



bulletin | cover story

Korea's core competencies

By Alex Talavera and Randy B. Hecht

Korea's research and private sector leaders target advances in environmental protection and energy efficiency.

The Korean people can trace their history back 700,000 years, as evidenced by Paleolithic implements discovered at such sites as Geomeunmoru Cave in Sangwon and Durubong Cave in Cheongwon. The people of that distant era had at least this much in common with their descendants in contemporary Korea: a talent for using materials at their disposal to create innovative solutions. Those artifacts are the prehistoric precursors to sophisticated ceramic tools and technologies being developed and marketed by Korea today—advances that play a significant role in the country's economic growth and prominence in the global economy.

To get a sense of the size, scope, and potential of ceramic export opportunity in Korea, consider that in 2014, ceramic application exports to the United States alone generated \$790.4 million, and they are expected to rise 21% to \$953.7 million in 2015. The biggest contributors to the 2014 figure were cutting and digging tools (\$152.5 million); precision machine control (\$107.5 million); glass (\$80.6 million); cement, lime, and plaster (\$60.9 million); and semiconductors and display products (\$56.4 million). These exports are expected to see a continued gradual rise, aided by supports provided by the U.S.-Korea Free Trade Agreement.

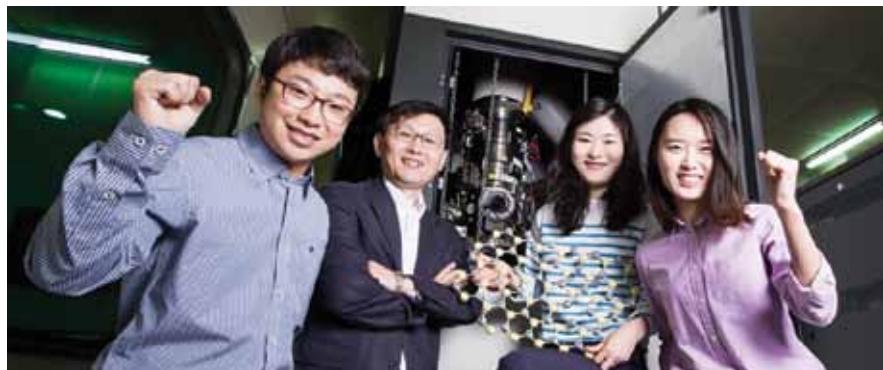
Growth rates are significant enough that the Korean government has promoted projects designed to support the sector's ability to ensure that its manufacturing capacity keeps pace with market demand. For example, the Ministry of Trade, Industry and Energy has sponsored a project devoted to "development of product application technology linked to demand

of nanomaterials,” and the Small and Medium Business Administration is promoting “development of new products for conditional purchase.” Market demand also creates pressure to increase the number of skilled professionals in the industry, and the Ministry of Education has responded by launching a Leaders in Industry–University Cooperation program, whose aim is to increase employment rate by placing students in internships and providing them with classroom training that is customized to industry demands.

On the research front, activity generally follows one of two directions. “First mover R&D” is intended “to lead future market through developing world-class core materials and promoting early commercialization,” while “fast follower R&D” facilitates accelerate follow-up on world market opportunities by analyzing products to identify demand for materials.

Nanotechnology

Look to see increased activity in Korean research and development with regard to nanotechnology, which the government believes will contribute to jobs growth. To that end, it supports collaboration among universities, industry, and research institutes to encourage creation of new industry and strengthen support to small and medium enterpris-



Credit: UNIST

Zonghoon Lee’s UNIST research team poses in front of an advanced transmission electron microscope. From left are Jongyeong Lee, Zonghoon Lee, GyeongHee Ryu, and HyoJu Park.

es. At the same time, government policy has committed to “enhancing global competitiveness of major industries, such as nanoelectronics, nanomaterials, nano-bio, nanoenergy, and other nano-related industries,” our panel said.

“The Ministry of Trade, Industry and Energy has also intensified investment for R&D of 13 future growth engine areas, such as nano-based biomimetic devices, wearable smart devices, unmanned aerial vehicles, advanced materials machining systems, and carbon materials, to create items leading to economic improvement in the future.” The government has identified 30 future core technologies in five industries for the industrialization of nanotechnology to meet demand of future society. Among them are nanosensors for the internet of things (IoT), MEMS nanotechnology for

bio, and flexible high-energy harvesting and saving nanomaterials. “It should be noted that about 50% of the nanotechnology companies in Korea are related to materials. The convergence between nanomaterials and various new technologies will be the key for future advances in nanotechnology.”

Semiconductors

Korea produces 60–70% of semiconductor supplies, and that trend is expected to continue at least “for a while,” our panel said, owing to limited competition and rising demand in the memory semiconductor space, particularly with the emergence of IoT. “As you know, the semiconductor companies in Korea, Samsung and SK Hynix, are so competitive and have a world market share of more than 60% in memory semiconductors like DRAM and NAND flash. But in system application semiconductors like logic devices and application processors, Korea’s world market share is less than 10%. However, it is hard to predict the long-term trend since the present shrinkage technology in semiconductor processing almost reaches its limit.”

Our panel drew attention to two areas of particular interest the semiconductor sector. “First, semiconductor industry demand is shifting to ceramic parts with less particulate contamination, because two semiconductor giants of Korea, Samsung Electronics and SK Hynix, are focusing on advanced nanotechnology below 20 nm, and thus they need suitable ceramic materials that at this time can be provided only by Korean ceramic companies. Second is the development of highly functional ceramic parts such as electrostatic chucks, ceramic heaters,

Our panel of experts

For this year’s international report on Korea, Hai-Doo Kim—president of the Korea Institute of Materials Science, chairman of PacRim 11, Academician at the World Academy of Ceramics, and a Fellow of the American Ceramic Society—assembled a panel of distinguished experts to provide information about the Korean ceramic industry and its role in the semiconductor, automotive, energy, and defense sectors. Their aggregated comments and insights are reflected in this article. Included on the panel were:

- Professor Hyeong Joon Kim, Seoul National University, president of the Korean Ceramic Society
- Professor Jong-Heun Lee, Korea University
- Professor Young Soo Yoon, Gachon University
- Professor Wook Jo, Ulsan National Institute of Science and Technology
- Professor Soo Wohn Lee, Sun Moon University
- Professors Sang-Im Yoo and Seong-Hyeon Hong, Seoul National University
- Jo-Woong Ha, president of InnoCera.com, Korea
- Byung Ik Kim, vice president, and Sung-Min Lee, principal researcher, Korean Institute of Ceramic Engineering and Technology
- Hae-Weon Lee and Jong-Ho Lee, principal researchers at Korea Institute of Science and Technology
- Young-Jo Park, Chul-Jin Choi, Sang-Kwan Lee, and Jong-Jin Choi, principal researchers at Korea Institute of Materials Science ■

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and ceramic cathodes. Those parts are so important for the development of new semiconductor processing technology that there is a strong need for domestic development and production, which provides the semiconductor industry more freedom in development of new nanotechnology. But intellectual property can be a major barrier."

Despite these developments, the panel reported that to date, "Korean universities and students do not have much interest in ceramics for semiconductor suppliers." Industry itself has stepped in to address the shortfall between its requirements and activity on campus. For example, Samsung founded Sungkyunkwan University's Department of Semiconductor Engineering "to educate students who can work at Samsung immediately after graduation." Initiatives of this kind, which create a direct link between areas of academic concentration and opportunities for employment, are expected to influence student interest in specific areas of ceramic research and development.

Automotive

Korea's automotive industry is experiencing growth in the Asian and Latin American markets. Are Korean ceramic and carbon fiber manufacturers under pressure to reduce the cost of their automotive components to meet price demands in those markets?

"Korean automotive companies themselves are under pressure to improve performance with reasonable prices rather than to reduce the cost," our panel said. "For fuel efficiency improvement, for example, they are



Credit: SK Hynix; YouTube

SK Hynix is the second largest manufacturer of memory semiconductor.

interested in utilizing lightweight bodies using carbon fiber, hybridized systems of combustion engines and electrical motors, and green engines using hydrogen gas. In contrast, Korean companies, such as Hyosung and Taekwang, have already developed and been producing carbon fibers. They are also trying to reduce production cost of the carbon fiber to \$10~13/kg, which is required by automotive manufacturers, one of the largest sources of demand. For example, they are focused on applying low cost precursors and developing innovative carbonization processes as well as producing large tow carbon fibers."

These demands have also sparked research and development activities through a consortium that includes material suppliers, part manufacturers, research institutes, universities, and finished-product manufacturers in Korea.

"They have developed portfolio technologies for carbon fiber reinforced composite parts, including low cost carbon fiber, new resin with fast cure and high heat resistance, fast liquid molding process, and new design technology for composite automotive bodies. It is, of course, that improvement of performance and durability as well as a cost-down of

ceramic components are urgent issues to all manufacturers. The ceramic components made and applied in Korea are knock sensors, temperature sensors, gas sensors, spark plugs, heaters, ultrasonic sensors, pressure sensors, anti-friction-coatings, wear-resistant coatings, emission after-treatment systems, etc. It seems that all the manufacturers' R&D priority is to reduce cost. Further, carbon fibers and ceramic fibers for automotive applications in Korea are faced with both cost balance and performance improvement. Therefore, manufacturers are developing optimal processing technology for ensuring both high performance and competitive price. For example, there is ongoing R&D for improvement of product capacity of composite components through developing rapid-hardening technology of fiber and resin and for fuel efficiency improvement and competitive price through hybridizing carbon fibers and basalt fibers."

What are the next steps or emerging trends that are most important to watch in Korean ceramic advances for the automotive industry? The panel pointed to application of ceramic fiber composites, such as SiC fiber composites. These are expected to deliver engine and breaker parts that feature long-term durability, ultra-light weight, and the ability to work in high-temperature and high-friction conditions. In addition, "environmentally friendly basalt fiber with low-cost benefits could be applied to automotive components."

Energy

What impact have new developments in fuel cell technology had on improved fuel efficiency and environmental performance?

"A fuel cell is a device that converts the chemical energy from a fuel into electricity through a electrochemical



Credit: Oak Ridge National Laboratory; Flickr CC BY-NC-ND 2.0

Korean companies, such as Hyosung and Taekwang, produce carbon fibers.

reaction. In general, as the energy conversion efficiency of fuel cell is much higher than that of Carnot engine, the fuel consumption and emission of pollutants and greenhouse gases can be reduced. Among fuel cells, solid oxide fuel cells (SOFCs) are getting attention as a next generation environmental-friendly electric power generation system, because SOFCs have 45%–65% thermal conversion efficiency and >85% of system efficiency through cogeneration system using waste heat. Recently, materials and processing technology have been developed to reduce operation temperature and improve durability and performance, so the application area of SOFC is expected to expand to not only households, buildings, and power plants,



Credit: Posco Energy, YouTube

Posco Energy is the world's largest fuel cell producer, offering molten carbonate and solid oxide power systems.

but also portable and transport auxiliary power supply," our panel said.

"In these circumstances, fuel cells are already competitive with regard to operating expenditure and greenhouse gas emission. This is why the Korean

government always considers fuel cell technology as a main candidate for highly efficient and environmentally clean energy sources. Fuel cell systems, such as molten carbonate fuel cell (MCFC) and SOFC power plants, led by Posco

Directory of Korean ceramics industry, associations, universities, and institutes

UNIVERSITIES

Gachon University

(461-701) 1342 Seongnamdaero, Sujeong-gu, Seongnam-si, Gyeonggi-do

Phone: 82-31-750-5114

Website: www.gachon.ac.kr/english

Nanoscale biological research is a strong area of focus at the university, whose schools include a College of BioNano Technology. In addition, it operates the Gachon BioNano Research Institute. Founded in 2007, the Research Institute's objective is to "showcase innovative research and developing trends in fusion technology and nurture professionals in this field."

Hanyang University

Seoul campus: 222 Wangsimni-ro, Seongdong-gu, Seoul 04763

ERICA campus: 55 Hanyangdaehak-ro, Sangnok-gu, Ansan, Gyeonggi-do 15588

Phone: 82-2-2220-1421

Website: www.hanyang.ac.kr/english

The Ceramic Materials Research Institute and the Institute of Nanoscience and Technology are among 44 centers of study within the university. Among the facilities within its National Research Laboratory are the Thin Film Electronic Materials, Nano SOI (Silicon-on-Insulator) Process, and KINETIC Coating Laboratories. The university offers a major in materials and chemical engineering (chemical, ceramic, textile, and advanced materials).

Korea Advanced Institute of Science and Technology (KAIST)

KAIST 291, Daehak-ro, Yuseong-gu, Daejeon 34141

Phone: 82-42-350-2114

Website: www.kaist.ac.kr/html/en

KAIST describes its mission as "fostering the growth of science and technology leaders with a business mindset." In keeping with its focus on bringing research ideas to market, the institution launched Startup KAIST to "create an entrepreneurial culture based on science and technology." Aligned with this initiative is the work of the Office of University-Industry Collaboration, which works in turn with the Technology Commercialization Center and the Technology Business Incubation Center.

Korea University

45 Anam-ro, Seongbuk-gu, Seoul, 136-701

Phone: 82-2-3290-1152

Website: www.korea.ac.kr/mbshome/mbs/en/index.do

Among the university's areas of research concentration are microelectronics and nanotechnology systems, where the focus is on "studying microsystem and nanosystem design, optoelectronic devices, nanoscale devices, MEMS and NEMS fabrication, and microstructured and nanostructured materials," the website notes. The university also is home to a Microelectronics & Micro/Nano Systems Laboratory that pursues advances in microsystems and nanotechnology-based microsensors and microactuators.

Pohang University of Science and Technology (POSTECH)

77 Cheongam-ro, Nam-gu, Pohang-si, Gyeongsangbuk-do

Phone: 82-54-279-0114

Website: www.postech.ac.kr

POSTECH is home to 64 research centers and many state-of-the-art research facilities, including Korea's only synchrotron radiation facility. Among its research institutes is the National Institute for Nanomaterials Technology, conceived as "a core research center for the advancement and commercialization of nanotechnology."

Seoul National University

Gwanak Main Campus: 1 Gwanak-ro, Gwanak-gu, Seoul 08826

Phone: 82-2-880-4447

Website: en.snu.ac.kr

Among the university's 16 colleges is the College of Engineering, home to the Department of Materials Science and Engineering. It also operates the Graduate School of Convergence Science and Technology and the Advanced Institute of Convergence Technology, whose areas of research include energy semiconductors, nano-bio convergence, carbon dioxide recycling, green batteries, biomedical implant convergence, nano imaging and therapy, and nanoparticle innovation.

Sungkyunkwan University

Humanities and Social Sciences Campus: 25-2, Sungkyunkwan-ro, Jongno-gu, Seoul

Natural Sciences Campus: 2066, Seobu-ro, Jangan-gu, Suwon-si, Gyeong Gi-do

Phone directory: www.skku.ac.kr/eng_home/skku/campusinfo/find_tel_02.jsp

Website: www.skku.ac.kr/eng_home/index.jsp

Sungkyunkwan University's history dates to 1398, but the school is keeping its focus on the future and its goal to be ranked among the top 100 universities in the world. As part of its strategy for achieving that goal, the university founded the SKKU Advanced Institute of Nanotechnology (SAINT) in 2005. Comprised of faculty and students, SAINT's interdisciplinary nanomaterials group is described as "studying design, preparation, and integration of nanoscale materials and advanced nanotechnology-based application," the website says. Working with the financial support of the Samsung Advanced Institute of Technology, it established a target of becoming one of the world's top five nanotechnology institutes.

Sun Moon University

Asan campus: Kalsan-ri, Tangjaong-myaon, Asan-si, Chungnam, 336-708

Phone: 82-41-530-2114

Chonan campus: Samyong-dong, Chonan-si, Chungnam, 330-150

Phone: 82-41-559-1214

Website: tulip.sunmoon.ac.kr/english/main.do

The university's schools include the College of Advanced Materials Engineering, whose education and research programs focus on development and application of industrial materials at the core of the future industries. It conducts "industrial on-site practical education associated with 2,000 materials-related small businesses."

Ulsan National Institute of Science and Technology (UNIST)

50, UNIST-gil, Eonyang-eup, Ulju-gun, Ulsan

Phone: +82 52 217 0114

Website: www.unist.ac.kr

Since opening in 2009, UNIST is already a leading science and technology university, and the institution aims to be a top ten-ranked science and technology university worldwide by 2030. UNIST operates a School of Materials Science and Engineering that is active in industry research. The school's two tracks, Advanced Materials Science and Nano Materials Engineering, merge research and education with industrial innovation.

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Energy in Korea, are expected to hold a dominant position not only in fuel efficiency but also with regard to emission rates of CO₂, NO_x, SO_x gases, and noise levels in comparison with traditional gas-turbine based power generation systems. In addition, the Korean government has focused on proton and anion based membrane fuel cells, which require corrosion resistive catalyst structure."

Defense

Two trends are most prominent in ceramic research and development for the defense sector. The first relates to advances in ceramic applications that can function in extreme environments, and areas of focus include aerospace, rockets, and bulletproof materials. The

second is precision sensor materials, with applications encompassing such areas as ultrasonic sensors, precision missile sensors, and infrared sensors. These materials are being developed primarily for the domestic market but are seen as having export potential over the long term.

Finally, our panel offered this guidance and advice to U.S. companies that are interested in exploring trade, joint venture, or shared research opportunities with partners in Korea.

"Currently, Korea-U.S. joint research is activated at the government level, and the energy sector is especially active." The U.S. Department of Energy and Korea's Ministry of Science, ICT and Future Planning recently launched a joint venture, the International Nuclear

Energy Research Initiative, "to develop nuclear power technology through a consortium with industry, university, and institute collaboration." The Department is also collaborating with Korea's Ministry of Trade, Industry and Energy on "international joint research for energy, so U.S. companies can participate in the joint research program and initiate shared research opportunities with partners in Korea. To participate in the INERI program, both sides must support equal research funds and the research proposal must be submitted to both countries."

See our market snapshot for information about additional resources available to U.S. companies interested in joint ventures with Korean counterparts. ■

Directory of Korean ceramics industry, associations, and institutes

University of Seoul

163 Seoulsiripdae-ro, Dongdaemun-gu, Seoul
Phone: 82-2-6490-6114
Website: english.uos.ac.kr

Founded in 1918, the University of Seoul is a public institution with more than 10,000 students enrolled in seven undergraduate colleges and nearly 90 fields of study in the Graduate School. Three research centers are affiliated with the Institute: the Nanoscience & Technology Center, Seoul Jewelry Research Center, and High Performance Computing Research Center.

Yonsei University

50 Yonsei-ro, Seodaemun-gu, Seoul
Directory: www.yonsei.ac.kr/eng/about/contacts/index.asp
Website: www.yonsei.ac.kr/eng

Founded in 1885, Yonsei University is Korea's oldest private university and includes 18 graduate schools, 22 colleges, and 133 subsidiary institutions. Its Department of Materials Science and Engineering is building on a 50-year record of success in materials research. At the graduate level, its 280 students are engaged in the study of materials technology that has an impact on nanotechnology, biotechnology, and information, energy, space, structural, and clean technologies.

GOVERNMENT AGENCIES AND INSTITUTES

Korea Institute of Ceramic Engineering and Technology (KICET)

101, Soho-ro, Jinju-si, Gyeongsangnam-do, 660-031
Phone: 82-55-792-2500
Website: www.kicet.re.kr/en

As "Korea's sole research institute specialized in ceramic technology," KICET, a government-sponsored entity, partners with Korean companies to provide them with research, development, testing, analysis, and technology support. Its area of concentration is the "foundation technology" intended to "provide an independent growth platform for Korea's next-generation focus industries."

Korea Institute of Industrial Technology (KITECH)

89, Yangdaegiro-gil, Ipjang-myeon, Seobuk-gu, Cheonan-si Chungcheongnam-do 31056
Phone: 82-41-589-8235
Website: eng.kitech.re.kr/main

Research at KITECH falls into three areas of concentration: root technology; manufacturing system technology; and industry convergence technology. The institute's work in these areas supports its economic focus, which is to strengthen the autonomy and economic viability of small- and medium-sized enterprises.

Korea Institute of Materials Science (KIMS)

797 Changwondaero, Seongsan-gu, Changwon, Gyeongnam 51508
Directory: www.kims.re.kr/eng/sub.php?code=05_01&Radd=05_01
Website: www.kims.re.kr/eng

KIMS is a government-funded research institute whose objective is "to comprehensively facilitate R&D, test, and evaluation and provide technical support related to materials technology in order to promote innovative technology and industrial development." Its research divisions include Metal Materials, Powder & Ceramics, Surface Technology, Composites Research, Commercialization Research, and Industrial Technology Support & Safety.

Korean Institute of Metals and Materials (KIM)

6th Floor, Seocho-daero 56-gil 38, Seocho-gu, Seoul 137-881
Phone: 82-2-557-1071
Website: eng.kim.or.kr

KIM was founded in 1946 to facilitate "exchanges with institutes of metals and materials in other countries." A member of the International Organization of Materials, Metals, & Minerals Societies, KIM participates in conferences designed to promote science and technology exchanges and maintains relationships with member organizations, which, in the U.S., include ASM International, the Iron and Steel Society, and the Minerals, Metals, and Materials Society.

Korea Institute of Science and Technology (KIST)

5, Hwarang-ro 14-gil, Seongbuk-gu, Seoul 02792
Phone: 82-2-958-5114
Directory: eng.kist.re.kr/kist_eng/?sub_num=416
Website: eng.kist.re.kr/kist_eng/main

Founded in 1966 as Korea's first science and technology research institute, the institute operates the KIST Gangneung Institute of Natural Products and the KIST Jeonbuk Institute of Advanced Composite Materials, which was established in 2008 "to develop and disseminate composite material related original technology that enables national industry to lead the world."

Ministry of Science, ICT, and Future Planning

Government Complex-Gwacheon, 47, Gwanmun-ro, Gwacheon-si, Gyeonggi-do 13809
Website: english.msip.go.kr/english/main/main.do

The Ministry aims to promote a creative economy and societal happiness through its support of science, technology, and information and communications technology (ICT). Through global partnerships, the Ministry is committed to furthering science and technology R&D through the development of various institutions and support of research efforts.

ASSOCIATIONS AND JOURNALS

Korean Ceramic Society

137-849 76 Seocho-gu, Gangbae
Phone: 82-2-584-0185, 588-5140
Email: ceramic@kcers.or.kr
Website: www.kcers.or.kr

Journal of the Korean Ceramic Society

Han-Il Yoo, Editor
Email: hiyoo@snu.ac.kr
Website: www.koreascience.or.kr/journal/AboutJournal.jsp?kojic=SRMHB8

Published bimonthly, the *Journal of the Korean Ceramic Society* "contains reports of original research on all aspects of ceramics and ceramics-based composites," the website notes. "Topics of the journal include a broad range of material science as follows, but are not limited to: chemistry and physics of conventional ceramics and glasses; engineering ceramics, including composites; advanced inorganic glasses with special properties; nanostructured ceramics; and materials for biological application."

On Jeju Island, Korea, PACRIM 11 participants exchange ideas on ceramic industry megatrends



Leaders and representatives of the five PACRIM partners met in Jeju Island during PACRIM 11. Societies represented were the Korean Ceramic Society, American Ceramic Society, Chinese Ceramic Society, and Ceramic Society of Japan. The Australian Ceramic Society was not present.

Credit: PACRIM11

The 11th International Conference of Pacific Rim Ceramic Societies (PACRIM 11) was held on Korea's Jeju Island Aug. 30–Sept. 4, 2015. Chaired by Hai-Doo Kim, president of the Korea Institute of Materials Science and a Fellow of ACerS, the conference and exhibition were organized by the Korean Ceramic Society with the support of the ceramic societies of Australia, China, Japan, and the U.S.

The umbrella theme of plenary presentations at the conference, "Megatrends: what will come next?," included the following plenary speakers and their topics:

- **Suk-Joong Kang**, Korea Advanced Institute of Science and Technology *Grain growth: An enduring subject in materials science and engineering*
- **Yu Zhou**, Harbin Institute of Technology, China *Fabrication, microstructural evolution, and mechanical properties of carbide, nitride, and boride ceramics*
- **Teruo Kishi**, Innovative Structural Materials Association, Japan *Megatrend of materials research and introduction of projects of structural materials in Japan*
- **Oh-Hun Kwon**, Saint-Gobain Northboro R&D Center, U.S. *Living comfortably with multifunctional*

ceramics: the opportunities and challenges ahead.

Abstracts of plenary presentations are available at pacrim11.org/Plenary_Speakers.php. In addition, dozens of speakers from Asia, Europe, and North America participated in the conference's 38 symposia, which addressed topics related to multi-scale modeling and simulation; innovative processing and manufacturing; nanotechnology and structural ceramics; multifunctional materials and systems; ceramics for energy and the environment; and ceramics in biology, medicine, and human health.

The conference's more than 1,000 attendees hailed from more than 30 countries and included some 300 students. ACerS was represented at PACRIM 11 by Kathleen Richardson, president; Mrityunjay Singh, president-elect; Richard Brow, past president; and Charlie Spahr, executive director. Members of ACerS Board of Directors H.T. Lin and Tatsuki Ohji were also at the conference, as well as past BOD members Michael Hoffman, Ivar Reimanis, and Raj Bordia. Mario Affataglio, co-editor of ACerS *International Journal of Applied Glass Science*, and Dileep Singh, PACRIM 12 chair, represented the ceramics and glass community at the event, among many other attendees from the field.

"The PACRIM collaboration is as strong as ever," says Spahr. "The Korean Ceramic Society, with Hai-Doo Kim as chair and Young-Wook Kim as technical program chair of PACRIM 11, produced a truly international event in Jeju at a world-class venue. ACerS looks forward to building on the momentum generated here for the next event in 2017."

The first PACRIM conference was held in Hawaii and hosted by the American Ceramic Society in 1993. Successive conferences have been held in countries throughout the Asia-Pacific region and North America. The conference series has established a strong reputation for state-of-the-art presentation and information exchange on the cutting edge ceramic technologies and have facilitated global dialogue and discussion with leading global experts.

The next conference in the series, PACRIM 12, will be held May 21–26, 2017, at the Hilton Waikoloa Village in Waikoloa, Hawaii. Dileep Singh, who leads the Thermal Management team at Argonne National Laboratory's Center for Transportation Research, is organizing the conference. Go to ceramics.org/meetings/pacrim12 to sign up to receive PACRIM 12 updates by email. ■

Directory of Korean ceramics industry, associations, and institutes

Journal of Asian Ceramic Societies

Website: www.journals.elsevier.com/journal-of-asian-ceramic-societies

With responsibility for peer review shared by The Ceramic Society of Japan and the Korean Ceramic Society, the *Journal of Asian Ceramic Societies* publishes "papers documenting original research and reviews covering all aspects of science and technology of ceramics, glasses, composites, and related materials. These papers include experimental and theoretical aspects emphasizing basic science, processing, microstructure, characteristics, and functionality of ceramic materials."

COMPANIES

Korea Murata Electronics Company

22nd floor, GT Tower (East) 411, Seocho-daero, Seocho-gu, Seoul 137-856
Phone: 82-2-561-2347

Website: www.murata.com/en-eu

Murata describes itself as "a global leader in the design, manufacture, and supply of advanced electronic materials, leading-edge electronic components, and multifunctional, high-density modules. Murata innovations can be found in a wide range of applications from mobile phones to home appliances, and automotive applications to energy management systems and healthcare devices."

LG

LG Twin Tower 128, Yeoui-daero, Yeongdeungpo-gu, Seoul

Phone: 82-2-3777-1114

Website (U.S.): www.lg.com

LG's Commercial Division serves industries with commercial displays, solar panels, lighting, and more. Its R&D arm covers all business areas to develop applications and technologies for its products. According to the company's website, "The organization is concentrating on research in basic technology, quality inspection, and standards fulfillment to improve its product quality, along with research in production-related core technologies and design."

Posco Energy

16F, POSCO Center West Wing, 440, Teheran-ro, Gangnam-gu, Seoul 135-933

Website: eng.poscoenergy.com/eng/renew_service/main.asp

In 2007, Posco Co. Ltd. spun off its fuel cell business, and, the following year, the new enterprise established its Fuel Cell BOP factory in Pohang. The business, renamed Posco Energy in 2012, now has expanded its operations in the Asia-Pacific region, Europe, and South America. It is the world's largest fuel cell producer and describes itself as "taking the lead in green energy business through a fuel cell, hydrogen-based, eco-friendly power generation system."

Samsung

14, Seocho-daero 74-gil, Seocho-gu, Seoul, 06620
Phone: 82-2-2145-2114

Website: www.samsungelectronics.com/global/index.jsp

Samsung Electro-Mechanics describes itself as providing "a total solution for all electronic component needs, from materials and parts to modules." To achieve this goal, it operates three business divisions. The Digital Module Division works on advances in camera modules, wireless solutions, power modules, and vibration motors. The Linkage of Magnetic Flux Coil, Capacitor, Resistor Division is dedicated to innovation in MLCCs, tantalum capacitors, chip inductors, chip resistors, and EMCs. The Advanced Circuit Interconnection Division focuses on the development of technology related to HDI, rigid flex, BGA, and FC BGA.

Ssangyong Materials Corporation

151, Seongseogongdannam-ro, Dalseo-gu, Daegu

Phone: 82-53-580-4217, 4218

Website: www.ssym.com/eng/html/main.html

A branch of Ssangyong Group, which in turn is operated by holding company Ssangyong Cement, Korea's biggest cement company, Ssangyong Materials Corporation is a leader in the field of advanced materials industry. The company is headquartered in Taegu and has plants there and in Pohang as well as a marketing office in Seoul that serves as its global sales contact. Ssangyong works with ceramic materials that include alumina, silicon nitride, zirconia, and silicon carbide.

Export expert

A foreign trade powerhouse, Korea drives its economic growth by pursuing foreign partnerships

By Alex Talavera and Randy B. Hecht

The Republic of Korea's 38,502 square miles of territory—an area slightly smaller than Pennsylvania and slightly larger than Indiana—is home to 49.12 million people, 82.5% of whom live in urban areas. The labor force numbers 26.27 million, and unemployment stood at 3.5% in 2014.

From 2013 to 2014, the country's GDP (purchasing power parity) rose 3.3% to \$1.781 trillion, or \$35,400 per capita, and the country recorded a budget surplus equal to 0.9% of GDP. Its economic position is particularly noteworthy given how radically it has changed in just a few decades. "In the 1960s, GDP per capita was comparable with levels in the poorer countries of Africa and Asia," the CIA World Factbook notes. "In 2004, South Korea joined the trillion-dollar club of world economies."

Services generate 59.4% of Korea's GDP, followed by industry (38.3%) and agriculture (2.3%). The three sectors employ, respectively, 70.4%, 24%, and 5.7% of the labor force. Leading industries include electronics, telecommunications, automobile production, chemicals, shipbuilding, and steel. Industrial production rates remained flat from 2013 to 2014.

Korea maintains a positive trade balance: 2014 exports reached \$572.7 billion, up from \$559.6 billion in 2013, while 2014 imports were \$525.5 billion, up from \$515.6 billion in 2013. Leading export commodities include semiconductors, petrochemicals, automobiles and automobile parts, ships, wireless communication equipment, flat screen displays, steel, electronics, plastics, and computers. The country's chief export markets are China (26.1%), the United States (11.1%), Japan (6.2%), and Hong Kong 5%.

According to the CIA World Factbook, the country needs to foster greater equilibrium between exports and domestic sectors, such as services. Although heavy reliance on exports is a particular concern, its long-term challenges also include a rapidly aging population, an inflexible labor market, and the dominance of large conglomerates known as chaebols.

Leading import commodities include crude oil and petroleum products, semiconductors, natural gas, coal, steel, computers, wireless communication equipment, automobiles, fine chemicals, and textiles. Top trading partners for imported goods include China (16.1%), Japan (11.6%), U.S. (8.1%), Saudi Arabia (7.3%), Qatar (5%), and Australia (4%).

Almost 80% of U.S. consumer and industrial products exported to Korea became duty free under the U.S.–Korea Free Trade Agreement, which went into effect on March 15, 2012. The Office of the U.S. Trade Representative



Credit: Republic of Korea; Flickr CC BY-SA 2.0

notes that under the trade treaty, "nearly 95% of bilateral trade in consumer and industrial products will become duty free within five years of that date." When the agreement went into effect, the U.S. International Trade Commission estimated that "the reduction of Korean tariffs and tariff-rate quotas on goods alone" would add \$10–\$12 billion to the U.S. GDP annually "and around \$10 billion to annual merchandise exports to Korea."

For further details and export support, see "Tools to Help Utilize the U.S.–Korea FTA" at ustr.gov/trade-agreements/free-trade-agreements/korus-fta/tools-to-help-utilize. Information about trade or joint venture opportunities in Korea can be obtained from the U.S.–Korea Business Council, the American Chamber of Commerce in Korea, or resources on the website of the U.S. Embassy in Seoul. In addition, the U.S. Commercial Service maintains an online library of resources (export.gov/southkorea/index.asp) related to doing business in Korea. ■



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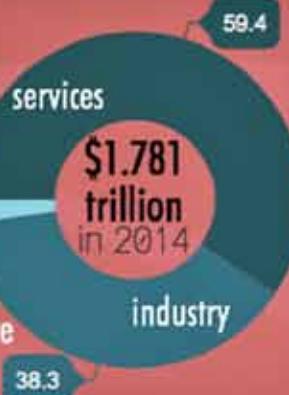
KOREA

gross domestic product



up
3.3%
from
2013

agriculture



trade

imports
\$525.5 billion
2014
exports
\$572.7 billion

chief export markets

Hong Kong, 5%
Japan, 6.2%
U.S., 11.1%
China, 26.1%

CERAMIC EXPORTS

to U.S. alone generated **\$790.4 million** in 2014

