irradiation, and radiation safety training.

Many of ANSTO's research publications are available online at **www.ansto.gov.au/Resources/Publications/index.htm**.

The agency also maintains an online glossary of nuclear terminology at **www.ansto.gov.au/NuclearFacts/GlossaryOfNuclearTerms/index.htm**.

ANSTO Institute of Materials Engineering

Website: **www.ansto.gov.au/ResearchHub/IME**

ANSTO's Institute for Materials Engineering develops, manufactures, characterizes, and models materials in support of the advanced nuclear fuel cycle and next-generation power systems. Recognized worldwide for its expertise in nuclear waste immobilization, radioactive waste management, and associated technologies, it is the home of ANSTO's synroc waste form technology, which the U.S. and U.K. are exploring as a solution to their radioactive waste immobilization needs.

Australian Tile Council

Website: **www.australiantilecouncil.com.au**
National office and officer contact details:
www.australiantilecouncil.com.au/contact-us

State websites, including contact details for member companies:
Australian Capital Territory: **www.australiantilecouncil.com.au/act**
New South Wales: **www.atcnsw.com.au**
Queensland: **www.tilecouncilqld.com.au**
South Australia/Northern Territory: **www.sa-tile.on.net**
Tasmania: **www.tilecouncilvic.com.au**
Victoria: **www.tilecouncilvic.com.au**
Western Australia: **www.australiantilecouncil.com.au/downloads/WA-Membership.pdf**

Commonwealth Scientific and Industrial Research Organisation Australia

CSIRO Enquiries
Locked Bag 10
Clayton South, Victoria 3169
Phone: **+61 3 9545 2176**
Fax: **+61 3 9545 2175**

Directory of international locations and contacts:
www.csiro.au/Portals/Contact/Locations.aspx
Website: **www.csiro.au**

CSIRO is Australia's national science agency. It was created by the Australian government with passage of the Science and Industry Research Act of 1949 to conduct scientific research that could be used to assist Australian industry. The law also gave the agency responsibility for "contributing to the achievement of Australian national objectives or the performance of the national and international responsibilities of the Commonwealth" and acting "as a means of liaison between Australia and other countries in matters connected with scientific research."

Today, CSIRO describes its vision as using its science "to make a profound and positive impact for the future of Australia and humanity." To that end, sustainability figures prominently in its current areas of focus under the manufacturing and materials research umbrella.

One of the world's largest and most diverse scientific institutions, CSIRO employs 6,400 people at 56 sites throughout the world. Among these facilities are 33 research facilities, including three major National Research Facilities. Headquartered in Canberra, it maintains a laboratory in France and has staff in Ireland, the Netherlands, and the U.S.

CSIRO Materials Science and Engineering

Website: **www.csiro.au/Organisation-Structure/Divisions/CMSE.aspx**

Research at CSIRO's Materials Science and Engineering Division spans a variety of projects related to ceramics, including:

- **Nanostructured electronic materials:** The agency is conducting research into "the development of scalable synthetic protocols for a wide variety of metal and semiconductor nanocrystals."
- **Surfaces and nanosciences:** "We use our capability in controlling molecular function, structure, and surfaces at the micro- and nano-scale to understand, model, and develop new materials, such as membranes, coatings, sensors, and hierarchical structures," the agency notes.
- **Fiber science:** In 2010, the Australian government approved a $37 million allocation for the launch of the Australian Future Fibres Research and Innovation Centre (AFFRIC). Two years later, a CSIRO team was assigned to the project, which is focused on research and development of nanofibers, smart fibrous materials, green natural fibers, and carbon fiber.