bulletin | cover story

Israel—Middle East Mavericks

In Israel, a small-scale country with big ambitions finds ways to make its mark on ceramic innovation.

By Alex Talavera and Randy B. Hecht

Bootstrap origin stories have become a staple of the corporate history of many of the biggest names in the tech sector today. Ever since Bill Gates started Microsoft in his father's garage, we have been in love with the idea of the micro-entrepreneur who starts from close to zero and builds a technology empire.

A look at the ceramic industry in Israel presents us with an entire country in that startup–upstart mode. Its population is still more than a decade away from hitting the 10 million mark, and its human capital for ceramic ventures is constrained. But by courting bilateral strategic partnerships and recruiting industry talent from abroad, Israel is determined to advance toward ambitious goals in ceramic research, development, and commercialization.

It is working on adding to its home-grown talent, as well. A government report (www.mfa.gov.il) based on Central Bureau of Statistics data found that between the 1989–1990 and 2011–2012 academic years, higher education enrollment rose from 88,800 students to 306,600 students. But the report noted that the most common courses of undergraduate study are in the humanities and social sciences. Graduate students gravitate toward the humanities, business, and management; only at the doctoral level do natural sciences and mathematics predominate.

There also is a gender gap, the report found, and one that some might find surprising: 66 percent of women will pursue an undergraduate degree, as opposed to just 53 percent of men. Perhaps with that in mind, the government is actively promoting women's increased participation in STEM research and development via the Ministry of Science and Technology's Council for the advancement of Women in Science and Technology. Its work extends to Israeli cross-border efforts with the European Union.

For now, from universities and research institutes to commercial enterprises, if Israel were dependent exclusively on domestic human resources, it would be too short-staffed to achieve its science and technology ambitions.

To address the labor shortage, the government has made a public commitment to doubling high tech employment over the next decade. In its 2017 annual report (www.economy.gov.il), the Israel Innovation Authority noted that just 8.3% of salaried employees work in the technology sector and set a target of 500,000 technology employees by 2027. Among the strategies outlined in the report: "Expanding spheres of employment in hi-tech, including integration of women, members of the Arab sector and Ultra-orthodox Jews in the workforce, along with veteran engineers above the age of 45."

Military and market might

But there is another factor constraining research, development, and commercialization in technology in general and ceramics in particular: the demands and priorities of the well-financed defense sector. The CIA World Factbook notes that military expenditures represent 5.62 percent of Israel's GDP.

"The Israeli market is quite small," says the Israel Ceramic & Silicate Institute's (ICSI) Zvi Cohen. "And the defense and military industry takes quite a large percentage of the usage of ceramic material. For civilian uses, it is much lower, and usually it is targeted for abroad and not for the Israeli market."

To the extent that research activities are always influenced by the funding available to support them, this focus on defense is felt even at the academic level. Prof. Shmuel Hayun of the Department of Materials Engineering at Ben-Gurion University of the Negev reflects on the programmatic impact of what the funders want to finance.

"One of the major things that I'm working on since my master's degree is armor-based materials such as boron carbide," he says. "This stems from the need of the Department of Defense in Israel." The project was launched more than 20 years ago by his former advisors, Professors Moshe Dariel and Nachum Frage. Hayun and Frage are still working on it.

"After we developed new materials and new methods, we shared that with the industry," he adds. "So it came from the need, and it goes to industry." (See Figure 1 from Hayun's article, "Reaction-bonded boron carbide for lightweight armor: The interrelationship between processing, microstructure, and mechanical properties," *ACerS Bulletin*, August 2017.)

ICSI has also been involved in research and development that has its roots in defense requirements, although again, these can ultimately have civilian applications, as well. "We have a few products in the field of ballistic protection, mainly based on boron carbides and a little bit on silicon carbides," Cohen says. "For optical requirements, there are a few embedded products that we developed and designed. And in the field of piezoelectrics, there are companies that use our design, our formula. So there are quite a lot of products that you can find in security or military applications, and on the civilian side there are also some."

Figure 1. A BorLite reaction-bonded boron carbide armor plate, manufactured by Paxis Ltd. (Savion, Israel), after impact with 7.62X63 AP M2 projectiles. (Image from *ACerS Bulletin*, August 2017)

3-D printing pioneers

Although additive manufacturing only captured popular attention relatively recently, 3-D printing has a history in Israel that dates to 1985, which saw the birth of one of the pioneers in the field, a company called Cubital.

Haim Levi was a member of one of the first Israeli teams to develop a 3-D printing system (Figure 2). Today, he is vice president responsible for the manufacturing and defense industries at XJet (10 Oppenheimer St. Science Park, Rehovot 7670110, Israel), which developed a proprietary technology for ceramic and metal additive manufacturing using liquid materials rather than powders.

The company's founder, Hanan Gothait, is a serial entrepreneur in additive manufacturing whose previous launches include Objet Geometries, which introduced the world's first polymer jetting technologies and photopolymer 3-D printing systems. It later merged with Stratasys. "So we are here for many years, and we know the technology inside out," Levi says.

The company, which holds 80 patents, has had a global focus from the outset, in part because the Israeli market is so small, but also because additive

Credit: XJet

Figure 2. XJET Carmel 1400 additive manufacturing system.

manufacturing as an industry tends to think globally. As Levi's title suggests, Xjet develops solutions that meet defense and manufacturing requirements simultaneously. The technology and materials are the same, although applications "vary quite significantly," he says. "Nevertheless, we did not develop anything targeted to any specific market."

As with the technology overall, additive manufacturing for ceramics delivers value in making short runs and eliminates the need for molding or other high-level investments in creating parts. It also removes limitations on geometries. "We can create any geometry that the designer can think of, and in certain cases, we can even make geometries that could not be manufactured with traditional technologies," Levi says. The end result is increased freedom of design relative to traditional manufacturing techniques.

XJet's use of liquid rather than powder eliminates the risk of explosion or fire. Its technology also "works in absolutely normal conditions," Levi says, meaning that there is no need for inert gas, high temperature, pressure, or a vacuum.

The third advantage is high productivity. "We aim at smaller parts with high complexity and highly detailed parts, very accurate parts. Because we work with nanoparticles in very, very thin layers, like 8 microns, it allows us to reach almost fully near net shape result of the production," he says. "There is very little post-production needed. This is extremely important because machining ceramic parts is pretty tough and can be done only with diamond tools, which is quite expensive and requires a lot of know-how. We are coming very close to the final size and shape of the part in our geometry."

Another innovation is use of a material for support that "fills out the whole part, internal and external, and thus provides support for the next layer, layer by layer," Levi says. "By the end of the process, it fills out all the internal voids, cavities, overhangs, and undercuts without being restricted by requirements of support structures. This is a huge benefit, because it means freedom of design. On top of that, there is no need to clean out the supports manually like in other technologies because we dissolve it."

The company has been using zirconia but intends to expand its portfolio of ceramic materials next year. "We're definitely looking for sources of raw materials that will go into the liquid," Levi says. "We are big believers in ceramics in general, and in additive manufacturing within ceramics in particular. We believe there is a big future for that."

For additional information about Israeli work in additive manufacturing, see the profile of Nano Dimension in the directory.

Technion – Israel Technology Institute in Haifa.

Nanotechnology knowledge base

Israel has targeted nanotechnology as a driver of market growth and is committing resources to its economic development. Early-stage Israeli companies abound in the sector. According to the Israel National Nanotechnology Initiative (INNI), whose board is appointed by the Ministry of Economy's Chief Scientist, Israel has "the third largest concentration of startup companies in the world" in the nanotechnology space, outpaced only by Silicon Valley and Boston's technology corridor. (See the directory for more information regarding INNI.)

The program at the NANO.IL. 2018 Congress, held October 9–11, at Jerusalem's International Conference Center, covered a broad spectrum of nano topics, from bio-nano materials, fabrication, mechanics, and tribology to nano-material synthesis and characterization. Sessions were devoted to applications for the defense, nano-electronics, and energy industries, and featured plenary speakers attended from major universities and institutes in the United States and Europe as well as organizations in Israel.

And all is not in a fledgling state in Israel's nano-universe. In early 2018, Technion (Israel Technology Institute) and the Israel Space Agency announced plans to launch the world's first nanosatellite formation. The three nanosatellites (each about the size of a shoebox) are to be launched by Innovative Solutions in Space—a Dutch company—and will orbit in controlled formation for one year.

In May, the United Nations International Iberian Nanotechnology Laboratory and Bar-Ilan University's Institute of Nanotechnology and Advanced Materials (BINA) announced a research and cooperation agreement. And in keeping with its objective of introducing scientific concepts to the general public, BINA is planning the launch of the Joseph Fetter Museum of Nanotechnology. It intends to offer exhibits that make researchers' work "come to life at the hands of artists, designers, and visionaries." Guidelines for artworks submitted for consideration may be found online at https://www.drive.google.com/file/d/1l_c19lEMwR8J6mEW-UaRmZT_4Zv3GK9C/view.

MARKET SNAPSHOT

Cross-border competitor

With a small population and big tech ambitions, Israel relies on foreign partners in R&D and commercialization

By Alex Talavera and Randy B. Hechtt

May 14, 2018, marked 70 years since Israel's founding. According to the Central Bureau of Statistics, the population was 806,000 that year, and it grew at an average rate of 3.8 percent from then through 2007. The agency projects that the population will reach 10 million by 2030. Metropolitan areas are home to 92.4 percent of the population, which is projected to continue the urbanization trend at a pace of 1.64 percent annually from 2015 to 2020, according to the CIA's World Factbook.

Despite that growth, Israel's population has not kept pace with the demand for science and technology research, development, and commercialization. The labor force totaled 4.02 million in 2017; services employed 81.6 percent, followed by industry (17.3 percent) and agriculture (1.1 percent). While the 2017 unemployment rate was just 4.3 percent, down from 4.8 percent in the previous year, 22 percent of the population lives below the poverty line of $7.30 a day.

Calculated in 2017 dollars, Israel has seen its GDP rise from $294.5 billion in 2015 to $306.1 billion in 2016 and $315.6 billion in 2017, the World Factbook reports. This translates to growth rates of 2.6 percent, 4 percent, and 3.1 percent, respectively, for those years. Per capita GDP, again calculated in 2017 dollars, was $35,200 in 2015, $35,800 in 2016, and $36,200 in 2017. (All figures are purchasing power parity GDP.)

Services, industry, and agriculture generated 69.5 percent, 26.6 percent, and 2.3 percent, respectively, of GDP in 2017, and the industrial production growth rate was 4 percent. Leading industries include high-technology products (notably aviation, communications, computer-aided design and manufacture, medical electronics, and fiber optics), wood and paper products, potash and phosphates, food, beverages, and tobacco, caustic soda, cement, pharmaceuticals, construction, metal products, chemical products, plastics, cut diamonds, textiles, and footwear.

Israel operates at a trade deficit, with $60.6 billion in exports against $66.76 billion in imports for 2017. Leading commodities include machinery and equipment, software, cut diamonds, agricultural products, chemicals, textiles, and apparel on the export side and raw materials, military equipment, investment goods, rough diamonds, fuels, grain, and consumer goods on the import side. The United States is Israel's largest trading partner for both imports and exports, followed by the United Kingdom, Hong Kong, China, and Belgium (exports) and China, Switzerland, Germany, the United Kingdom, Belgium, the Netherlands, Turkey, and Italy (imports).

Additional details and export support are available via the Export.gov Israel Country Commercial Guide, the Israel-America Chamber of Commerce, the U.S.–Israel Business Initiative, and Business Israel, a project of the U.S. Chamber of Commerce. There are also geographically specific opportunities, such as the Israel-Florida Innovation Alliance, a joint venture of the Israel Innovation Authority and StartUp Nation Ventures LLC., which is based in Florida.

Ceramic sector trade programs and opportunities

There are also resources for bilateral research collaboration and joint ventures specific to science and even to ceramics in particular. The United States–Israel Binational Science Foundation has granted $600 million to 5,000 research projects since its inception in 1972. It funds the Joint Program in Ceramics in partnership with the National Science Foundation.

As described on the Hebrew University of Jerusalem website, the program "supports fundamental scientific research in ceramics (e.g., oxides, carbides, nitrides and borides), glass-ceramics, inorganic glasses, ceramic-based composites and inorganic carbon-based materials…Research to enhance or enable the discovery or creation of new ceramic materials is welcome. Development of new experimental techniques or novel approaches to carry out projects is encouraged."

See the directory entries for the Israel Innovation Authority and Israel National Nanotechnology Initiative for further trade resources, including databases of Israeli researchers and companies, a partner matching service, a list of calls for proposals, and a page dedicated to resources for strategic initiatives between Israeli entities and companies in the Americas. ■

Source: CIA World Fact Book

And the Nano-Fabrication center at Ben Gurion University's Ilse Katz Institute for Nanoscale Science & Technology provides support to the academic, industrial, and governmental sectors. The "R&D and prototype fabrication infrastructure" is suited to "Nano/Microelectronics, BioMEMS, BioChip, Microfluids, Multielectrode array, Nanophotonics and Optoelectronics and Nano/Micro systems (MEMS)."

Not all academic

As these examples illustrate, there can be a strong connection between university-sponsored research, industry, and commercialization of ceramic technology.

Technion sponsors five-day Innovation Workshops that are customized to the needs of the business managers who enroll in each session. The goal is to "promote innovation as a means to enhance sustainable competitive advantage," the website explains. It uses a process model to walk through problem identification, idea generation, the transformation from idea to product, and market introduction.

The same is true for research institutes like the ICSI, which Cohen describes as doing "research for application"—that is, research with a commercial end in mind. "The commercial, the product, is very important for us. We always take into consideration the economic issues and what will be the price target of the product. We always have it in mind. We do try to commercialize our intellectual property."

Prof. Hayun of Ben-Gurion University of the Negev says, "The idea of this organization is to develop the technology and the infrastructure in Israel. So they don't care who is making the money. They care that the technology exists in Israel. And in that way, if there is an Israeli company, then they will support the company to get the knowledge and to market it and sell it."

At the same time, market limitations can become research limitations. Hayun's team has for the past five years been researching "the effect of pulse-magnetic oscillation on the solidified structure of casted aluminum." However, there are no big foundries in Israel. "So our research was published, and if somebody wants to do a startup or a company with that, they will need to go abroad to a country that actually manufactures aluminum. It is an issue. A lot of times, you're working in fields that you can't do with the resources that exist in the country. And if the resources are nonexistent, you will go outside."

Israeli associations, institutes, and government agencies

Israel Ceramic & Silicate Institute
Website: http://www.isracer.org
Address: Technion city, Haifa 3200003
Phone: 972-4822-2107, 972-4822-2108
Email: isracer@actcom.co.il

The ICSI was founded in 1963 as a joint venture of the Israeli and U.S. governments, the United Nations, and the ceramics and glass industries. An independent nonprofit organization, it is housed within Technion (Israel Institute of Technology). Its primary areas of research focus are transparent ceramics, materials for the building industry, microwave and flash sintering, glass and glass-ceramics for laser devices, piezoceramic actuators, synthesis of fine powders, armor, polymer/ceramic nano-filler composites, wear resistant ceramics, thermal spray ceramic coatings, and medical implants.

Israel Innovation Authority
Address: 1 Arava Street (or 4 HaYarden Street), Airport City, Israel
Mailing Address: 4 HaYarden St., P.O. Box 1099, Airport City, 7019900
Phone: 972-3715-7975/6/7/8
Email: contactUs@innovationisrael.org.il

This "independent and impartial public entity" is responsible for Israel's innovation policy. Its mission is "strengthening the innovation ecosystem," and to that end, it "provides a variety of practical tools and funding platforms aimed at addressing the dynamic and changing needs of the local and international innovation ecosystems." Its services include programs designed to support multinational corporations that are interested in Israeli technology and Israeli companies seeking new markets abroad.

The agency's online resources include a searchable database (www.matimop.org.il/database.aspx) of Israeli and international companies, a partner matching service, a list of calls for proposals, and an Americas collaboration page. That page includes names and contact details for staff members responsible for strategic initiatives with partners in the Americas.

Israel Ministry of Economy and Industry
Website: http://www.economy.gov.il/English/Pages/default.aspx

In 2014, the Office of the Chief Scientist of the Ministry of Economy published a 25-page guide to R&D Incentive Programs in Israel. The guide is available for download in PDF format at www.economy.gov.il. The Ministry's English-language content is limited and does not include any contact information, but the website does provide a link to addresses and phone numbers in Hebrew at www.economy.gov.il/English/About.

Israel Ministry of Science and Technology
Website: https://www.gov.il/en/Departments/ministry_of_science_and_technology

This Ministry also employs a chief scientist, who chairs its research foundation and is scientific consultant to the Minister. "The chief scientist spearheads and cultivates scientific relations with Israeli and international professional institutions regarding scientific issues," the Ministry's website notes. "He also initiates and develops new international scientific relationships." Further information is available at www.gov.il/en. Most contact information for the Ministry is published in Hebrew only, but one can reach the Chief Scientist via email at Pniyot_ChiefScientist@most.gov.il.

The Israel National Nanotechnology Initiative (INNI)
Website: http://www.nanoisrael.org
Address: Industry House, 11th Floor, 29 Ha-Mered Street, P.O. Box 50364, Tel Aviv 61500
Email: Rafi Koriat, Industry and Academia Cooperation, rafi.koriat@nanoisrael.org
Email contact list and form: http://www.nanoisrael.org/contact.aspx

INNI's mission is to create "an engine for global leadership" that makes nanotechnology "the next wave of successful industry in Israel." To achieve this goal, it promotes "fruitful collaboration between Israeli and global nanotechnology stakeholders," and to that end, it maintains a publicly accessible national database of Israel's nanotechnology researchers and industry.

Weizmann Institute of Science
Website: https://www.weizmann.ac.il/pages
Address: 234 Herzl Street, POB 26, Rehovot 7610001
Phone: 972-8934-9106
Professor Igor Lubomirsky,
Department of Materials and Interfaces
Phone: 972-8934-2142
Email: Igor.Lubomirsky@weizmann.ac.il

"Advancing science for the benefit of humanity" is the Weizmann Institute's mission. "In parallel, it educates a substantial proportion of Israel's scientific leadership and advances science literacy in schools and among the public." Its 250 experimental and theoretical research groups span five faculties: Biology, Biochemistry, Chemistry, Mathematics and Computer Science, and Physics. Among the inventions developed at the Institute are nanomaterials and compounds for industrial and medical uses.

The Department of Materials and Interfaces draws on chemistry, physics, and materials science to conduct interdisciplinary research into "all aspects of hard, soft, and living matter" and "the properties of interfaces between different phases of matter." Its facilities are equipped for materials science research in such areas as synthesis, fabrication, and chemical and physical characterization. Research activities organized around three major themes: soft and biological materials and interfaces, functional materials and nanomaterials at interfaces, and materials for energy.

In the area of ceramics, Professor Igor Lubomirsky focuses on research in the areas of electromechanic and inelastic effects in oxygen deficient ceramics, fundamentals of polar dielectrics and ice nucleation, and null-ellipsometry to measure ionic diffusion. In addition, he works on environmentally oriented projects.

Israeli associations, institutes, and government agencies

CORPORATIONS

Dip-Tech

Website: http://www.dip-tech.com
Address: 5 Atir Yeda Street, Kfar-Saba
Email form: https://www.dip-tech.com/contact

A pioneer in digital glass printing, Dip-Tech offers a line of technologically advanced glass printers and high-performance digital ceramic inks supported by expert consultation and international business development assistance. Among its innovations for the architectural and automotive sectors are:

- The New Era printing engine, which features automated ink recirculation in the print head, wide gradual drop placement, durable stainless steel nozzle plate, fully refurbishable printing components, dual-technology drop fixation, and automatic fast color change system.
- DXP software, which converts graphic files into printed glass projects. Its pattern generator performs automatic conversions, and the software's features also include easy scale-up for facades, tiling, and paneling and a color atlas that matches thousands of RAL and Pantone colors.

M&R: Minerals & Refractories Ltd.

Website: http://www.m-r.co.il/profile
Email: mandr@m-r.co.il

Founded in 1961, M&R provides consultation on refractory and insulation lining, conducts complete lining engineering and design work, and performs heat transfer calculations and new product testing.

On the supply side, its refractory materials include "bricks, monolithics of all types, the complete range of ceramic fiber products, heat resistant textiles, insulating bricks and other insulation products, abrasion resistant products, acid resistant materials, crucibles, ceramic heating elements, advanced industrial ceramics, kiln furniture, and state of the art refractories and industrial ceramics developed in the last decade."

It is also "the leading importer of minerals, ferro-alloys, recarburizers, and other metals to the Israeli industry, and particularly to the steel, cast iron, and non-ferrous industry," and serves as the Israeli representative of European, North American, Asia, and South African companies in the sector.

Nano Dimension

Website: https://www.nano-di.com
Address: 2 Ilan Ramon Street, Ness-Ziona Science Park, Ness Ziona 7403635
U.S. Address: 3671 Enochs Street, Santa Clara, CA, 95051
Email contact form: https://www.nano-di.com/contact-us

Nano Dimension's work in additive electronics targets the market for 3-D printing technology for printed electronics by developing "electronic devices that require increasingly sophisticated features and rely on encapsulated sensors, antennas and printed circuit boards (PCBs)." Its R&D addresses existing and emerging needs in consumer electronics, medical devices, defense, aerospace, automotive, IoT, and telecom.

The company's multimaterial 3-D printing technology makes it possible "to print polymers and metals together to create functional electronic parts," its website notes, an approach "with the potential to enable more compact, denser and ultimately non-planar designs."

On June 11, the company announced that its U.S. subsidiary had qualified as a United States Government Certified Vendor with a Commercial and Government Entity Code awarded by the United States Department of Defense's Defense Logistics Agency. On July 9, the company announced its entry into the Chinese market via a strategic partnership with the AURORA Group, which will market and sell its DragonFly 2020 Pro 3-D printer for electronics in China. And on August 1, the company announced the expansion of its channel network to include Fisher Unitech, which will purchase the DragonFly 2020 Pro 3-D Printer and make the technology available to its customer base.

Nanonics Imaging

Website: http://www.nanonics.co.il
Phone: 972-2678-9573
Email: info@nanonics.co.il

Nanonics manufactures scanning probe and atomic force microscopes for integration with optical and spectroscopic tools as well as electron microscopes. Its Nanonics Multiprobe SPM Systems "enable thermal, electrical, and optical transport studies on graphene and other 2-D materials," its website notes. "Photoconductivity, AFM, Raman and TERS, as well as SNOM/NSOM measurements, are all available in a variety of environments within the same platform."

NANO-Z COATING LTD

Website: http://www.nanoztec.com/?lat=en
Address: Shedlovski 1, Yavne
Phone: 972-3716-6565
Email: nanot862@gmail.com

Since 2011, the company has produced and marketed nano technology coatings for domestic and export markets. It promotes its products as "easy to clean, economical in terms of day-to-day maintenance costs, as well as improving the quality of life in the fields of stone and marble, construction, infrastructures and industry, textiles, leather and suede, wood, glass, ceramics, iron, vehicles, plastic, greenhouses, solar collectors, and more." Its products for the glass and ceramics industries include nano-glass and ceramics GL-01, nano-glass solar panels GL-2, E-4 solar shield, nano-optic NOP-400 and NOP-500, Bulldog Shield Ti-9H, and glass nano coating NC-18.

Paran Holding Group Ltd., Parent Company of: Esh-Dar Refractory Industries Ltd.

Website: http://www.esh-dar.co.il
Phone: 972-8636-0666
Email contact form: http://www.esh-dar.co.il/contact-us

Na'aman Refractories

Website: http://www.naaman-ref.com/ParanGroup.aspx
Address: P.O. Box 245, Industrial Zone, Akko 24101
Phone: 972-4981-9933
Email: info@naaman-ref.com

These sister companies in the refractory space operate under the Paran Holding Group umbrella. (Note: that is the company name, but it is not a holding company.) Their focus is industrial high temperature ceramics and industrial abrasion and corrosion-resistant ceramics.

Na'aman is a monolithic refractory specialist with a focus on development and production of castables for a variety of high end industrial applications under abrasive or corrosive conditions as well as extreme temperatures. It also serves as a local representative for international companies. Esh-Dar is a specialized contractor for refractory installations. They serve the domestic market and countries in the immediate surrounding region.

By working in partnership, they offer turnkey design, materials, and installation projects as well as consultation, logistics support, and project management to companies in their target markets, which include petrochem and refineries, power plants, and the cement, chemical, mining, steel, and nonferrous industries. Among their most recent projects is a 120 MW solar power plant.

SP NANO Ltd.

Website: http://www.spnano.com

Address: 2 Paran St, level 1, Suite 17, P.O. Box 13175, Yavne 8122502

Phone: 972-8946-0232

Email: inquiry@spnano.com

SP Nano has commercialized the use of nanoparticles in components and products made from composite materials. The company's patented technology includes its proprietary SP1/protein, which "utilizes genetically engineered proteins to create self-assembly nanostructures with Carbon NanoTubes (CNTs) bound to structural fabrics such as carbon fiber, aramid and glass fiber composites," the company website explains. "The SP1 protein complex is the core of a 3-D nanostructure, with SP Nano's developing its first nanostructures for carbon nanotubes (CNTs) bound to carbon fabric, aramid and CNT reinforced polymers." Applications cover the aerospace, energy, and automotive industries.

StoreDot

Website: https://www.store-dot.com
Address: I 3 Shenkar St. Herzeliya I 4672503
Phone: 972-3509-7710
Email: info@store-dot.com

StoreDot created an "instant-charging" flash battery that in just five minutes "soaks up enough power…to last an entire day." The battery is compatible with smartphones, wearables, tablets, and laptops and includes a flash charger in pocket and car versions.

The website notes: "The flash battery demonstrates rapid redox activity, and optimized compounds that increase the absorption of lithium ions and their counter-ions. In contrast to other batteries that contain toxic, polluting heavy metals, StoreDot's materials leave minimal environmental footprint.

"Specially designed for high-current charging, StoreDot's flash battery contains, in addition to lithium, non-flammable organic compounds encased in a multi-layer safety-protection structure that prevents over-voltage and heating, and is therefore considerably safer than traditional LiBs. Containing proprietary electrolyte, an ecologically friendly material, the flash battery incorporates polymers and metal oxide together, resulting in an increased electrode stability and SEI performance at high temperatures."

The company is pursuing research and development of an automotive application of its technology for use in electric cars. In May, BP ventures announced that it would invest $20 million in this application.

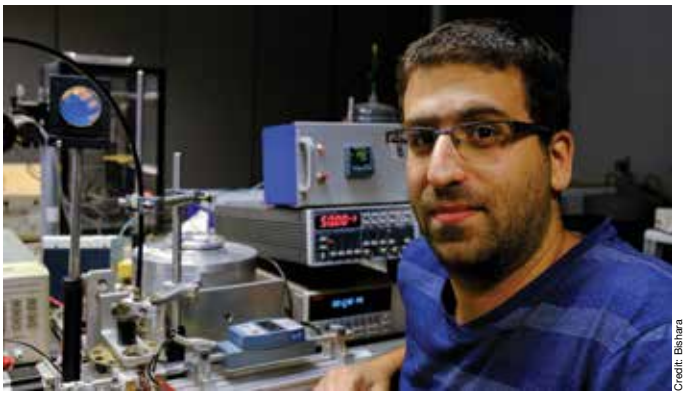
XJET

Website: https://www.xjet3-D.com
Address: Science Park, 10 Oppenheimer Street, Rehovot 7670110
Phone: 972-8931-4620
Email: info@xjet3d@.com

Founded in 2005, XJet develops and markets metal and ceramic additive manufacturing technologies and solutions. Among these is its NanoParticle Jetting technology, which "enables the production of metal or ceramic parts with the same ease and versatility of inkjet printing without compromising throughput or quality." In July, the technology was recognized with a Frost & Sullivan Technology Innovation Award.

Credit: Creative Commons

Ben Gurion University of Negev, Israel



Credit: Bishara

Figure 3. Hanna Bishara, Ph.D. researcher in his laboratory at Israel's Technion.

That can create a vicious cycle—but Technion's Hanna Bishara (Figure 3), a Ph.D. researcher, sees the classroom as part of the solution.

His research focus is "manipulating crystal growth processes of linear and non-linear dielectrics in order to achieve highly-sensitive piezoelectric materials, in the scale of sub-Pascals." While like any researcher, he would be pleased to be offered research funding by a corporate entity, at this stage of his career, his focus is on research for its own sake rather than on research with commercial potential.

"Whenever we get a solution to some technological problem, we are in a dilemma as to whether to publish it as a scientific report or an article or a paper," he says. "I want to go more into academia than business, so there's more worth to me to publish a paper."

Israeli associations, institutes, and government agencies

UNIVERSITIES

Azrieli—College of Engineering Jerusalem
Website: https://english.jce.ac.il
Address: 26 Yaakov Shreibom Street, Ramat Beit Hakerem, Jerusalem 9103501
Phone: 972-2658-8000
Email contact form: https://english.jce.ac.il/contact-us

A nonprofit organization, the college was founded in 1999 "to provide a solution for Jerusalem's growing demand for human capital in the high-tech sector.

The Advanced Materials Engineering department's undergraduate program covers general theory along with "specialized studies such as materials used in microelectronics and electro-optical devices, nanostructured materials, and materials processing using novel methods." In the year before graduation, students must complete a final project that affords them practical, hands-on experience; often, they complete the projects in an industrial plant.

The Electronic and Electrical, Software, Pharmaceutical, Industrial, Mechanical, and Civil and Environmental engineering departments round out the college's courses of study.

Bar-Ilan University
Website: https://www1.biu.ac.il/indexE.php
Address: Bar-Ilan University Ramat Gan, 5290002
Phone: 972-3531-8111
Email contact form: https://www1.biu.ac.il/indexE.php?id=103&pt=7&pid=102&level=1&cPath=103

Institute for Nanotechnology and Advanced Materials
Phone: 972.3531-7067 I
Email contact form: https://nano.biu.ac.il/contact

Founded in 1955, Bar-Ilan was one of Israel's first comprehensive research universities. It offers degree programs in the areas of Jewish Studies, Medicine, Engineering, Law, Life Science, Exact Sciences, Social Sciences, and Humanities as well as Interdisciplinary Studies, including Nanotechnology and Advanced Materials.

Established in 2007, Bar Ilan's Institute for Nanotechnology and Advanced Materials (BINA) brings academia and industry together to collaborate on nano-based approaches to energy, magnetism, optics, clean tech, and biomedicine. It is home to 40 laboratories and "Scientific Service" facilities "for electron microscopy, nanofabrication, surface analysis, fluorescence, and magnetic measurement, all of which are available for use by the wider scientific community."

BINA has a strong global focus that extends from its partnerships with multinational corporations (among them GM, Merck, Phillips, Siemens, and IBM) to its "large number of young faculty members recruited from abroad."

Ben-Gurion University of the Negev
Website: http://in.bgu.ac.il/en/Pages/default.aspx
Address: P.O.B. 653 Beer-Sheva
Switchboard: 972-8646-1111
Engineering faculty contact page: http://in.bgu.ac.il/en/engn/Pages/FacultyRoles.aspx

Ben-Gurion University is home to 20,000 students and 4,000 faculty members in the Faculties of Engineering Sciences, Health Sciences, and Natural Sciences as well as additional Faculties in humanities, social science, business and management, medicine, and desert studies.

The Faculty of Engineering Sciences "focuses on promoting and advancing research and development of new technologies and methodologies," and the website further notes that many of the school's researchers work with colleagues in Israel and abroad. In addition to materials and electro-optical engineering, its departments offer degree programs in electrical and computer, mechanical, chemical, industrial, nuclear, biomedical, biotechnology, communication systems, information systems, software, structural, management and safety, environmental, energy, and mechatronics engineering.

The Hebrew University of Jerusalem
Website: http://new.huji.ac.il/en

Center for Nanoscience and Nanotechnology
Website: http://www.nano.huji.ac.il
Mailing Address: The Hebrew University of Jerusalem, The Harvey M. Krueger Family Center for Nanoscience and Nanotechnology, Edmond J. Safra Campus, Jerusalem 91904
Phone: 972-2658-6088/2658-4919
Phone, 3-D Printing Center: 972-2658-5719
Email: huj-nano@savion.huji.ac.il

The Hebrew University opened in 1925 and counts among its founders Albert Einstein, Martin Buber, Chaim Nahman Bialik, and Chaim Weizmann. Fields of study span "the

Some of his colleagues work in a manner more integrated with industry. But Technion also supports that study-centric perspective. "They don't oblige people to commercialize their research. As a result, you can see a variety of people in Technion, some who do only basic research, and others who are doing a big start-up," says Bishara.

That opens the door to practical laboratory experience for undergraduates. "For human resources, at Technion, we rely a lot on our bachelor's students," Bishara says. "They are integrated into the laboratory in their final year. That's how I got to my laboratory. I did my final project as an undergraduate, and I liked the research."

(It is important to remember that these are older students than would be found typically on U.S. campuses because of the requirement that they serve three years in the army before they begin university studies. The average Israeli college student therefore is more mature and has more work experience.)

Hayun also sees the current generation of students as an important asset in advancing Israel's knowledge of ceramics and capacity for competing in the global market. "Because of the situation Israel is in, we always need to reinvent ourselves from scratch," he says. "The students always have new ideas. They give us more and more ideas about how to make ideas work. They know a thing or two about life and what they want to do. This is one reason why you want to collaborate with Israel."

For now, the country will remain reliant on collaborations with other countries and will have to continue to compete for academic and industry talent on the global market. But by bringing promising members of the next generation into the research realm as early as possible, Israel hopes to cultivate stronger domestic human resources and increased capacity for driving its own growth in ceramic research, product development, and marketing. ■


Credit: Commons, Wikimedia

The Porter School of Environmental Studies Building, Tel Aviv

humanities, social sciences, exact sciences, and medicine," and the university "encourages multi-disciplinary activities in Israel and overseas and serves as a bridge between academic research and its social and industrial applications."

To that end, the university operates Yissum, its own technology transfer company, whose mission is "to benefit society by converting extraordinary innovations and transformational technologies into commercial solutions that address our most urgent global challenges." Its available technologies are divided into categories, including chemistry and materials, cleantech and environment, micro and optoelectronics, nanotechnology, and the searchable database (http://www.yissum.co.il) facilitates connecting with experts, accessing express licensing information, or finding startups in search of funding.

The university also houses a Center for Nanoscience & Nanotechnology (HUCNN), whose Units for NanoCharacterizaton and NanoFabrication "provide hi-tech nanotechnological services and facilities to researchers from across the University's faculties, other universities and industry." Its researchers have won €24 million in European Community grants, and HUCNN is the source of 300 papers published annually in leading scientific journals. It also, the website notes, "is at the frontline of fighting Israel's academic brain drain by recruiting almost half of its members from abroad."

Technion, Israel Institute of Technology

https://www.technion.ac.il/en/home-2

Directory: https://www.admin.technion.ac.il/engtelbook

Technion, Materials Science and Engineering Faculty

https://materials.technion.ac.il

Technion's cornerstone was laid in 1912, 36 years before the foundation of Israel. It has evolved into a leading center of research in such fields as biotechnology, stem cells, space, computer science, nanotechnology, and energy.

The Department of Materials Science and Engineering is engaged in research activities that encompass most advanced topics in the field and operates research centers and laboratories dedicated to electron microscopy, atomic force microscopy, physical measurements, x-ray diffraction, focused ion beam, sputtering, and electronics.

Its website hosts links to faculty members' personal pages and research group sites to showcase the full scope of research focus.

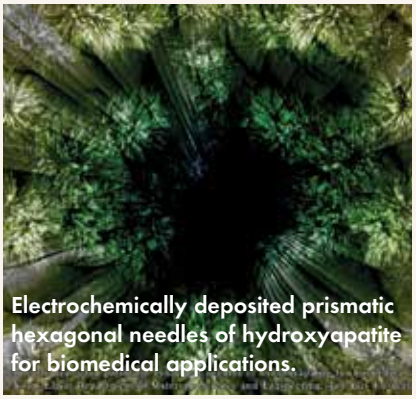
Tel Aviv University

Website: https://english.tau.ac.il
Address: P.O. Box 39040, Tel Aviv 6997801
Staff directory: https://english.tau.ac.il/tau/index

Tel Aviv University's academic units cover the arts, engineering, exact sciences, humanities, law, life sciences, management, medicine, social sciences, neuroscience, and foreign languages.

At the Iby and Aladar Fleischman Faculty of Engineering, Dr. Tal Ellenbogen "studies the interaction between light and matter at the nanoscale level in order to explore underlying physical mechanisms, which can be used to develop novel optical and electro-optical components."

Since 1994, the university has operated its Wolfson Applied Materials Research Centre, where work focuses on electronic and opto-electronic, energy, structural, biological, and environmental materials. Prof. Noam Eliaz, who chaired the 2009 Israel Materials Engineering Conference, is engaged in expanding the school's engineering degree offerings with the establishment of the Department of Materials Science and Engineering. The core faculty includes Prof. Nava Setter, who will divide her time between Tel Aviv and Lausanne, and the university is recruiting additional faculty in advanced ceramics. "It can be thin films," Eliaz says, "although a combination with bulk ceramics is even better. We expect this new faculty to be able to synthesize ceramic materials in his/her lab."


Credit: Professor Noam Eliaz, Department of Materials Science and Engineering, Tel Aviv University.

Electrochemically deposited prismatic hexagonal needles of hydroxyapatite for biomedical applications.