Ceramic advances in Japan:

Achieving new breakthroughs, meeting new challenges

By Alex Talavera and Randy B. Hecht

The earthquake and tsunami that hit eastern Japan on March 11, 2011 left the world wondering how long it would take that country to recover from the devastation—and then, in the weeks and months that followed, marveling at how rapidly the rebirth progressed. As the country began to rebuild its infrastructure, Japan's leading ceramic companies and research institutes demonstrated their ability to achieve advances in fine (advanced) ceramics and glass even under the most challenging circumstances. At the same time, they continued to provide leadership in the development of products and processes that encourage sustainable industry and "green" business practices.

The year saw many impressive breakthroughs emerge in Japan. Asahi Glass reported that it had developed the world's thinnest sheet float glass and the world's thinnest soda-lime glass substrate for touch screens. Kyocera unveiled the industry's first mobile handset "crystal unit" with a precision thermistor. Murata became the first manufacturer in the industry to commercialize ceramic capacitors that are designed for automotive uses and certified under the safety standards established to prevent accidents caused by finished products or electronic components. The National Institute of Advanced Industrial Science and Technology (AIST) announced that for the first time in the world, it had demonstrated electricity generation by directly reformed fuel at low temperature (450°C).

Here, we take a look at some of the most prominent players in Japan's ceramic businesses, research institutes and universities as they continue to explore, develop and launch technological advances.

BUSINESSES

AGC: Asahi Glass Co.

Asahi Glass Company's target product lines include flat glass; automotive glass; display, electronics and energy devices; and chemicals. With more than a century of technical innovation behind it, AGC and its global team of 50,000 employees is known for its expertise in glass, fluorine chemistry and ceramics technologies, which have been put to use by customers in more than 30 countries.

"Refractory lining materials for glass melting furnaces that we develop not only tolerate high temperatures but also ensure a high degree of uniformity and composition suited for glass processing," the company notes on its website. "Also, by improving the quality of refractory lining materials, we successfully extended the service life of glassmelting furnaces. On another front, ceramic material technologies are used for the development of new materials and products such as semiconductor materials, heat-resistant protective materials and sputtering targets."


(Credit: Kyocera.)

Kyocera headquarters building in Kyoto, Japan.

Areas of the company's research and development include specialty glass materials technology and thin-glass production technology, which the company notes "are crucial for the realization of highly promising next-generation displays and info-communication devices."

Earlier this year, AGC announced development of the world's thinnest sheet float glass. Constructed of alkali-free glass and measuring just 0.1 mm, the paper-thin sheet float glass was developed for use in next-generation displays, lighting, touch screens and high-tech applications such as medical devices. The announcement came just one month after the company

unveiled the world's thinnest soda-lime glass substrate for touch screens. That product measures 0.28 millimeters, which the company says represents a 15 percent reduction from what had been the thinnest commercial substrate. The company salso says the substrate is 15 percent lighter and would lend itself to manufacture of smaller, lighter smart phones and tablets. Recent announcements also include the start of sales of an AGC glass substrate used in back-grinding processes to reduce the thickness of semiconductor chips.

Kyocera

From its global headquarters in Kyoto, Kyocera manages operations in more than two dozen countries located throughout the Asia-Pacific region and in Europe, Africa and the Americas. Its business segments include fine ceramic components, applied ceramic products, semiconductor components, electronic devices, and telecommunications and document imaging equipment. Kyocera has a presence in markets as diverse as solar power generating systems for residential use, medical and dental products, cutting tools, lenses, automotive components, telecommunications equipment and semiconductor equipment. Most of its ceramics research and development is conducted in Japan, and manufacture is completed both in Japan and abroad.

Using refined materials of uniform particle size and optimal purity, Kyocera develops fine ceramics that are more resistant to heat, wear and corrosion than plastics, metals or other conventional materials and are designed to meet engineering challenges in a variety of industries. Its wafer-processing, lithography, etching, deposition and inspection systems have extensive applications in semiconductor and LCD processing equipment. Research and development on single-crystal-sapphire applications encompass crystal growth for sapphire wafers, plasma etching for sapphire tubes and the fabrication of sapphire windows.

"Recently a number of our fine ceramic products have gained recognition for their use in a wide range of pioneering applications," says Elly Yoshikawa, manager of Kyocera's International Corporate Communications Section. "One example is a temperature-resistant, thermal shock-resistant cordierite ceramic filter used in garbage incinerator plants. [The filter] received Japan's Ministry of Economy, Trade and Industry's award for its environmental performance. By using a fine ceramic filter for this application, incinerators can now be run at temperatures of 250°C to 900°C, unattainable temperatures for conventional filters, thus enhancing performance and lowering operating costs. Furthermore, the filter can be cleaned with water and reused, so that they do not need to be replaced."

In June, the company unveiled the first cell phone crystal unit package that also contains a thermistor—a temperature sensing component. This sandwich-like product has a ceramic wall in the middle. The crystal unit is placed on the top of the wall, with the thermistor underneath the wall. It was designed to enhance communications stability in cellular phones by providing temperature tracking and compensation that can minimize frequency change under a wide operating temperature range.

The following month, the company announced its selection by Japan's New Energy and Industrial Technology Development Organization (NEDO) for participation—along with Toshiba, Hitachi, Sharp, NGK Insulators, Itochu Techno-Solutions, NEC and Shimuzu—in a smart-grid demonstration project in New Mexico that will be a collaboration among NEDO, the New Mexico state government, Los Alamos' Department of Public Utilities, and the Los Alamos National Lab.

"We believe that there are even greater possibilities in store for fine ceramic materials and technology, and we continue to strive forward with the underlying rationale of contributing to both environmental protection and advancement of society through fine ceramic technology," Yoshikawa says. She cites the example of the company's development of a ceramic mounting wafer for LEDs that "has contributed greatly to increasing LED performance and lowering costs. Compared with conventional materials, ceramics have good insulation, heat dissipation and reflectance. Kyocera also uses alumina and aluminum nitride ceramics to produce multilayer packages and single-layer submounts for high-power, high-brightness LEDs. We contribute to improving the environment with our components for LED lighting that saves more energy than incandescent lights, has a longer life than fluorescent lighting and uses no toxic substances such as mercury."

Another example is Kyocera's codevelopment of solid oxide fuel cells with several natural gas providers. "The cell, with its high energy efficiency, is expected to be a new source of energy, and should lead to the reduction of carbon dioxide emissions," Yoshikawa says. "In joint development at this time, Kyocera uses our fine ceramic technology in developing the SOFC cell and stack and has been able to significantly increase durability by improving the cell electrode structure."

The company also plays an active role in providing the general public with virtual and real-world education in the field of fine ceramics. Its Fine

Japan to host UNITECR'11

Oct. 30 – Nov. 2, 2011

Kyoto International Conference Center will be the venue for the 2011 biennial meeting of the Unified International Technical Conference on Refractories. Tsuneo Kayama (Krosaki Harima Corp.), president of the UNITECR 2011 meeting organizing committee, says the theme of the conference is "Refractories-Technology to Sustain the Global Environment." Besides symposia, short courses and an exhibition are being offered.

For information, see www.unitecr2011.org

Fine ceramics components manufactured by Kyocera.

Ceramics World website explains advanced ceramic production processes; offers an overview of the electrical, optical, physical, thermal, and chemical characteristics of fine ceramics; and includes an extensive FAQ section.

In addition, the global headquarters houses The Kyocera Museum of Fine Ceramics, which the company opened to the public in 1998. Visitors can learn about the company's technical work since its founding in 1959. (In May, the company opened a sister institution, The Inamori Kyocera Fine Ceramics Museum, the first of its kind in the United States, located on the campus of Alfred University (in upsate New York) and named for Kyocera founder and chairman emeritus Kazuo Inamori.

Murata Manufacturing Co.

Murata's core electronics products have application across diverse industries, including mobile phones, computers, audio-visual equipment, automotive electronics, environment, energy and healthcare. The company's radiofrequency technology furthers advances in built-in inductors and capacitors for communication applications that allow for the development of more compact communication modules.

In the area of applied ceramic products, Murata's low-temperature cofired ceramics multilayer circuit boards are designed to "realize miniaturization of modules due to multilayering of the circuit and also reduction of the number of mounted components. They are widely used as vehicle-mounted circuit boards which have high reliability, even in integrated electro-mechanical-type applications." Among their successes are an antilock brake system and electronic stability controls.

In 2011, Murata introduced its KCM series of chip monolithic ceramic capacitors. These are equipped with metal pins and designed for automotive electronic devices. "The elastic action of the metal pins helps to reduce the amount of stress generated by thermal and mechanical impact and also makes the capacitors very reliable," the company explained in its announcement. "By stacking a pair of capacitors one on top of the other, less space is required for mounting, and a high level of capacitance is achieved."

The company also commercialized the DE6 series type KJ ceramic capacitors aimed at the plug-in hybrid electric vehicle and electric vehicle markets. The company says the new capacitors provide better performance in these applications and notes that other capacitors have potential problems: "[Because] PHEVs and EVs are recharged directly from external power supplies, it is possible that the capacitors that are connected directly to the primary circuits of the vehicle-mounted chargers will be subjected to high-voltage surges from the external power supplies." With this product launch, Murata says it became the first manufacturer to commercialize ceramic capacitors that are designed for these automotive uses and certified under safety standards established to prevent accidents caused by finished products or electronic components.

NEG: Nippon Electric Glass

Nippon Electric Glass develops high-tech glass used in flat panel displays, cellular phones, digital cameras and in emerging products within such areas as kitchen appliances, automobiles, and building materials. The company is engaged in the development of new materials and processes that increase the potential and broaden the applications of high-tech glass. In addition, it is conducting research into nonglass areas such as composite materials and applied thin-film products. In describing its objectives, the company says, "It is our aim to utilize the fusion of material design technology and process technology in our future environmental activities and for the development of new products and technologies."

In August, the company delivered to the Japan Aerospace Exploration Agency ultra-thin lightweight mirrors for use in space-based solar power systems that collect and transmit space-harvested solar energy to a receiving facility on Earth. The mirrors were created using NEG's ultra-thin glass sheet manufacturing and coating technologies.

Earlier this year, in response to the growing demand and regulations for environmentally friendly products, the company developed lead-free glass tubes for encapsulating diodes and other chips. NEG says the new glass is also free of halogen-based substances and antimony, and is capable of low-temperature sealing at a level it says is comparable with conventional lead glass.

INSTITUTES

AIST: National Institute of Advanced Industrial Science and Technology

A public research institution, AIST receives a large portion of its fund-

At AIST, ceramic advances are a significant factor in research across these fields:

AIST 'Base'	Priority Fields of Research
Hokkaido	Biology-related manufacturing technology
Tohoku	Chemical processing technology with low environmental oads
Tokyo Waterfront	Integrated bio-information technology
Chubu	Advanced material processing technology
Kansai	Ubiquitous energy technology; collaboration of engineering and medicine; information technology for embedded systems
Chugoku	Biomass energy technology
Shikoku	Health technology
Kyushu	Production measurement technology; hydrogen energy technology

ing from the Japanese government. Established as an autonomous entity in 2001, it is the successor to organizations whose work in advanced technology dates to 1882. Its approximately 2,400 researchers collaborate with thousands of visiting scientists, postdoctoral fellows and students from Japan and abroad.

In addition to dual headquarters located in Tokyo and Tsukuba, AIST operates more than 40 research units located at research labs (or "bases") that are dedicated to specific priority fields:

The year after AIST gained autonomy, its mesoporous ceramics research group developed a novel ceramic catalyst capable of killing *Escherichia coli* and methicillin-resistant *Staphylococcus aureus*. This ceramic material also is regarded as potentially useful for water decontamination.

AIST has a history of interest in promoting green practices in ceramic manufacture, a topic addressed during a day-long workshop cohosted by the institute in 2004. In 2009, AIST research led to publication of a report that presented a strategy for reducing energy usage in ceramic fabrication. Researchers "investigated low-energy processing techniques for ceramic components … with the goal of realizing new ceramics that can be manufactured using conventional manufacturing processes and equipment at low cost without significant degradation in material properties," the strategy abstract states. "We concluded that a decrease in the amount of organic binder is the most effective technique to promote low-energy processing, and have successfully developed a novel binder technology." Indeed, AIST says this strategy does significantly reduce the amount of energy required for ceramic fabrication.

Interview with Tatsuki Ohji

Prime senior research scientist, National Institute of Advanced Industrial Science and Technology

Q: What is unique about how Japan's private enterprise, government, institutes and academia collaborate on technological advances? What strengths does this create for Japanese ceramic companies in the global market?

A: Since the 1970s, our government has made large investments in a variety of national R&D projects (including the field of ceramic science and engineering), usually with a five- to 10-year time frame for innovative achievements. These government projects have been joined by several private companies, component makers and end manufacturers (sometimes more than 10 individual companies in a single project) as well as by universities and government labs. Some of these projects contained aspects of fundamental science, an area that normally doesn't involve industry researchers

Besides research achievements, one of the benefits of these projects is the growth of networks among the researchers and engineers formed during the projects. These are often useful for efforts even after the project is completed.

However, because of the recent severe financial situation of the Japanese government, the current national R&D projects tend to be of smaller size with shorter terms, and they tend to be more application oriented.

Q: What are Japan's greatest strengths in advanced and fine ceramics in the global market, and which areas of this sector of the industry would benefit most from greater multilateral collaboration?

A: High quality is one of the nation's greatest strengths in ceramic products. Not only is the quality high, it also is reproducible. The properties and performance of ceramic materials and products can be easily affected by slight differences in manufacturing conditions. Therefore, critical control of manufacturing processes is required for ensuring high-quality products. Japanese ceramic producers generally do this relatively well.

Another strength is Japan's capability—via integrating multiple breakthroughs—of developing new products needed for the next-generation's industry and society. An example is diesel particulate filters, which are now widely used in diesel engines to trap particulate matters in the exhaust gas stream. Many of the DPFs used worldwide are produced by Japanese ceramic companies, such as Ibiden Co. and NGK Insulators. And, because of the high combustion efficiency and low carbon dioxide emission of diesel engines, the demand for DPFs is expected to grow.

Q: Which ceramic trends have you been most interested in following, and, of the trends that are just emerging now, which ones do you believe will gain increased dominance in the industry either soon or during the next five years?

A: One of the trends that I have been most interested in is the development of ceramic manufacturing processes that are more eco-friendly, have lower costs and use more-abundant resources.

In particular, environmentally benign manufacturing technologies are a major focus of research and development in the Japanese ceramics industry. Generally two issues are important. One is to avoid unnecessary use and generation of compounds hazardous to the environment. The other is to protect the global environment by conserving energy and natural resources during fabrication and manufacturing. The volumes of consumed raw materials, energy (and emitted carbon dioxide) and wastes are indicative of the sustainability of the process.

In ceramics, a variety of manufacturing technologies have been developed, including low-temperature (or room-temperature) binderless and rapid sintering processes. One example is the development of sintered reaction-bonding processes for producing silicon nitride components, which combines rapid nitridation of silicon and postsintering. It is possible to obtain fine and uniform nitrided compacts with good mechanical properties, by selecting proper sintering additives. The advantages are large energy savings, cheap raw powder and little shrinkage after postsintering. Another example is the New Energy and Industrial Technology Development Organization's R&D project, "Innovative Development of Ceramics Production Technology for Energy Saving (2009–2013)" led by Hideki Kita of AIST. In this NEDO project, new processes—based on technology to join hollow ceramic units—are being developed for producing large-scaled or complex-shaped components used in a variety of industries, including non-ferrous casting and steelmaking as well as liquid-crystal and semiconductor manufacturing. As a result, compared with conventional approaches, major energy savings are expected in addition to high product performance, especially in the areas of lightweight designs, high rigidity, reduced wettability and high thermal insulation.

I also have a particular interest in ceramic integration technology. Because of their unique properties, ceramics tend to be often used as key parts in many products in various fields, such as energy, environment, IT, electronics, bio-industry, transportation and space. This tendency definitely will grow in the future. Thus, adaptive or

Within the past year, research by the ceramic mechanical parts processing group led to the development of a silicon nitride material that maintains its strength even under large thermal changes. Researchers found that dispersion of fine particles of boron nitride results in dramatic improvement in thermal shock resistance. Published results revealed, "The material does not break and its strength does not decline even when repeatedly dropped into room-temperature water after heating to 1,400°C. The material displays identical performance even when used in objects with complex shapes or large sizes."

Tatsuki Ohji, AIST's prime senior research scientist (see below), notes that the institute's ceramics research, frequently conducted in collaboration with private companies and universities, spans structural, biomedical, electronics, energy and environmental applications. He reports that research into tough silicon nitride with very high thermal conductivity is among AIST's most recent achievements.

"This finding shows that silicon nitride, which is a typical structural ceramic, is now the most potential candidate for substrates of future power modules," he says.

Also this year, AIST announced its development of "a technology for direct reforming of a methane-steam fuel at low temperatures by forming a nanometer-scale ceria-based layer as the reforming catalyst on the inner surface of a tubular micro-SOFC with a nickel-based fuel electrode (anode). In addition, for the first time in the world, we have demonstrated the electricity generation by directly reforming the fuel at a low temperature of 450°C."

Synesthesiology, AIST's journal for

innovative approaches that allow the integration of ceramics into products in harmony with other types of materials are critically important issues to maximize or optimize the function of the products. In fact, I recently coedited the book, Ceramic Integration and Joining Technologies (recently published by Wiley and The American Ceramic Society). Many frontline researchers of Japan authored chapters on a variety of topics, such as thermoelectric devices, SOFCs, gas sensors, thermal barrier coatings, microdevices, nanointegration and prosthetic devices.

In terms of fundamental studies, there have been many new trends on emerging science topics. A typical example is the 2008 discovery of iron-based superconductors by Hideo Hosono, a professor at the Tokyo Institute of Technology, which triggered a tremendous amount of related studies. I cannot describe every new trend here, but another topic that has received much attention in the Japanese ceramics community is nanocrystal ceramics. The concept is that nanocrystal particles—whose chemical structure, size, shape, etc., are carefully tailored—can be intentionally arrayed and accumulated to obtain, for example, specific photonic, dielectric, magnetic and piezoelectric properties. A nanocrystal ceramics consortium has been formed by AIST, NIMS, universities and industries, with the goal to collaboratively develop the various technologies necessary for using this material concept.

Q: Rare earths is another issue of growing concern, particularly in Japan. How is this being addressed?

A: Rare earths are becoming indispensable for many parts, products and devices in various advanced industries, but these materials can be mined only in limited regions of the world. Japan currently relies on imports for 90 percent of its rare-earth supply, from China mostly. The increased demand for these materials, or decreased supply, has caused a rapid increase in their prices, producing a large impact on the Japanese industry and economy. To mitigate this, several measures are being taken, including searches for alternative sources in other countries, systematic storage of these materials and recycling from electronic wastes that have significant rare-earth components. On this latter point, although it is estimated that approximately 300,000 tons of rare earths are stored in unused electronics, the recycling is relatively costly and may leave serious environmental consequences if not conducted properly.

Also regarding the rare-earths problem, the Japanese government has initiated several R&D projects. One of them is NEDO's "Rare Metal Substitute Materials Development Project (2008–2013)." The goal is to develop technologies to reduce the quantities of rare earths used or provide alternate materials to replace them. This project focuses on alternatives for iridium for transparent electrodes, dysprosium for rare-earth magnets, tungsten for cemented carbide tools, platinum for exhaust-gas purification, cerium for precision polishing, and terbium and europium for fluorescent bodies. Some of these efforts are closely related to ceramics. The Japan Science and Technology Agency initiated another effort with a similar goal, called the "Element Strategy Project."

Q: Finally, can you comment on which areas the ceramics industry and ceramics technology advances are helping Japan to meet and overcome the challenges that resulted from the events in March?

A: First, I would like to express our sincere appreciation for the enormous and kind help and support that the United States and other countries have provided since the disasters of the 2011 East-Japan earthquake and tsunami, via various routes such as the US Armed Forces' Operation Tomodachi (Friends).

The earthquake and tsunami have brought heavy casualties of around 15,800 deaths, including 4,100 people missing, as well as massive economic impacts. Critical damage also was suffered by the Fukushima Dai-ichi nuclear power station, resulting in failure of cooling systems, nuclear meltdown and severe release of radioactive materials. These major accidents have made the Japanese nation skeptical that our nuclear power reactors are really safe, and many other nuclear reactors throughout the country have been suspended from operation because local authorities refuse permission to restart reactors after safety checks. Because Japan has depended on nuclear power generation for about one-third of its demand, a result is that we face now a severe problem of electrical power shortage. Particularly in summer, when the power demand is the greatest because of the use of air conditioners, substantial restriction of the use of electricity has been applied to the heavy-industrial users.

The March situation has invoked several issues. One is that we are attempting to further reduce electrical energy consumed to produce ceramic products. Again, the energy-saving manufacturing technologies that I have mentioned earlier are of great importance. Another issue is that we have to further increase the efficiency of electrical energy. Ceramics are used as key parts and components in various power generation, storage and conversion systems, such as the thermal barrier coatings for gas turbines. Moreover, they play a role in solar cells, wind turbines, batteries, fuel cells, power devices and power modules. Ceramics also play a substantial role in increasing energy efficiency. So, many have high expectations of ceramic scientists and engineers with regard to these challenges.

In addition, we have had many discussions on what we shall do with nuclear power generation, now and in the future, but it is difficult to go into details of it here. Before March 11, it had been regarded as one of the most potential sources for a steady and economical power supply with no carbon dioxide emission. People now pay more interest to renewable energy sources, including solar power, wind power and geothermal energy, and in August 2011 the Japanese government passed a bill to subsidize electricity from renewable sources. However, it will take a long time for them to become the primary and steady sources.

publishing research papers, was established in 2007 and has an English-language edition. The "Research Results" page of Koyocera's website also offers links to English-language texts of additional studies as well as its "Research Results Presentation Database."

Japan Fine Ceramics Center

The nonprofit Japan Fine Ceramics Center's mission is "to exploit the unlimited possibilities of fine ceramics to develop and vitalize industries." It describes its philosophy as centered on the needs of technology users, and it prioritizes practical, rather than fundamental research. JFCC's research and development activities target such areas of interest as technology infrastructure development and projects for small and medium-sized enterprises. It also targets efforts that promote international cooperation.

"In modern nanotechnology, it is necessary to control atomic structures and electromagnetic properties in nanoscale regions for purposes of creating new materials and devices with a high level of performance," JFCC states in the English-language section of its website. Its goal is "to support manufacturing in nanotechnology by analysis of the functions of atomic structures and nanoscale regions, and by clarifying structures for manifestation of physical properties."

Research and development activity at JFCC spans microstructure analysis, energy, ecology, electronics and information, carbon nanotube, safety and biomaterials, and evaluation and analysis. Some examples of its focuses are

- Electron microscopy and its application to nanotechnology;
- High-efficiency ceramic membranes for high-temperature separation of hydrogen;
- Preparation of specimens of microporous ceramic membranes for high-resolution electron microscopy;
- Precise measurement of electric field-induced distortion in piezoceramics; and
- Development of machining techniques for ceramics.

In addition, JFCC engages in technical consulting in a variety of topics, techniques and fields, "from investigation of product defects to assistance in developing materials."

NIMS: National Institute for Materials Science

NIMS is Japan's only independent administrative institution dedicated to materials science. It is charged with responsibility for achieving "policies laid out by the Japanese government in the [national] Science and Technology Basic Plan." It engages in research that uses nanotechnology to produce new materials and discover higher functions for metals, ceramics, organic materials and biomaterials.

Japan ceramics & glass directory

BUSINESSES

The following information provides a partial overview of the scope and breadth of activities within the Japan ceramics industry. It includes profiles of prominent research and manufacturing organizations plus contacts to assist networking within the country.

AGC: Asahi Glass
Www.agc.com/english/index.html
1-5-1, Marunouchi, Chiyoda-ku, Tokyo, 100-8405
Kazuhiko Ishimura, president & CEO
AGC's English-language "Contact Us" page includes links for email inquiries specific to each of its lines of business: www.agc.com/english/mail_box/

Ariake Materials Co.
www.ariake-materials.co.jp/index_e.html
3-3-3 Toyosu, Koto-ku, Tokyo, 135-6006
Phone: 81-3-5560-2113
Fax: 81-3-5560-2192

Central Glass Co.
www.cgc-jp.com/

Denki Kagaku Kogyo KK
Www.denka.co.jp/eng/top.htm
Shinsuke Yoshitaka, president

FDK Corp.
www.fdk.com/
Hamagomu Bldg., 5-36-11 Shimbashi, Minato-ku, Tokyo, 105-8677
Phone: 81-3-3434-1271
Fax: 81-3-3434-1375

Hitachi
Global Www.hitachi.com/

Ibiden Co.
www.ibiden.com
2-1, Kanda-cho, Ogaki, Gifu 503-8604
Phone: 81-584-81-3111
Ibiden says its primary businesses are electronics- and ceramics-related. Its ceramic products include speciality carbon products and diesel particulate filters.

IHI Aerspace Co.
www.ihi.co.jp/ia/en/index.html
Phone: 81-3-6204-7232
Fax: 81-3-6204-8689

INAX
http://global.inax.lixil.co.jp/
INAX is a keystone of LIXIL Corporation, one of Japan's leading manufacturers of tiling, building materials and sanitary fixtures for residential, commercial and public buildings and facilities. The company says it "looks to create ambience through a distinct vision, texture and form that is based on the company's origins and historical craft aesthetics. This essence is not simply a design that suggests or uses Japanese motifs; it is a contemporary expression of a time-honed and honored artisan vision that is borderless, which we call Beaux Japonica."

Kanto Chemical Co.
www.kanto.co.jp/english/
2-1, Nihonbashi Muromachi 2-Chome, Chuo-ku, Tokyo,103-0022
Phone: 81-3-6214-1050
Fax: 81-3-3241-1007

Konoshima Chemical Co.
www.konoshima.co.jp/en/index.html
80 Koda, Takuma-cho, Mitoyo-city, Kagawa, 769-1103
Phone: 81-875-83-3155
Fax: 81-875-83-8188

Koyo-Sha Co.
www.koyo-sha.co.jp/e/index.html
Koyo-Sha Bldg. 9th Floor, No.48-5, Higashi Nippori 5-Chome, Arakawa-ku, Tokyo, 116-0014
Phone: 81-3-3805-8375 (International Business Div.)
Fax : 81-3-3805-8369

Krosaki Harima Corp.
www.krosaki.co.jp/english/
1-1, Higashihamamachi, Yahatanishi-ku, Kitakyushu City, Fukuoka 806-8586
Phone: 81-93-622-7224
Fax: 81-93-622-7200

Kyocera
http://global.kyocera.com/
6 Takeda Tobadono-cho, Fushimi-ku, Kyoto, 612-8501
Phone: 81-75-604-3416
Fax: 81-75-604-3516
Tetsuo Kuba, president

Mino Yogyo Ceramic Co.
www.mino-ceramic.co.jp/english/index.html

Murata Manufacturing Company, Ltd.
www.murata.com/index.html
10-1, Higashikotari 1-Chome, Nagaokakyo-shi, Kyoto, 617-8555
Phone: 81-75-951-9111
Tsuneo Murata, president

NEG: Nippon Electric Glass
www.neg.co.jp/EN/
7-1, Seiran 2-Chome, Otsu, Shiga, 520-8639
Phone: 81-77-537-1700
Fax: 81-77-534-4967
Masayuki Arioka, president

Nippon Crucible Co.
www.rutsubo.com/
1-1, Higashihamamachi, Yahatanishi-ku, Kitakyushu City, Fukuoka 806-8586
Phone: 81-3-3443-5551
Fax: 81-3-3443-5191

Among NIMS priorities is advanced materials research and development that responds to Japan's social needs. To that end, its goal is "To reduce loads on the environment and build a safe, secure society, and to conduct materials research that produces environmental and energy materials with economic and social value, and secures high reliability and safety."

Sukekatsu Ushioda, who became president of NIMS in 2009, has a strong connection to the scientific community in the US. He completed his undergraduate studies at Dartmouth College and his MA and PhD at the University of Pennsylvania. He also was on the faculty at the University of California, Irvine, for 16 years. In a statement issued when he accepted his position, Ushioda distinguished NIMS from universities in that its "primary mission is to execute national policies in the area of materials science research," and to conduct research that helps to meet Japan's national requirements. "At the same time it is imperative that we minimize the effects of human activities on the global environment," he said. "Thus we must plan a research strategy to minimize negative effects on the global environment."

In 2009, NIMS announced successful atomic-level three-dimensional tomography of a stabilized zirconia-spinel nanocomposite. Its announcement noted that this "demonstrated that the 3D atom probe technique can be employed to obtain 3D atomic tomography of even insulating ceramics. This work will trigger applications of the 3DAP technique in nanoscale analyses of a wider variety of inorganic materials."

NIMS' Nano Ceramic Center is dedicated to research into "functional and/or multifunctional ceramics with novel optical, electric, dielectric, magnetic, thermal, chemical and/or mechanical properties," says managing director Yoshio Sakka. "For this purpose, we are developing several types of nanoparticle processing originally discovered at NIMS and are investigating novel techniques of evaluation and design of grain-boundary nanostructures."

NIMS projects include work on

• Fabrication of highly structured controlled ceramics through nanoparticle processing in the liquid phase;

• Processing for functional ceramics by nanomolecular mixing;

• Synthesis of fine nitride particles for optical applications;

• Development of multifunctional oxide ceramics by designing grain-boundary nanostructures;

• Synthesis of functional ceramic nanoparticles through controlled reactive thermal plasma processing; and

• Development of nanostructures through design and modification of nanopores on anodic oxide films.

Nippon Rotary Nozzle Co.
www.rotarynozzle.jp/
2-2-1, Otemachi, Chiyodai-ku, Tokyo 100-0004

NGK Spark Plug
www.ngkntk.co.jp/english/index.html
4-18, Takatsuji-cho, Mizuho-ku, Nagoya, 467-8525
Phone: 81-52-872-5915
Fax: 81-52-872-5999
Shinichi Odo, president and CEO

NGK's products include sensors, electronic components, industrial components, spark and glow plugs, semiconductor components, medical products and cutting tools. In the latter category, its ceramic grade product(s) are described as "a thermally and chemically stable tool material with a high level of hardness, and it has a compact and fine organization that consists mainly of high-purity alumina." It is used to cut tube scarfings; for lathe-turning of normal cast iron and materials with a high level of hardness; and for finish-cutting of normal cast iron and ductile cast iron.

Nihon Yamaura Glass Co.
www.yamamura.co.jp/english/index.html

Nippon Light Metal Co.
www.nlmetal.com/
Tennozu Yusen Bldg., 2-2-20 Higashi-Shinagawa, Shinagawa-ku, Tokyo, 140-8628
Phone: 81-3-5461-9211

Nippon Steel
www.nsc.co.jp/en/
6-1, Marunouchi 2-Chome, Chiyoda-ku, Tokyo, 100-8071
Phone: 81-3-6867-4111
Fax: 81-3-6867-5607

Noritake Co.
www.noritake-elec.com/

Shinagawa Refractories Co.
www.shinagawa.co.jp/English/index.html
2-1 Otemachi 2-chome, Chiyoda-ku, Tokyo 100-0004
Phone: 81-3-6265-1606
Fax: 81-3-6265-1616
Yoshihiko Shimizu, president

Shoei Chemical Inc.
www.shoeichem.co.jp/english/company/index.html
Shinjuku Mitsui Bldg., 1-1 Nishi Shinjuku 2-Chome, Shinjuku-ku, Tokyo, 163-0443
Phone: 81-3-3344-6662
Fax: 81-3-3344-6657
Eiichi Asada, president

Shoei Chemical's work in the development and manufacture of electronic materials focuses chiefly on conductive pastes, resistive pastes, dielectric pastes, and powders for use in electronic devices and components. Founded in 1956, the company's first product was conductive paste made from fine silver powder for use in ceramic disk capacitors. Since then, its new product development has generated more than 100 patents in Japan and abroad.

Today, its research efforts are responding to the growing cross-industry demand for electronic components whose sub-micron and nano dimensions deliver miniaturization and higher performance.

Taiko Refractories Co.
www.taiko-ref.com/index-e.html
Phone: 81-93-871-1631
Fax: 81-93-883-2151
Hiroshi Kobayashi, president

TDK Corp
www.global.tdk.com
1-13-1, Nihonbashi, Chuo-ku, Tokyo 103-8272
Phone: 81-3-3278-5111

TDK says it is basically a ceramics company and a process technology company that uses expertise in ceramics. It notes that it was the first company in the world to commercialize ferrites and that it is a core technology. "TDK's strength is in using its entire manufacturing capacity to turn the ferrite material into electronic components."

Toyota Central R&D Labs
www.tytlabs.co.jp/eindex.html
41-1, Aza Yokomichi, Oaza Nagakute, Nagakute-cho, Aichi-gun, Aichi-ken, 480-1192
Shoichiro Toyoda and Masatami Takimoto, CEOs

Established in 1960, Toyota Central R&D Labs Inc. are engaged in basic research in a variety of fields, including resource conservation, energy conservation, environmental preservation and safety so that, in the words of company president Takashi Saito, "we may create a sustainable society."

The enterprise's research activities fall under four categories: environment, energy, and power train; materials and processing technology; information, safety and comfort, and electronics; and research fundamental technologies.

Toyota Technical Institute
www.toyota-ti.ac.jp/english/index-e.htm
2-12-1 Hisakata, Tempaku-ku, Nagoya, 468-8511
Phone: 81-52-802-1111

World Lab Inc.
www.tokushinkai.or.jp/english/wl/
3-2-25 Miyuki-cho, Akiha-ku, Niigata-city, Niigata, 956-0023
Phone: 81-250-23-2009
Fax: 81-250-25-2444

Yageo Corp.
www.yageo.com/portal/index.jsp
16th Namiki Building, 3F, 4-116-1, Miya-cho Omiya-ku, Saitama, 330-0802
Phone: 81-48-795-8953
Fax: 81-48-795-8954

NIMS also participates in joint graduate school programs with Tsukuba University and Hokkaido University.

New Glass Forum/Japan Glass–Industry Center

The New Glass Forum's mission is to promote information exchange among professionals in high-tech glass ("new glass"), industries and the businesses they serve. In pursuing that mission, it hopes to contribute to further development of those industries and to worldwide improvements in standards of living and prosperity. NGF was established as a nonprofit organization in 1985 through Japan's Ministry of International Trade and Industry to work with companies that manufacture or use glass, as well as with academic and institutional researchers.

Besides conducting technical research, NGF disseminates the results of studies and surveys on broader topic areas, such as human resources development and training, and developing data on industrial standardization.

NGF also led the construction of the International Glass Database System. INTERGLAD Ver. 7, which was released in Japan during 2009 and worldwide in October 2010, contains data on properties and structural features of approximately 300,000 types of glasses.

The Ministry of Economy, Trade and Industry also commissioned NGF to oversee the Nanotechnology Glass R&D Project, an effort launched "to create objects of the nanometer size different from the matrix, that is the atomic or molecular level to the virus-sized level, in the amorphous material glass and thereby create glass having completely new functions never before obtained from glass alone," NGF explains.

Nanotechnology Glass Project says its work can be "classified as belonging to following four fields:

- Optical technology products, such as 3D optical circuit devices for future optical computers;
- Products for ultrathin plasma televisions, computer screens, reuseable cups and bottles;
- Biomedical products to trap endocrine disruption chemicals and separate out harmful gases; and
- Substrates for ultra-high performance DNA analysis chips.

The nanotechnology project has also helped its staff gain expertise in the use of femtosecond lasers, the use of super-high pressure processing, plasma etching, chemical vapor deposition, sputtering and other thin film forming systems.

Additional research underway at NGF include projects related to conjugate materials, glass melts, and high-efficiency processing technology for 3D optical devices.

Looking ahead

Japan has an extensive history with ceramics and glass, and the groups detailed above represent only a fraction of all of the businesses, schools and institutions that have a significant impact on ceramics and glass there. Serious challenges lay ahead, from the recovery from the effects of the earthquake and tsunami to ensuring supplies of strategic raw materials to coping with an aging population. But Japan has remained an international leader in ceramics and glass fields for decades because it has maintained a remarkable ability to turn challenges into opportunities. It is evident that Japanese business, government, universities and laboratory investigators are maintaining a strong commitment to strategic planning, cooperation and collaboration, and the nation's leadership is poised to continue in the materials science and technology sectors for decades to come. ■

Japan ceramics & glass directory, continued

INSTITUTES

Aichi Institute of Technology
www.aitech.ac.jp/~english/
1247 Yachigusa, Yagusa-cho, Toyota, 470-03
Phone: 81-565-48-8121
Fax: 81-565-48-0277

AIST: National Institute of Advanced Industrial Science and Technology
www.aist.go.jp/index_en.html
Tokyo Headquarters: 1-3-1 Kasumigaseki, Chiyoda-ku, Tokyo, 100-8921
Phone: 81-3-5501-0900
Tsukuba Headquarters: 1-1-1 Umezono, Tsukuba, Ibaraki, 305-8568
Phone: 81-29-861-2000
Tamotsu Nomakuchi, president

Ashikaga Institute of Technology
www.ashitech.ac.jp/ehome/
268-1 Omae-cho, Ashikaga City, Tochigi, 326-8558
Phone: 81-284-62-0605

Ceramics Society of Japan
www.ceramic.or.jp/index.html
2-22-17 Hyakunin-cho, Shinjuku-ku, Tokyo, 169-0073
Phone: 81-3-3362-5231
Fax: 81-3-3362-5714
Shuichi Sarasawa

Chiba Institute of Technology
www.it-chiba.ac.jp/english/
Tsudanuma Campus: 17-1, Tsudanuma 2-Chome, Narashino, Chiba, 275-0016
Shibazono Campus: 1-1, Shibazono 2-Chome, Narashino, Chiba, 275-0023

Exploratory Nanomaterials Research Lab
www.nims.go.jp/eng/index.html
1-2-1 Sengen, Tsukuba-city, Ibaraki, 305-0047

Fukuoka Institute of Technology
www.fit.ac.jp/EN/
3-30-1 Wajiro-higashi, Higashi-ku, Fukuoka, 811-0295.
Phone: 81-92-606-3131
Fax: 81-92-606-8923

Japan Fine Ceramics Association
www.jfca-net.or.jp
6th Floor, Halifax Onarimon Building, 3-24-10 Nishi-Shinbashi, Minato-ku, Tokyo, 105-0003
Phone: 81- 3-3437-3781
Fax: 81- 3-3437-3790
Yumi Akimoto, president

Japan Fine Ceramics Center
www.jfcc.or.jp/en/
2-4-1 Mutsuno, Atsuta, Nagoya, 456-8587
Phone: 81-52-871-3500
Fax: 81-52-871-3599
Tanemura Sakae, executive director

Japan Ultra-High Temperature Materials Research Institute
www.jutem-gifu.jp/index3.html
3-1-8 Higashimachi, Tajimi-shi, Gifu, 507-0801
Phone: 81-572-25-5380
Fax: 81-572-21-1045

Kanagawa Institute of Technology
www.kait.jp/english/
1030 Shimo-ogino Atsugi, Kanagawa, 243-0292
Phone: 81-46-291-3313

Japan ceramics directory

Kitami Institute of Technology
www.kitami-it.ac.jp/old/eng/index.html
165 Koen-cho kitami, Hokkaido, 090-8507
Phone: 81-157-26-9370
Fax: 81-157-26-9373

Kyoto Institute of Technology
www.kit.ac.jp/english/
Matsugasaki, Sakyo-ku, Kyoto, 606-8585
Phone: 81-75-724-7128
Fax: 81-75-724-7710

Muroran Institute of Technology: OASIS
www.muroran-it.ac.jp/index-e.html
27-1 Mizumoto-cho, Muroran, 050-8585

Nagoya Institute of Technology
www.nitech.ac.jp/eng/
Gokiso-cho, Showa-ku, Nagoya, Aichi, 466-8555

NIMS: National Institute for Materials Science
www.nims.go.jp/eng/
1-2-1 Sengen, Tsukuba-city, Ibaraki, 305-0047
Phone: 81-29-859-2000
Fax: 81-29-859-2029
Sukekatsu Ushioda, president

NIMS Nano Ceramic Center
www.nims.go.jp/eng/units/p02_nano-ceramics.html
1-2-1 Sengen, Tsukuba-city, Ibaraki, 305-0047

New Glass Forum/Japan Glass-Industry Center
www.newglass.jp/c2e.shtml
3-21-16, Hyakunin-cho, Shinjyuku-ku
Tokyo 169-0073
Phone: 81-3-6279-2605
Fax: 81-3-5389-5003

Research Center for Advanced Science and Technology
www.rcast.u-tokyo.ac.jp/en/
4-6-1 Komaba, Meguro-ku, Tokyo, 153-8904

Shizuoka Institute of Science and Technology
www.sist.ac.jp/en.html
2200-2 Toyosawa, Fukuori, Shizuoka, 437-8555
Phone: 81-538-45-0111
Fax: 81-538-45-0110

The Technical Association of Refractories, Japan
www.tarj.org
New Ginza Bldg.,7-3-13,Ginza, Chuo-ku, Tokyo 104-0061
Phone: 81-3-3-3572-0705
Fax:81-3-3-3572-0175
Tsuneo Kayama, president

UNIVERSITIES

Kyoto University
www.kyoto-u.ac.jp/en
Nishikyo-ku Kyoto 615-8510
Phone: 81-75-383-2408
Fax: 81-75-383-2410
Hiroshi Matsumoto, president

Kyoto University's materials science department offers a course of study that covers inorganic, organic and polymer materials. Rising interest in ceramic materials has prompted an increase in the university's ceramic and glass labs. Professor Kazuyuki Hirao, an ACerS Fellow, says, "I am now working on developing flexible glass materials for solar cell applications. Lithium-ion battery and fuel cell research is also increasing, which is especially important due to the loss of some our nuclear power stations. We know that ceramic materials have great promise in the energy fields."

NUT: Nagaoka University of Technology
http://voice.nagaokaut.ac.jp/
1603-1, Kamitomioka, Nagaoka, Niigata, 940-2188
Phone: 81-258-46-6000
Niihara Koichi, president

NUT's inorganic materials engineering group focuses on three areas of study. Its coursework in the development of new glasses and glass-ceramics covers photogenic crystals, superconducting glasses-ceramics, non-linear optical glasses, and computer simulation for glass structure. The curriculum also includes the study of reconstruction and re-examination of ceramic manufacturing processes through novel characterization methods. Classes also provide students with training in the fabrication of metal chalconide and metal oxide films used for opto-electronics devices and quantum chemical simulation for ceramics science.

Nagoya University
www.nagoya-u.ac.jp/en/
Furo-cho, Chikusa-ku, Nagoya, 464-8601
Phone: 81-52-789-51111
Michinari Hamaguchi, president

National Defense Academy of Japan
www.mod.go.jp/nda/index-e.html
Hashirimizu 1-10-20 Yokosuka-shi, Kanagawa, 239-8686
Phone: 81-468-41-3810
Makoto lokibe, president

The Academy was established to educate and train future officers in the three branches of Japan's military forces. However, its course of study focuses on academic education rather than military training. Its Department of Materials Science and Engineering curriculum covers basic and specialized knowledge of materials science and seeks to "advance the understanding and application of scientific principles."

Ryukoku University
www.ryukoku.ac.jp/english2/
Fukakusa Campus: 67 Tsukamoto-cho, Fukakusa, Fushimi-ku, Kyoto, 612-8577
Phone: 81-75-645-7898

Seta Campus: 1-5 Yokoya, Seta Oe-cho, Otsu, Shiga, 520-2194
Phone: 81-77-543-5111

Omiya Campus: 125-1 Daiku-cho, Shichijo-dori, Omiya Higashi-iru, Shimogyo-ku, Kyoto, 600-8268
Phone: 81-75-343-3311
Tesshin Akamatsu, president

Opened in 1639 as a Buddhist institution of higher education, Ryukoku University gained its contemporary name and university status in 1922. Although it continues to offer many courses of study related to Buddhism and philosophy plus Japanese history, language and literature, today's university also offers extensive undergraduate and graduate level programs in science and technology fields. Areas of focus include materials chemistry, electronics and informatics and environmental solution technology.

Tama Art University
www.tamabi.ac.jp/english/dept/cr.htm
Department of Ceramic, Glass and Metal Works
Phone 81-42-679-5651
Tama Art University's Department of Ceramic, Glass and Metal Works is dedicated to preserving the tradition of handcrafted ceramic art. Its mission is to "promote an awareness of the importance of individually-crafted works in everyday life." Students enrolled in the program complete a course of study that covers the characteristics of ceramics, glass and metals plus the basic processes for treating each material."

Tohoku University
www.wpi-aimr.tohoku.ac.jp/en/index.php
Phone: 81-22-795-6417
Akihisa Inoue, president

Tohoku University's WPI Advanced Institute for Materials Research is an international research center dedicated to the creation of new materials that promote sustainable development in Japanese industry. In keeping with that mission, in October 2007, it established the Advanced Institute for Materials Research, which is dedicated to four fields of study: bulk metallic glass, nanophysics, nanochemistry/biology, and device/systems construction.

Tokyo Institute of Technology
www.titech.ac.jp/english/

Center for Public Information
2-12-1 Ookayama, Meguro-ku,Tokyo 152-8550
Phone: 81-3-5734-2975
Fax: +81-3-5734-3661

Ookayama Campus: 2-12-1 Ookayama, Meguro-ku, Tokyo, 152-8550

Suzukakedai Campus: 4259 Nagatsuta-cho, Midori-ku, Yokohama, Kanagawa, 226-8503

Tamachi Campus: 3-3-6 Shibaura, Minato-ku, Tokyo, 108-0023
Kenichi Iga, president

The Tokyo Institute of Technology's department of metallurgy and ceramics science offers programs of study in the science and engineering of inorganic materials, including metals and alloys, ceramics, intermetallics, and semiconductors. Its curriculum covers such topics as manufacturing processes, fundamental mechanisms of material properties and applications of materials to electronics, mechanics, aerospace and other engineering fields.

University of Tokyo
www.u-tokyo.ac.jp/index_e.html
Contact: www.u-tokyo.ac.jp/public/contact_e.html
Junichi Hamada, president

University of Tsukuba
www.tsukuba.ac.jp/english/
Tenodai 1-1-1, Tsukuba, Ibaraki, 305-8571
Phone: 81-29-853-7296
Fax: 81-29-853-7296
Nobuhiro Yamada, president

The University of Tsukuba offers both a Materials Science and Materials Science and Engineering. The Masters and Doctoral Program in Materials Science uses experimental and theoretical methods at microscopic to atomic levels to propel research into the structures, methods of synthesis, physical and chemical properties, and potential applications of various novel and innovative materials. The Material Science and Engineering program is helpful to develop materials IT and telecommunications, construction, transportation, energy, environment and medicine.