



(Credit: Western Refractory Services, Ltd., Edmonton, Alberta, Canada)

Refractory installation of a rotary hearth dome in western Canada.

Canadian ceramic clout

Universities, corporations, and government agencies team to foster research advances and commercial opportunities.

By Alex Talavera and Randy B. Hecht

Canada may not be the most prominent nation to appear in industry headlines, but universities, businesses, and government agencies throughout the country are collaborating on impressive advances in ceramic technology. These breakthroughs are being driven by a combination of commercial opportunity and societal demands in areas such as environmentalism, which is a particular concern among students and young professionals.

"Strictly speaking about ceramics, I would say the big focus is in sustainable use of materials, trying to make materials last longer or degrade less or make them out of materials that are going to prevent fracture or degradation," says Mary Anne White, University Research Professor of Chemistry at Dalhousie University, which conducts ceramics research in the departments of chemistry and engineering. "I think that students are going to be ever more concerned about energy and sustainability, and I think materials hold a lot of answers to some of our major problems."

Partha Sarkar is principal scientist, environment and carbon management, in the Clean Energy group at Alberta Innovates—Technology Futures, which supports Alberta's strategy for playing a significant role in the global nanotechnology market. "My projects are geared toward reduction of greenhouse gases and improving environmental sustainability," he says. "Within our work, we have developed tubular micro solid oxide fuel cells (μ SOFC) where we employed an electrophoretic-deposition-based tubular cell manufacturing method. We have developed a novel concept of 'porous matrix embedded stack' to improve the μ SOFC performance and mechanical robustness."

Sarkar also is working in partnership with Raj Gupta, a professor at University of Alberta, and AITF's combustion expert, Allan Chambers, on carbon capture projects related to alternate combus-



(Credit: ACAMP)

Low temperature cofired ceramic sections for advanced sensor assemblies and processes (left). The assembled device is about the size of a Canadian dime (above).

(Credit: ACAMP)

tion technology—chemical looping combustion (CLC). “The CLC process has two coupled fluidized-bed reactors, fuel and air,” he says. “In the air reactor, a metal is oxidized in contact with air. The metal oxide is then supplied to the fuel reactor, where it supplies the oxygen required for combustion. The metal oxide is thus reduced and resupplied to the air reactor in a continuous process. The metal/metal oxide solids act as an oxygen carrier. In the CLC process, the fuel does not come in contact with air during combustion, and the fuel reactor exhaust is mainly CO₂ and water vapor. The water is condensed and the CO₂ is captured.”

Hydraulic fracturing (fracking) presents another area of environmental concern and another field in which Canadian ceramic researchers are seeking solutions in nanotechnology. “Some of the extraction technologies today use a lot of water,” says Ken Brizel, CEO of ACAMP, Alberta Centre for Advanced Micro Nano Technology Products. “The nano-catalysts that are being created would require a lot less water to be able to do the same amount of extraction. That’s work that’s going on in a lot of research areas around Alberta. Everybody wants to be greener.”

At McMaster University, Igor Zhitomirsky, professor of materials science and engineering, conducts research focused on nanostructured materials for energy storage and generation. “The most promising project I have is related to electrochemical supercapacitors,” he says. “One of the most important materials for electromechanical supercapacitors is manganese oxide. Our research is focused on fabrication of nanoparticles, fabrication of composite electrodes, and testing of electrochemical devices.” His team is testing a prototype device that should be ready to be offered to industry within the next year or two.

White’s colleague at Dalhousie University, professor Jeff Dahn, is leading a team that has been working on materials for lithium-ion batteries and developing new cathode materials. Dahn reports that there is a 35% chance that material he

discovered is found in any given lithium-ion battery on the market today. The materials are manufactured in the United States.

Canadian graduate students also are active in ceramic research. One of White’s students, Carl Romao, is attempting to combine positive thermal expansion and negative thermal expansion materials to create composite materials that are immune to thermal stress.

Refractory industry—international and innovative

An interesting characteristic of the refractories sector in Canada is that although it is dominated by national and international corporations, such as Clayburn Refractories and Vesuvius, it also allows space for smaller players. Greg Langlois is president of Refractories Plus Inc. in Hamilton, Ontario. “In our business, a lot of it is personal. There’s still some relationship selling here,” he says. “The big players will work with us here.” His operation is nimble enough to react more quickly than some larger companies. His company has managed to land some big cross-border projects. “I have an arrangement with some trading companies in China that we have our own engineers on the ground over there. We were able to buy better-quality brick at lower cost and bring it over here.”

That interaction between small and big business, often in partnership with academic researchers and government-sponsored initiatives, is seen throughout the Canadian ceramic sector. “There’s one company we work with that’s involved in using titanium dioxide nanomaterials interwoven into aluminum—so they do titanium aluminide. Those are super strong, and they’re used in everything from energy to automotive applications,” Brizel says. “That’s a startup here in Alberta—90% of the companies we tend to work with come right out of universities or someone’s garage.” It is an approach that, although centered on small players, is producing big results in Canada’s ceramic industry.

Canadian ceramic clout

Investing in growth

The Natural Sciences and Engineering Research Council of Canada (NSERC) "supports university students in their advanced studies, promotes and supports discovery research, and fosters innovation by encouraging Canadian companies to participate and invest in postsecondary research projects." The government agency, which was created in 1978, reports that during the past decade it has "invested more than \$7 billion in basic research, projects involving partnerships between postsecondary institutions and industry, and the training of Canada's next generation of scientists and engineers." For fiscal year 2011–2012, NSERC awarded grants for pursuit of the following ceramic-related research projects:

- Development of direct fuel injection technology based on piezoceramic actuation. To Ridha Ben Mrad of the

University of Toronto's Mechanical and Industrial Engineering Department.

- MRI characterization of implantable drug delivery bioceramics. To Steven Beyea of Dalhousie University's Physics and Atmospheric Science Department.

- Mechanical behavior of zirconia-based ceramics for use in CANDU supercritical water nuclear reactors.

To Lukas Bichler of the University of British Columbia's Okanagan School of Engineering.

- Fabrication of porous ceramic from multilayer-coated SiC particles through sol-gel followed by in-situ polymerization. To Jamal Chaouki of the École Polytechnique de Montréal Génie Chimique.

- Advanced ceramic structures and coatings for corrosion protection and thermal insulation for generation IV SCWRs; and Fabrication and potential

application of macroporous ceramic materials/structures through chemical sintering. Both to Weixing Chen of the University of Alberta's Chemical and Materials Engineering Department.

- Solution precursor plasma spray deposition of nanocrystalline functional ceramic coatings. To Thomas Coyle of the University of Toronto's Materials Science and Engineering Department.

- Metal and ceramic interactions in materials processing. To Robin Drew of Concordia University's Mechanical and Industrial Engineering Department.

- Ceramic electrolytes and secondary recovery. To Thomas Etsell of the University of Alberta's Chemical and Materials Engineering Department.

- Development of high-toughness silicon nitride ceramics. To Vladimir Krstic of the Queen's University Mechanical and Materials Engineering Department.

- Development and characterization of high-performance ceramic–metal composites; and High-performance ceramic–metal composites. Both to Kevin Plucknett of Dalhousie University's Process Engineering and Applied Science Department.

- Amine–borane functionalized materials: Hydrogen storage media and precursors to boron nitride ceramics. To Eric Rivard of the University of Alberta's Chemistry Department.

- Synthesis and characterization of novel biomedical glass-ceramic polymer composites. To Amin Rizkalla of the University of Western Ontario's Chemical and Biochemical Engineering Department.

- Process engineering for smart bio-ceramic cements. To Tom Troczynski of the University of British Columbia's Materials Engineering Department.

- Laser machining of ceramics with controlled microstructure. To Gennady Zak of the Queen's University Mechanical and Materials Engineering Department.

Moreover, NSERC awarded 13 ceramic-related research scholarships for the 2011–2012 fiscal year. ■

Northern (market) exposure

US–Canadian trade ties create jobs and economic opportunity on both sides of the border.

By Alex Talavera and Randy B. Hecht

Although Canada's land mass is 61,002 square miles greater than that of the United States, its citizens number just 11% of the US population. In fact, fewer people live in all of Canada than in the state of California. In terms of trade with the US, however, Canada bench-presses many times its body weight.

It is the world's number one destination of US exports and is second only to China as a source of goods imported by the US. Prominent among those imports are oil, gas, uranium, and electric power. Canada is the largest foreign supplier of energy to the US. The petroleum sector is a particularly significant economic driver, and the country's proven oil reserves place it third in the world, behind Saudi Arabia and Venezuela. Moreover, Canada is the world's fifth-largest investor in the US.

For 2012, Canada's purchasing power GDP is estimated at \$1.513 trillion, or \$43,400 per capita, which reflects a 1.8% growth rate over 2011. This makes Canada the 13th-largest national economy in the world, although it ranks 37 in terms of population. Services generate 69.8% of GDP, followed by industry (28.5%) and agriculture (1.7%).

Canadian export volume for 2012 is estimated at \$462.9 billion. Its leading commodity exports

include motor vehicles and parts, industrial machinery, aircraft, telecommunications equipment, chemicals, plastics, fertilizers, wood pulp, timber, crude petroleum, natural gas, electricity, and aluminum. Import volume for 2012 is estimated at \$474.8 billion. Leading commodity imports include machinery and equipment, motor vehicles and parts, crude oil, chemicals, electricity, and durable consumer goods.

It all adds up to significant economic performance and market opportunity in "an affluent, high-tech industrial society in the trillion-dollar class," notes the *CIA Fact Book*. The US State Department terms this bilateral relationship "among the closest and most extensive in the world" and adds that the trading relationship is "the world's largest and most comprehensive" and "supports millions of jobs in each country."

For guidance on competing successfully in Canada and connecting with trading or business partners there, contact the American Chamber of Commerce in Canada, the Canada–US Chamber of Commerce, or the Canadian–American Business Council. The US Commercial Service has published *Doing Business in Canada*, and US–Canada trade news can be followed on the website of the Embassy of the United States in Ottawa. ■

Sulfur recovery unit reaction furnace checker wall in a sour gas plant.



(Credit: Western Refractory Services Ltd.)

Canada ceramics directory and profiles

★ ACerS Corporate Member

COMPANIES AND COMMERCIAL ENTERPRISES

Alberta Innovates

Website: www.albertainnovates.ca

Alberta Innovates functions as a globally competitive research and innovation system where government, industry, and academia interact to develop solutions to global challenges and use knowledge for the growth and diversification of Alberta's economy. Alberta Innovates operates as an integrated system aligned with the strategies and priorities of the province.

Alberta Innovates Technology Futures

Website: www.albertainnovatestechfutures.ca

Highly client and industry focused, Alberta Innovates Technology Futures advances ideas and innovations, through applied research and commercialization support, to solve problems, enhance productivity, and move new products and services to market.

Antex Western

1340 Church Avenue
Winnipeg, Manitoba R2X 1G4
Phone: 204-633-4815
Fax: 204-633-0550
Website: www.antexwestern.com
Email: antex@antexwestern.com

Established more than 80 years ago and employee owned since 2004, the company is a leader in installing interior commercial building products in Manitoba. It specializes in the commercial construction industry.

Avalon Rare Metals Inc.*

1901-130 Adeline Street West
Toronto, Ontario M5H 3P5
Phone: 416-364-4938
Fax: 416-364-5162
Website: www.avalonraremetals.com
A mineral development company, ARM focuses on rare metals and materials.

Barrday Energy Solutions

Barrday Protective Solutions

75 Moorefield Street

PO Box 790

Cambridge, Ontario N1T 1S2

Toll-free: 800-667-3725

Website: www.barrday.com

Founded in 1958, the company is a technical leader in the protective, composite, and energy markets. Working in the area of advanced material solutions, it develops fiber reinforcements, preps and laminates, coating adhesives, and core materials.

Brampton Brick Ltd.

225 Wanless Drive

Brampton, Ontario L7A 1E9

Phone: 905-840-1011

Admin. Fax: 905-840-1535

Sales Fax: 905-840-6461

Website: www.bramptonbrick.com

Email: sales@bramptonbrick.com

Canada's second largest manufacturer of clay brick, the company also manufactures stone veneer products and concrete window sills. Its concrete interlocking paving stones, retaining walls, garden walls, and environmental products are manufactured in Canada and sold in Canada and the United States for residential construction and for industrial, commercial, and institutional building projects.

Clayburn Refractories Ltd.

33765 Pine Street

Abbotsford, British Columbia V2S 5C1

Phone: 800-859-4885

Fax: 604-8592923

Email: tdigiuistini@clayburngroup.com

16010 118th Avenue

Edmonton, Alberta T5V 1C6

Phone: 780-468-4100

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Email: gjornsson@clayburngroup.com

108 4140 6th Street Northeast

Calgary, Alberta T2E 8C8

Phone: 403-276-4421

Fax: 403-277-8661

Email: bmanz@clayburngroup.com

2409 39 Riedel Street

Fort McMurray, Alberta T9E 3E1

Phone: 780-790-0464

Fax: 780-790-0475

Website: www.clayburnrefractories.com

Email: swhitehead@clayburngroup.com

Clayburn's refractory products include brick, castables, plastic refractories, anchoring systems, and insulation. The company has completed installation of castables, brick, plastics, and many other high-temperature and abrasion-resistant linings on thousands of major projects. Its crews are experienced in bricklaying, casting and pouring, ceramic fiber, demolition, guniting, plastic refractory, shotcreting, and pumping.

DuraSystems

199 Courtland Avenue

Vaughan, Ontario L4K 4T2

Toll-free: 866-338-0988

Phone: 905-660-4455

Fax: 905-660-8887

Website: www.durasystems.com

Email: durasystems@durasystems.com

Founded more than a half-century ago, this manufacturer specializes in supplying fire-rated systems and assemblies to the industrial, commercial, and institutional market sectors. The company can provide passive fire protection solutions for telecommunication and electrical power utilities; petrochemical, mining, and resource industries; transportation industry; and offshore oil and gas platforms.

Endurance Technologies

71, 4511 Glenmore Trail Southeast

Calgary, Alberta T2C 2R9

Phone: 403-720-3633

Toll-free: 877-806-3910

Website: www.endurancetechnologies.com

Email: info@endurancetechnologies.com

Established in 1993 to serve the oil and gas industries with diffusion alloying technology, the company provides abrasion and corrosion-resistant solutions to clients worldwide. Its technology provides protection to materials exposed to high-temperature and highly corrosive environments in the process industry.

Canadian ceramics directory and profiles

IMACRO Inc.

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Established in 1988, IMACRO offers refractory products, magnesium and aluminum sacrificial anodes, magnesium extrusions, strontium metal, specialty alloys, and consulting services to the iron, steel, aluminum, and other nonferrous metals and manufacturing industries.

Jazbrick

18 Namco Road
Toronto, Ontario M9W 1M5
Toll-free: 888-772-8999
Phone: 416-741-4498
Fax: 416-741-5657
Website: www.jazbrick.com
Email: info@jazbrick.com

A leading manufacturer and distributor of brick and stone products, Jazbrick also hosts the annual Jazbrick Forum to share information about new technology, green certification, and other topics for builders, developers, and architects.

Refractories Plus Inc.

600 Wentworth Street North
Hamilton, Ontario L8L 5X3
Phone: 905-540-4224
Website: www.refractoriesplus.com

Refractories Plus has installed refractory and insulation products in almost every application. It specializes in servicing the iron and steel, aluminum and nonferrous metals, industrial, and ceramic and glass sectors.

Sanjel Corporation

200, 505 2nd Street Southwest
Calgary, Alberta T2P 1N8
Phone: 403-269-1420
Fax: 403-716-4024
Website: www.sanjel.com/Index.cfm

Sanjel offers two specialized products: pressure pumping and completions. Each product offering is complete with its own innovative engineering products and custom-designed and manufactured equipment.

SIMCO Technologies Inc.

2666, Boul. du Parc-Technologique
Suite 100
Quebec QC G1P 4S6
Phone: 418-656-1003
Fax: 418-656-6083
Website: www.simcotechnologies.com
Email: info@simcotechnologies.com

Established in 1997, SIMCO offers integrated solutions for optimum design and maintenance of concrete infrastructure that combines sophisticated materials analysis techniques and leading-edge service life predictive software.

Morgan Thermal Ceramics

Thermal Ceramics Canada
1185 Walkers Line
Burlington, Ontario L7M 1L1
Phone: 905-335-3414
Website: www.morganthermalceramics.com

Morgan Thermal Ceramics supplies intelligently engineered insulation solutions to a wide variety of industries and market sectors. Its advanced ceramic insulation products include insulating fibers, firebrick, and monolithics.

Treibacher Industrie AG

515 Consumers Road, Suite 212
Toronto, Ontario M2J 4Z2
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Fax: 416-535-2602
Website: www.treibacher.com/en.html
Email: customerservice@treibacherinc.com

Treibacher Industrie AG develops and produces technically demanding materials and powders for many applications in the advanced ceramic sector. Its areas of focus include precision investment casting, thermal spraying powder, engineering ceramics, structural ceramics, sputter targets and evaporation materials, and electroceramics and ionic conductors.

Western Refractory Services Ltd.

10008 32 Avenue
Edmonton, Alberta T6N 1G7
Phone: 780-466-4540 (24 hours)
Fax: 780-465-5099
Website: www.westernrefractories.com
Email: Sales@westernrefractories.com

A privately owned Canadian company established in 1984, Western Refractory Services has completed refractory projects throughout Canada and supplied engineering, materials, and supervision for projects worldwide. The company's turnkey services span planning, engineering, and dryout.

Zochem Inc.

1 Tilbury Court
Brampton, Ontario L6T 3T4
Toll-free: 800-324-1806
Phone: 905-453-4100
Fax: 905-453-2920
Mailing address:
PO Box 1120
Brampton, Ontario L6V 2L8
Website: www.zochem.com/
Email contact form: <http://zochem.com/contact-us/>
Established in 1933, Zochem is Canada's largest zinc oxide manufacturer and the second-largest single-site producer in North America. Its complete line of zinc oxide grades serves the needs of most industries, including rubber products, chemicals, ceramics, paints, pharmaceuticals, and agriculture

UNIVERSITIES AND RESEARCH INSTITUTES

Dalhousie University

Halifax, Nova Scotia B3H 4R2
Phone: 902-494-2211
Website: www.dal.ca
Faculty directory: <https://directory.dal.ca/>

Polytechnique Montréal (École Polytechnique de Montréal)

2900, Boul. Édouard-Montpetit
Université de Montréal Campus
2500, Chemin de Polytechnique
Montréal, Québec H3T 1J4
Mailing address:
C.P. 6079, Succ. Centre-ville
Montréal, Québec H3C 3A7
Phone: 514-340-4711
Website: www.polymtl.ca/en
Faculty and other directories: <http://www.polymtl.ca/bottin/en>

McGill University

845 Sherbrooke Street West
Montréal, Québec H3A 0G4
Phone: 514-398-4455
Website: www.mcgill.ca
Departmental directory: <http://kb.mcgill.ca/kb/?ArticleId=1251&source=article&c=12&cid=2#tab:homeTab:crum>
b:7:artId:1251
Faculty and staff directory: www.mcgill.ca/directory/staff

McMaster University

1280 Main Street West
Hamilton, Ontario L8S4L8
Phone: 905-525-9140
Website: www.mcmaster.ca
Faculty directory: <http://telecom.mcmaster.ca/directory.cfm>

Queen's University

99 University Avenue
Kingston, Ontario K7L 3N6
Phone: 613-533-2000
Website: www.queensu.ca/
Faculty and departmental directory: <http://www.queensu.ca/search/people>

Thompson Rivers University

900 McGill Road
Kamloops, British Columbia V2C 0C8
Phone: 250-828-5000
Fax: 250-828-5086
Website: www.tru.ca
Faculty directory: <http://kamino.tru.ca/telbook>

University of Alberta

116 Street and 85 Avenue
Edmonton, Alberta T6G 2R3
Phone: 780-492-3111
Website: www.ualberta.ca
Directory: <http://faculties.ualberta.ca>

University of British Columbia

Vancouver Campus
2329 West Mall
Vancouver, British Columbia V6T 1Z4
Phone: 604-822-2211
Okanagan Campus
3333 University Way
Kelowna, British Columbia V1V 1V7
Phone: 250-807-8000
Website: www.ubc.ca
Faculty directory: www.ubc.ca/directories

University of Manitoba

Winnipeg, Manitoba R3T 2N2
Phone: 800-432-1960
Website: www.umanitoba.ca
Faculty and departmental directories: http://umanitoba.ca/faculties/info_links.html

University of Toronto

563 Spadina Crescent
Toronto, Ontario M5S 2J7
Phone: 416-978-2011
Website: www.utoronto.ca
Faculty and departmental directories: <http://directory.utoronto.ca/phonebook/pages/admin/main.xhtml>

University of Windsor

401 Sunset Avenue
Windsor, Ontario N9B 3P4
Phone: 519-253-3000
Website: www.uwindsor.ca
Faculty and departmental directories: <http://apps.uwindsor.ca/uwincpb/jsp/DirectoryServices.jsp>

Modern Mexico— Far-reaching research

From nanotechnology to dental ceramics to clean energy, Mexico plays a global role in advanced research and commerce.

By Alex Talavera and Randy B. Hecht

The phrase “Mexican ceramics” may first call to mind images of objects of art and tableware created by artisans whose work follows centuries-old and even pre-Columbian traditions. That’s understandable: In Mexico City, Puebla, and other major urban areas, there are multistory buildings whose entire exteriors are covered in handcrafted tile as shown in the image to the left. But those images do not begin to encompass the full range of advanced technological projects being researched, developed, and manufactured in contemporary Mexico’s ceramic sectors.

Nanotechnology is one area of strong focus and will be in the spotlight during the Nanotech Biotech 2013 New Venture Competition being held November 7–8 in Monterrey, one of the country’s largest business and industrial centers. Its purpose is to spark the launch of high-value businesses—in particular, small and medium enterprises—that work with emerging technologies.

Since 2000, the ceramics industry in Mexico has been advancing its work in research and development of applications in the area of nanotechnology. Growth in this area has been promoted by such institutions as the National Council of Science and Technology (CONACYT), the National Petroleum Institute, the National Polytechnic Institute, and the National Autonomous University of Mexico.

Work in the area of nanotechnology engineering has resulted in the launch of a range of new products and applications related to the manufacture of electricity-generating equipment and electrical apparatuses and computers, communications, and peripheral equipment. Product development has focused on the use of nonmetallic minerals in the manufacture of glass, cement, ceramics, refractories, and abrasives.

In the research arena, the Advanced Materials Research Center (a division of CONACYT known by its Spanish acronym CIMAV) published articles during 2013 on

- Microemulsions as reaction media for the synthesis of mixed oxide nanoparticles: Relationships between micro-



(Credit: Talavera)

Modern Mexico—Far-reaching research

emulsion structure, reactivity, and nanoparticle characteristics;

- Antimicrobial activity, cytotoxicity, and inflammatory response of novel plastics embedded with silver nanoparticles;

- Corrosion behavior of AISI 409Nb stainless steel manufactured by powder metallurgy exposed in H_2SO_4 and NaCl solutions;

- Density functional theory study of indigo and its derivatives as photosensitizers for dye-sensitized solar cells;

- Influence of sugar-cane bagasse ash and fly ash on the rheological behavior of cement pastes and mortars;

- Magnetic susceptibility studies of the spin-glass and Verwey transitions in magnetite nanoparticles;

- Effect of sintering temperature on the electric properties and microstructure of $SnO_2-Co_3O_4-Sb_2O_5-Cr_2O_3$ varistor ceramics;

- ZnO-Ag ceramics for ethanol sensors;

- Essential work of fracture: An approach to study the fracture behavior of acrylic bone cements modified with comonomers containing amine groups; and

- Alumina-toughened zirconia (ATZ) nanocomposite incorporating Al_2O_3 whiskers.

For a full listing of this year's research projects—there are 45 in all—and English-language abstracts, visit <http://cimav.edu.mx/investigacion/listado-articulos/listado-articulos-2013/#articulo1>.

This research is based on current industrial needs and on projections of future economic opportunity. According to a study by NANOTECH, Mexico's National Nanotechnology Lab, worldwide demand for specialists in microtechnology and nanotechnology will grow to two million jobs by 2015. Companies and universities, therefore, see the field as one that will help Mexico remain competitive in the world economy.

Another area of activity that reflects global concerns relates to sustainability. Leticia Torres, of the Department of Ecomaterials and Energy at the Autonomous University of Nuevo León's Institute of Civil Engineering, leads an investigation into the development of advanced materials that can aid the improvement of the environment through the use of clean technologies and processes. Her areas of inquiry center on superfunctional materials and clean, nonrenewable energy alternatives that offer integrated solutions to promote environmental decontamination.

tion. The goal is to generate energy based on technologies that are emerging internationally.

Torres and her team work in collaboration with industry to bring the fruits of their research to market. "Our research has had an indirect impact on the US market, because the majority of the businesses with which we've worked on development are transnational and offer their products in the international market," she says. With market globalization, companies have come to recognize the connection between supporting research into advanced technologies and sustaining cross-border competitiveness.

Dental ceramics—Restoring smiles

Ceramic dental prostheses are another area of focus in Mexico. Statistics reported by the country's National Oral Health Program indicate that an elevated number of people in the country are suffering from severe dental problems. For this reason, businesses and laboratories that specialize in ceramic dental prostheses are working on advances that use CAD/CAM and robotic technology in the construction of devices made of metal-porcelain and zirconia.

One of the advances in dental technology involves the development and use of porcelain veneers, a process that is more economical and improves the aesthetics of a partial reconstruction of a broken tooth. The technique is the work of Mexico's American Academy of Dental Technology. Further ceramic-based innovations in odontology have led to the development of metal-free implants that incorporate new applications of such materials as lithium silicate, fluorapatite, and zirconium oxide.

Ivoclar Vivadent is among the Mexican companies leading the exploration of these new applications. "The development of ceramics that our brand has implemented and disseminated has established us as pioneers in fields related to cosmetic dentistry. This has sparked considerable global fanfare with regard to the strength of metal-free ceramics, which are without a doubt one of the alternatives preferred by both middle and high-end customers in



Credit: CNyN

Scientists at the Center for Nanoscience and Nanotechnology (CNyN) in Ensenada, Mexico, have engaged in ceramics research since its founding in the 1980s, including work on doped oxides, ferroelectrics, and catalysts.

need of dental restoration," says Sergio Hernandez, coordinator of the company's Council for Open and Distance Education's Professional Services.

"Today we explore possibilities that involve the use of diverse materials, including lucite, lithium silicate, and zirconium, in order to realize a wide range of restorative procedures in the reconstruction of lost dental structures. Our objective is to achieve a solution that delivers an excellent long-term biological, functional, and aesthetic integration. At the global level we see high rates of successful application of this type of restoration, with product lifespans in excess of five years."

Refractories—Steel and cement enablers

Of course, refractories also play a prominent role in Mexico's ceramic industry and national economy. Mexico's history of ceramic production dates to pre-Columbian times. The city of Monterrey, capital of the border state of Nuevo León, began its ascent to business and economic prominence with the growth of its steel and cement industries.

Steel production, which stood at 13.3 million tons in 2001, rose to 17.6 million tons by 2007 but plummeted following the global economic crisis to 14.1 million tons in 2009. By 2012 the industry had recovered and surpassed that 2007 high. Production last year reached a volume of 18.1 million tons, according to CANACERO, the country's national chamber of the iron and steel industries. However, production remains on unsteady footing: The organization announced on July 8 that volume had fallen from 1.6 million tons in March to 1.4 million tons in April, the most severe drop in the preceding 13 months.

In March, Alonso Ancira Elizondo, CANACERO's president, told the Mexican daily newspaper *El Universal* that he anticipates a "tsunami" of steel imports into Mexico. Skyrocketing automobile manufacturing in Mexico will spur part of that increased import demand. An April 17 Bloomberg article reported that Mexico's automobile production nearly doubled since 2009



Graduate student Luz Zavala studies cathodoluminescence of doped hydroxyapatite materials to determine dopant distribution in powders and films at CNyN. This laboratory is under the direction of Manuel Herrera.

and that the steel industry was investing \$3 billion on factory improvements to catch up to that hike in production, which the Mexican Automobile Industry Association projects will grow

to four million vehicles a year by 2017.

In Mexico, the manufacture of crucibles for induction stoves is advancing via the use of graphite clay, which allows nonferrous metals, such as

Billion-dollar (a day) border

As our third-largest trade partner, Mexico powers US economic growth.

By Alex Talavera and Randy B. Hecht

Mexico's 758,449 square miles of territory are home to a population of 116,220,947. With an economy in the trillion-dollar class, this market is attractive to US businesses because of its proximity and free trade agreements and because of the size of the opportunity it represents. "The United States and Mexico trade over \$1.25 billion in goods and services each day, a number we expect to grow as we help more US companies succeed in Mexico," says US ambassador to Mexico E. Anthony Wayne.

The *CIA Fact Book* reports that since the North American Free Trade Agreement (NAFTA) went into effect in 1994, Mexico's share of US imports has increased from 7% to 12%. The US is the destination of 78% of Mexican exports and the source of 50.5% of the country's imports. "Mexico is the United States' second-largest export market (after Canada) and third-largest trading partner (after Canada and China)," the US State Department notes.

For 2012, Mexico's purchasing power GDP is estimated at \$1.799 trillion, or \$15,600 per capita, which reflects a 3.9% growth rate over 2011. On that basis, Mexico is the 11th-largest national economy in the world. Services generate 61.8% of GDP, followed by industry (34.2%)

and agriculture (4.1%). The industrial production growth rate for 2012 is estimated at 3.6%. Key industries include food and beverages, tobacco, chemicals, iron and steel, petroleum, mining, textiles, clothing, motor vehicles, consumer durables, and tourism.

Mexican export volume for the year is estimated at \$370.9 billion, up from \$349.4 billion in 2011. Leading commodity exports include manufactured goods, oil and oil products, silver, fruits, vegetables, coffee, and cotton. Import volume for the year is estimated at \$370.8 billion, up from \$350.8 billion in 2011. Leading commodity imports include metalworking machines, steel mill products, agricultural machinery, electrical equipment, car parts for assembly, repair parts for motor vehicles, aircraft, and aircraft parts.

For guidance on competing successfully in Mexico and connecting with trading or business partners there, contact the United States-Mexico Chamber of Commerce or the American Chamber of Commerce of Mexico. In addition, the US Commercial Service has published *Doing Business in Mexico*. US-Mexican business news and links to business data can be found on the website of the Embassy of the United States in Mexico City. ■

Modern Mexico—Far-reaching research

zinc, tin, bronze, and aluminum, to be heated to high temperatures without melting. Among the Mexican companies manufacturing crucibles to this standard is C.E. Fire, which specializes in crucibles and refractories for walls, vaults, work areas, and doors that can withstand a variety of heat treatments.

Another essential advance for the industry in Mexico is the development of concrete refractories to construct structures that contact molten metals or abrasive environments. They resist thermal shock and can be used for repairs in high-temperature environments.

Each of these areas of research, development, and new product launches builds on Mexico's long history of using and commercializing a wide



(Credit: Stock)

Central University Campus of the Mexico National Autonomous University. The image shows the Central Library Building covered with tile works from Juan O'Gorman.

spectrum of ceramic products and technologies. As the world sees continued demand for further advances in ceramic applications, Mexico is investing in the

academic, technological, and human resources necessary to remain an important global player in the industry's future. ■

Mexico ceramics directory and profiles

COMPANIES AND COMMERCIAL ENTERPRISES

AFIBRA

Av. 8 de Julio 1653
Col. Morelos
Guadalajara, Jalisco CP 44910
Website: www.afibra.com/sitio/index.php?lang=en
English language website: www.afibra.com/sitio/index.php?lang=en
Email: contacto@afibra.com
Phone: 52 33 3810 6625 or 52 33 3810 6629

The company has more than 40 years of experience manufacturing fiberglass. Working with materials that include wood, stone, brick, twig, quarry, reed, and bamboo, among others, it creates materials that require less maintenance and weigh less than those built conventionally.

Aislamientos y Control de Fluidos, S.A. de C.V.

Website: http://www.empaqacf.com/ACF/Pagina_de_Inicio.html
Email: aislamientosctrl@hotmail.com

The company has 30 years of experience in the manufacture and commercialization of a variety of packing materials, including fiberglass, chrysotile, tetrafluoroethylene, graphite, kevlar, and other materials used in industrial maintenance and repair.

Arta Cerámica

Grecia 87
Col. Los Encinos
Tlalpan/Ajusco, México DF
Phone: 52 55 5630 3142
Website: www.artaceramica.com
Email: info@artaceramica.com or proyecto@artaceramica.com

Arta Cerámica designs and produces decorative ceramic objects that have been exhibited at national and international fairs and expos. The company has collaborated on projects with the Museum of Modern Art in New York, architectural firms, and restaurants.

C.E. Fire

Av. Eugenio Garza Sada 6100 B21
Col Satelite
Monterrey, Nuevo León
Phone: 52 81 8103 2233 or 52 81 8103 2239
Website: www.ce-fire.com/
English language website: www.ce-fire.com/English.html
The company supplies such refractory products as insulating firebrick, ceramic filters, refractory castables, firebrick, mortars, and metallic and refractory anchors as well as ceramic fiber and insulation, high-temperature textiles, and microporous insulation.

Cerconsult

Phone: 52 81 8133 3741
Website: www.cerconsult.com
Email contact form: www.cerconsult.com/contact.html
Founded in Italy in 1994, the company has expanded to offices in Europe, Asia, and the Americas. Its North American operations are concentrated in Mexico.

Concejo Cerámico de Norte América

Batallón de San Patricio #109, Oficina 627
Col. Valle Oriente
San Pedro Garza García, Nuevo León CP 66269
Phone: 52 81 8625 3306
Fax: 52 81 8133 2707
Website: www.tcna.com.mx/perfil.htm
Email contact form: www.tcna.com.mx/contacto.htm
Member directory: www.tcnatile.com/es/resources/product-locator.html?categoryid=3
The Consejo Cerámico de Norte América México (TCNA México) was created in 2005 as a subsidiary of the Tile Council of North America. Its goal is to develop the industry, expand the market, and represent the interests of Mexico in an international context.

COMINSA

Calle del Molino #117
Frac. Industrial el Obispo
Santa Catarina, Nuevo León CP 66359
Phone: 52 81 8316 8019
Website: www.cominsaminerales.com

Email: Diana.Flores@cominsaminerales.com

Comercializadora de Minerales Cerámicos, S.A. de C.V., was founded in 2003 to meet the market demand for raw materials used in the manufacture of industrial ceramics.

Endress+Hauser México

Fernando Montes de Oca 21
Edificio A Piso 3
Frac. Industrial San Nicolás
Tlalnepantla de Baz, México CP 54030
Phone: 52 55 5321 2080
Fax: 52 55 5321 2099
Website: www.mx.endress.com
Email: eh.mexico@mx.endress.com

Endress+Hauser was founded in 1953 in Switzerland, home to its global headquarters, and is a global leader in measurement instrumentation, services, and solutions for industrial process engineering. The company entered the Mexican market in 1999 and has sales offices in many cities.

Innovaseals

Website: www.innovaseals.com.mx
Directory of offices, phone numbers, and emails: www.innovaseals.com.mx/contact.php
Founded in 1997, Innovaseals conceptualizes, designs, manufactures, repairs, and develops technological applications for a variety of mechanical seals.

Ivoclар Vivadent

Av. Insurgentes Sur No. 863, Piso 14
Col. Nápoles
México DF CP 03810
Phone: 52 55 5062 1000
Fax: 52 55 5212 0585
Website: www.ivoclarrivadent.com.mx/es-mx/
Directory of contacts: www.ivoclarrivadent.com.mx/es-mx/contacto/contacto

Ivoclär Vivadent is a global leader in innovative materials and processes for esthetic dentistry. Its products include direct restoratives as well as fixed and removable prosthetics. Launched in Zurich in 1923, its Mexican operations have advanced the development of lumine, lithium, and zirconium ceramics used to replace lost or damaged dental structures.

Krohne de México, SA de CV

Poza Rica 706
Col. Petrolera
Tampico, Tamaulipas CP 89110
Phone: 52 833 217 3830
Website: www.krohnemexico.com
Email: contacto@krohnemexico.com

Krohne's Mexican operations handle service and sales for a region that spans Mexico, Central America, and the Caribbean. The company's high-performance ceramic products include electromagnetic, variable area, ultrasonic, mass, and vortex flowmeters as well as flow controllers.

Laboratorio Nacional de Nanotecnología

Centro de Investigación en Materiales Avanzados, S.C.
Miguel de Cervantes 120, Comp. Ind. Chihuahua
Chihuahua, Chihuahua CP 31109
Website: www.nanotech.cimav.edu.mx/#
Email: www.nanotech@cimav.edu.mx

The National Nanotechnology Laboratory promotes the advance of nanoscience and nanotechnology in Mexico by supporting the academic and manufacturing sectors. Its mission is to serve as a hub of Mexico's national nanotechnology network.

Nitropiso

Eje 140 #1000, Zona Industrial
Deleg. la Pila, San Luis Potosí
Phone/Fax: 52 444 832 0100

Website: www.nitropiso.com
Email contact form: www.nitropiso.com/contacto

Founded in 2003, the company produces flooring and ceramic tile for domestic and international clients in one of the world's most modern manufacturing plants.

Polarimundo

Azalea Mz. 41 Lt. 22
Santa Rosa, Chimalcoapan
Website: www.polarimundo.mex.tl/12733_Quienes-somos-.htm

Email contact form: www.polarimundo.mex.tl/?mail=1

A specialist in the use of nanotechnology for ultraviolet protection of industrial glass, the company develops and manufactures ceramic nanoseals that reduce ultraviolet exposure by 99%.

Porcelanas Dentales

Hamburgos 108 Desp. 304
Col. Juárez
Cuauh temó, México DF CP 06660
Phone: 52 55 5511 5582
Fax: 52 55 5525 8141

Website: www.porcelanasdentales.com.mx

The company develops and manufactures metal-free porcelain, ceramic metal, and other resin, titanium, and laser products for dental use.

Praxair México

Website: www.praxair.com.mx

Directory by state: www.praxair.com.mx/portal/site/praxair/Sucursales

Email form: www.praxair.com.mx/praxair_view/jsp/sendlink_mail.jsp

Praxair Specialty Ceramics, a commercial segment of Praxair Surface Technologies, pioneers the development of products that make use of emerging technologies and have a variety of industrial applications, including microelectronic circuits, solid oxide fuel cells, superconductor cables, and cellular technology.

Prolec SA de CV*

Bvd. Carlos Salinas de Gortari km 9.25
Apodaca, Nuevo León 66600
Phone: 52 81 8030-2553
Fax: 52 81 8030-2500
Website: www.celeco.com.mx

Celeco manufactures electrical porcelain insulators for distribution and medium power (up to 138 kV) class. Celeco is the most modern facility in its field, reaching an annual capacity of 12,000 tons. Its principal products are transformer bushings, cutouts, arresters, and transformer components.

Refractarios Sajuri, S.A. de C.V.

Zahuatlán 366
Col. La Romana
Tlalnepantla, México CP 54300
Phone: 52 55 5565 8281
Fax: 52 55 5390 1965
Website: www.sajuri.com.mx
Email: info@sajuri.com.mx
Email contact form: www.sajuri.com.mx/formulario.html
Founded 20 years ago, the company develops and manufactures refractory products for a wide variety of industries.

Vitro Cerámica de México, S.A. de C.V.

Website: www.vitrocera.com.mx/vitro/index.asp
Directory of locations and phone numbers: www.vitrocera.com.mx/vitro/english/contacto.htm
English language website: www.vitrocera.com.mx/vitro/english/index.asp
Founded in Hermosillo in 1991, this ceramic tile company has expanded operations to Culiacán, Torreón, Ciudad Juárez, Mexicali, and Tijuana.

UNIVERSITIES AND RESEARCH INSTITUTES

Acta Universitaria

Website: www.actauniversitaria.ugto.mx/index.php/acta/index

This scientific journal, which operates under the auspices of the Universidad de Guanajuato, is published six times a year in print and digital editions, in English and Spanish.

Centro de Investigación Cinvestav

Av. Industria Metalúrgica #1062
Parque Industrial Saltillo-Ramos Arizpe
Ramos Arizpe, Coahuila, CP 25900
Website: www.cinvestav.edu.mx/saltillo

Foro Consultivo Científico Tecnológico

Insurgentes Sur No. 670 piso 9
Col. del Valle
Deleg. Benito Juárez, México DF CP 03100
Phone: 52 55 5598 8940 or 5598 8986/ 5611 8536
Website: www.foroconsultivo.org.mx/home
English language website: www.foroconsultivo.org.mx/home_ingles
Email: foro@foroconsultivo.org.mx

Established in 2002, the Foro Consultivo Científico y Tecnológico (Science and Technology Advisory Forum) is an autonomous and impartial body in charge of analyzing the development of science, technology, and innovation in Mexico. Its Board of Directors includes 21 representatives from the research, technology, and business sectors.

Instituto Politécnico Nacional

Av. Luis Enrique Erro S/N
Unidad Profesional Adolfo López Mateos, Zacatenco
Deleg. Gustavo A. Madero, México DF CP 07738
Website: www.ipn.mx/Paginas/inicio.aspx
English language website: www.ipn.mx/english/Paginas/Inicio.aspx

ITAM Instituto Tecnológico Autónomo de México

Campus Río Hondo
Río Hondo #1
Col. Progreso Tizapán

Deleg. Álvaro Obregón, México DF CP 01080

Campus Santa Teresa

Av. Camino a Santa Teresa #930

Col. Héroes de Padierna

Deleg. Magdalena Contreras, México DF CP 10700

Phone: 52 55 5628 4000

Website: www.itam.mx/es

Email directory: www.itam.mx/es/contactos/contactos.php

EGAP Gobierno y Política Pública del Tecnológico de Monterrey

Eugenio Garza Lagüera y Rufino Tamayo

Col. Valle Oriente

San Pedro Garza García, Nuevo León CP 66269

Phone: 52 81 8625 8300

Website: www.egap.itesm.edu/wps/portal/egap?WCM_GLOBAL_CONTEXT=

Email: egap.mty@servicios.itesm.mx

Tecnológico de Monterrey

Av. Eugenio Garza Sada 2501 Sur

Col. Tecnológico

Monterrey, Nuevo León CP 64849

Phone: 52 81 8358 2000

Website: www.itesm.edu

English language website: www.itesm.edu/wps/wcm/connect/ITESM/Tecnologico+de+Monterrey/English

Universidad Autónoma del Estado de México

Instituto Literario # 100

Col. Centro

Toluca, México, CP 50000

Phone: 52 722 226 2300

Website: www.uaemex.mx

Faculty and administrative directory: www.desarrollo.uaemex.mx/directories

Universidad Autónoma de Nuevo León

2013 Pedro de Alba s/n

San Nicolás de los Garza, Nuevo León

Website: www.uanl.mx

English language website: www.uanl.mx/utilidades/folletuanl_ingles.pdf

Universidad de las Américas Puebla

Sta. Catarina Mártir

Cholula, Puebla CP 72810

Phone: 52 222 229 2000

Website: www.udlap.mx/home.aspx

Universidad Jesuita de Guadalajara

Periférico Sur Manuel Gómez Morín 8585

Tlaquepaque, Jalisco CP 45090

Phone: 52 33 3669 3434

Website: www.portal.iteso.mx/portal/page/portal/ITESO

Departmental email and phone directory: www.portal.iteso.mx/portal/page/portal/ITESO/Informacion_Institucional>Contactanos

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Av. Universidad 3000

Coyoacán, México DF 04510

Phone: 52 55 5622 2522

Website: www.unam.mx

English language website: www.unam.mx/index/en
Phone and email directory: www.directorio.unam.mx/consultasvarias.htm