Latin America—Indigenous invention

Ceramic researchers and companies pursue homegrown solutions to global challenges in Latin America

By Alex Talavera and Randy B. Hecht

Industry partnerships drive the focus of much academic research across Latin America, but financial performance is not the only goal—efforts to address environmental impacts and pursue sustainability play large roles in research as well.

From a market perspective, Latin America is significantly bigger than you may realize. The Pew Research Center projects that Europe's population will peak in 2021—and by 2037 will be eclipsed by Latin America and the Caribbean, which will grow to 768 million by 2058.[1]

Combine those demographics with newly published World Bank research about the COVID-19 pandemic's impact on the productivity gap between developed and emerging economies,[2] and you may perceive the Latin American market's value with new appreciation. ACerS members in the region say that matters not just macroeconomically but also at the industry level.

A window to the world

"We are facing issues common with many countries around the world, like in Africa or Asia. When you provide a solution for these countries, you can make an impact on half the world," says professor Henry Colorado of Colombia's University of Antioquia. Latin American colleagues offer not only research expertise, he says, but also a more global mindset.

Professor Victor Carlos Pandolfelli of the Federal University of São Carlos hopes the United States will "open a bit more to the importance of networking with the world—and not waiting for the world to go to United

Capsule summary

LARGE POTENTIAL

By 2037, Latin America and the Caribbean are expected to eclipse Europe in population. Taken in consideration with World Bank research on the COVID–19 pandemic's impact, and the potential for Latin America as a global market is larger than many people realize.

CORPORATE FUNDING

For some countries in Latin America, corporate underwriting is essential to conducting academic research. That reality makes the market a key driver of areas of research focus.

SUSTAINABLE FOCUS

Even as industry partnerships drive the focus of research, projects must consider sustainability and humanitarian factors as well. Universities and companies throughout Latin America are working to address environmental impacts of their products.

States. I think that attitude will change due to a new, different world we'll be living in."

This year's international report looks at the state of the industry in Brazil, Colombia, and Chile to assess the opportunities for joint research and ventures with Latin American partners.

Brazil: Pursuing eco-innovation and Industry 4.0 advances

Companies open to collaboration with university researchers will find Brazil not only welcomes, but to some extent requires, their participation. Faculty members must adhere to strict parameters for use of university or government funding—which, for example, often cannot cover salaries for postdocs or administrative staff.

"Most of the funds I have, including the building where I have my office and a laboratory, were sponsored by a company," Pandolfelli says. That reality makes the market a key driver of his areas of research focus.

"We are the top country in Latin America in production of articles and scientific papers," he says. "In the materials area, and specifically in the ceramic area, I would point out three major research areas: refractories—that is, high-temperature materials—glass, and sensors." Of the three areas, industry plays the most prominent role in refractories, which also has the highest concentration of MSc and Ph.D. candidates. There are few jobs available in industry for those who specialize in glass, most of whom become academics, but Pandolfelli estimates that 60% of those who do graduate study in refractories go on to careers in industry.

Those with a concentration in sensors are more likely to teach, but some launch startups, Pandolfelli says. "There are just a few major industries in Brazil that produce electronics here. Most of the electronics come from abroad. In the refractory area, we have a much broader menu because the steel industry requires top quality products of the refractory producers," he says.

Sustainability strategies

One of Pandolfelli's areas of research interest is "how to adapt to the refractory area and high-temperature ceramic materials to industry 4.0," which involves extensive data mining and simulations. His goal is to help advance the capacity to develop products that are not just competitive in price and performance but also friendly to the environment. "We are carrying out research to have material and tech knowledge that is competitive for the present and will match with the needs of the future," he says.

Environmental concerns were the topic of the July 28 *Online Symposium on Materials and Sustainability*, co-presented by the Federal Universities of São Carlos and Rio Grande do Sul along with Portugal's Polytechnic Institute of Viana do Castelo.

And the schedule for the next Brazilian Ceramic Society Congress includes two seminars whose titles translate as *Circular economy: The sustainability bridge for intensive use of natural/chemical materials and energy in the ceramics and buildings industry* and *Asbestos-free fiber cement, the renewable material.*

Data-driven R&D

By law, intellectual property that emerges from research is owned equally by the university and whatever company funded the work. "The IP is co-shared, but the industry which funded the given research contract has the privilege of having a licensing agreement," says professor Edgar Zanotto, an ACerS member who works for the Federal University of São Carlos and is editor of the *Journal of Non-Crystalline Solids*. It can be frustrating negotiating with industry partners who balk at those terms. Inventors receive 1% of royalties.

Another challenge for Brazil is retaining its homegrown talent in physics, chemistry, and materials engineering. The country has excellent masters and doctoral students in those fields, but with postdoc salaries scarce, many find employment abroad.

And high-tech equipment, which is not manufactured in Brazil, presents a third complication for Zanotto and his colleagues. "We have to import this equipment, which is hard enough, okay. But sometimes we get some funding and we import equipment," he says. "However, when they break, and they often break, it's very expensive to get them fixed. Sometimes I had to fly a technician from Europe. And that's the problem, keeping up with advanced research equipment."

Despite these challenges, Zanotto is conducting research in three fields. The first is the fundamentals of crystal nucleation, crystal growth, and crystallization of glass. The second is glass-ceramics, "using the accumulated knowledge of nucleation crystallization to develop or to improve glass-ceramics with different types of properties in applications." And the third is "using computer simulations and machine learning to develop new glasses with exotic combinations of properties."

He embarked on this third field just two years ago and explains why he finds it exciting. "Suppose some industry needs glass which has a very high index of refraction, or special lenses, and a very low glass transition temperature (T_g) to be molded at very low temperatures. You can use machine learning to feed a given algorithm with data. And then you train the algorithm and ask it to suggest

Credit: Edgar Zanotto

Edgar Zanotto (front center) and his colleague and students in the Center for Research, Technology and Education in Vitreous Materials, located in Brazil.

combinations of these compositions that would lead to very high refractive index, very low T_g, for instance. We are doing that already."

Colombia: Seeking convergence of industrial and social progress

As in Brazil, academic research in Colombia depends on corporate underwriting, whether from domestic or international partners. Without it, research projects are not economically sustainable, says Colorado, whose work is concentrated in the diverse fields of composites, ceramics, arts, additive manufacturing, and solid waste management.

"I try not to work for a specific industry," he says. "The work I do in waste management and circular economy, for instance, can be used in several sectors and industry types."

But he adds that even as industry partnerships drive the focus of research, projects must consider sustainability and humanitarian factors, not just financial performance. "I always want my research converted into a successful product," he says, but his further goal is to advance solutions for the environment, communities, small companies, or even local communities in need. "I am an engineer, and I like to work with industry because it's one of the ways research becomes a real solution," he says.

Low-tech practices are common in his region, so these partnerships provide an opportunity to raise industrial awareness of more advanced products and methods as they address social issues. His favorite success story

LATIN AMERICA MARKET SNAPSHOTS

Brazil, Chile, and Colombia provide perspectives on Latin America's role in the world economy

By Alex Talavera and Randy B. Hecht

A look at the capabilities and challenges driving the region's growth as a foreign commerce force with which to be reckoned.

Unless otherwise noted, the information on each region comes from the CIA World Factbook at https://www.cia.gov/library/publications/the-world-factbook.

Brazil: South America's resourceful global trader

Brazil accounts for nearly half of the South American land mass and shares borders with every country in the region with the exceptions of Ecuador and Chile. The majority of its population of nearly 212 million lives along the Atlantic coast and is particularly concentrated in urban areas in the southeast. The most populous cities are Sao Paulo (22 million) and Rio de Janeiro (13.5 million); the capital city, Brasilia, is home to 4.6 million.

According to 2011 estimates (the latest available from the CIA World Factbook), the remainder of the country included 32.9% agricultural land and 61.9% forest. But those figures predate the fires that saw deforestation rates peak at 2,200 square kilometers per month in July 2019—between double and quadruple the highest monthly rates recorded in each of the preceding four years.[1] Land management and environmental protection are of particular concern in Brazil, whose natural resources include alumina, bauxite, beryllium, gold, iron ore, manganese, nickel, niobium, phosphates, platinum, tantalum, tin, rare earth elements, uranium, petroleum, and timber.

As home to much of the Amazon and other great waterways, the country is also a standout in its use of hydropower. Hydroelectric plants generate 64% of total installed electricity capacity, followed by other renewable sources (18%), fossil fuels (17%), and nuclear fuels (1%).

In 2017, Brazil's purchasing power parity GDP was $3.248 billion ($15,600 per capita), a 1% annual growth rate after two consecutive years in which GDP fell by 3.5%. Services generated 72.7% of GDP, followed by industry (20.7%) and agriculture (6.6%). Leading industries include textiles, shoes, chemicals, cement, lumber, iron ore, tin, steel, aircraft, motor vehicles and parts, and other machinery and equipment. The country's labor force is 104.2 million; services employ 58.5%, followed by industry (32.1%) and agriculture (9.4%).

Brazil has achieved a strong positive balance of trade, with $217.2 billion in 2017 exports against 153.2 billion in imports. Transport equipment, iron ore, soybeans, footwear, coffee, and automobiles are among the leading exports, and the country's chief export partners are China, the U.S., Argentina, and the Netherlands. Leading imports include machinery, electrical and transport equipment, chemical products, oil, automotive parts and electronics, and chief import partners are China, the U.S., Argentina, and Germany.

One notable resource constraint threatens to limit Brazil's capacity for continued sustainable economic advances: its rate of population growth, which stands at just 0.67%. "Brasilia has not taken full advantage of its large working-age population to develop its human capital and strengthen its social and economic institutions," the CIA World Factbook notes, "but is funding a study abroad program to bring advanced skills back to the country. The current favorable age structure will begin to shift around 2025, with the labor force shrinking and the

elderly starting to compose an increasing share of the total population."

To learn more about this market, see the U.S. International Trade Administration's *Brazil Commercial Guide*,[2] the World Bank's *Doing Business in Brazil* guide,[3] and resources available through the Brazilian–American Chamber of Commerce.[4]

Chile: Going to great lengths in foreign commerce

From its northern border with Peru to its termination at the southern tip of South America, Chile covers 2,700 miles. To put that in perspective, if you traveled from Cabo San Lucas to Vancouver, you would still have to log another 280 miles to cover a distance equal to the length of Chile. By contrast, the country runs only about 217 miles across at its widest point and not even 10 miles at its narrowest.[5]

From prehistory to the present, that long, skinny terrain was dotted with 481 volcanoes, as tallied by the Smithsonian Institution's Global Volcanism Program database.[6] Although only 105 of those have been active in the past 10,000 years, Chile's natural resource wealth owes a debt to volcanic eruptions dating to the Cenozoic Era that produced deposits of copper, iron, silver, molybdenum, manganese, and coal.[5]

The capital city of Santiago is home to 6.7 million people, roughly a third of the national population of nearly 18.2 million; 90% of Chileans live in the central third of the country and 87.7% are in urban areas. The labor force numbers 8.9 million, of whom 67.1% work in services, followed by 23.7% in industry and 9.2% in agriculture.

For 2017, Chile's purchasing power GDP was $452.1 billion ($24,500 per capita). Although this reflects an increase of 1.5% over the previous year, that growth rate was down for the third consecutive year, a shift driven largely by a reduction in copper prices. With the exception of 2009, Chile averaged annual real growth of almost 5% for every year from 2003 through 2013.

Services account for 63% of GDP, followed by industry (32.8%) and agriculture (4.2%). Leading industrial sectors include copper, lithium, other minerals, foodstuffs, fish processing, iron and steel, wood and wood products, transport equipment, cement, and textiles.

Chile has a positive balance of trade, with exports of 69.23 billion against imports of $61.31 billion. Copper, its top export, generates 20% of government revenue. Additional leading export commodities include fruit, fish products, paper and pulp, chemicals, and wine. The country's largest export partners are China, the U.S., Japan, South Korea, and Brazil. Among imports, the leading commodities are petroleum and petroleum products, chemicals, electrical and telecommunications equipment, industrial machinery, vehicles, and natural gas. China, the U.S., Brazil, Argentina, and Germany are Chile's largest import partners.

This level of foreign commerce activity, along with its market-oriented economy and global confidence in its financial institutions and policy, have enabled Chile to attain South America's strongest sovereign bond rating. However, its income inequality is ranked as the worst among members of the Organisation for Economic Cooperation and Development; Chile became the first South American member of the OECD in 2010.

For more information about this market, see the U.S. International Trade Administration's *Chile Commercial Guide*,[7] the World Bank's *Doing Business in Chile* guide,[8] and resources available through the North American–Chilean Chamber of Commerce.[9]

Colombia: Resources, reforms, and rising trade profile

With its Caribbean and Pacific beaches, Andean peaks, and Amazonian waterways, Colombia is home to diverse topographies and ecosystems. Like its neighbor Brazil, the country holds vast spans of land that have not given way to urbanization—forests and agricultural land occupy, respectively, 54.4% and 37.5% of its terrain. But as in Brazil, demand for timber has sparked deforestation in the Amazon jungle.

Another hydropower champion, Colombia generated 69% of its total installed electricity capacity via hydroelectric plants in 2017—but in a country of 49 million people, one million lack access to electricity. Its exploitable resources include petroleum, natural gas, coal, iron ore, nickel, gold, copper, and emeralds. These assets are key to Colombia's foreign trade activity but also increase its vulnerability to market fluctuations.

The Colombian labor force numbers 25.76 million. Services represent 62% of employment, followed by industry (21%) and agriculture (17%). Major industries include textiles, food processing, oil, clothing and footwear, beverages, chemicals, cement, gold, coal, and emeralds.

In 2017, the country's purchasing power parity GDP was $711.6 billion, or $14,400 per capita, and prior to that year, real GDP growth averaged 4.7% annually for a decade. But despite that performance, 28% of the population lives below the poverty line. Services generate 62.1% of GDP, followed by industry (30.8%) and agriculture (7.2%). In 2017, industrial production fell by 2.2%.

For 2017, export volume was $39.48 billion against import volume of $44.24 billion. Leading exports include petroleum, coal, emeralds, coffee, nickel, cut flowers, bananas, and apparel, while leading imports are industrial equipment, transportation equipment, consumer goods, chemicals, paper products, fuels, and electricity. Colombia's chief trading partners are the U.S., Panama, and China on the export side and the U.S., China, Mexico, Brazil, and Germany for imports.

Colombia ranks fourth worldwide in coal production and is the world's third-largest exporter of both coffee and cut flowers. It is also Latin America's fourth-largest producer of oil, after Brazil, Mexico, and Venezuela. But it continues to face obstacles to sustained growth. The CIA World Factbook notes: "Colombia's economic development is hampered by inadequate infrastructure, poverty, narcotrafficking, and an uncertain security situation, in addition to dependence on primary commodities (goods that have little value-added from processing or labor inputs)."

In April 2020, Colombia became the third Latin American country (along with Chile and Mexico) to join the Organisation of Economic Cooperation and Development. (Costa Rica is in the final stages of completing its requirements.) Colombia's admission to the OECD is the culmination of five years of reform efforts that conformed the country's legislation, policies, and practices to OECD standards. These reforms covered such areas as labor practices, judicial reform, corporate governance of state-owned enterprises, antibribery measures, and establishment of a national policy on industrial chemicals and waste management.

To learn more about pursuing opportunities in this market, see the U.S. International Trade Administration's *Colombia Commercial Guide*,[10] the World Bank's *Doing Business in Colombia* guide,[11] and resources available through AmCham Colombia.[12] ■

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Latin America—Indigeneous invention

Pan-American Market Snapshot

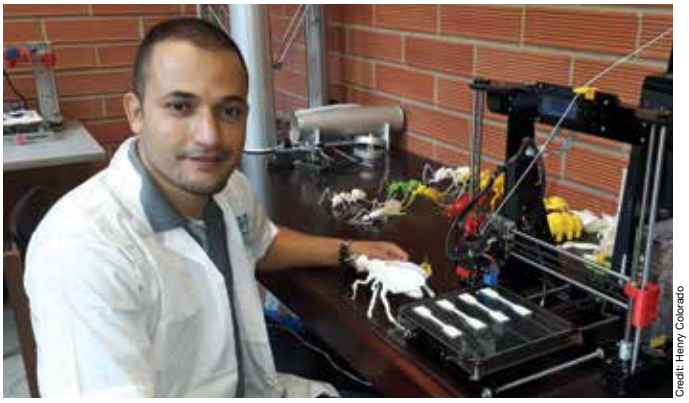
Country	Purchasing Power Parity GDP	Import Volume	Chief Imports	Export Volume	Chief Exports	Chief Trading Partners
Argentina	$922.1 billion $20,900 per capita	$63.97 billion	Machinery, motor vehicles, petroleum and natural gas, organic chemicals, plastics.	$58.45 billion	Soybeans and derivatives, petroleum and gas, vehicles, corn, wheat.	**Imports:** Brazil 26.9%, China 18.5%, US 11.3%, Germany 4.9% **Exports:** Brazil 16.1%, US 7.9%, China 7.5%, Chile 4.4%
Brazil	$3.248 trillion $15,600 per capita	$153.2 billion	Machinery, electrical and transport equipment, chemical products, oil, automotive parts, electronics.	$217.2 billion	Transport equipment, iron ore, soybeans, footwear, coffee, automobiles.	**Imports:** China 18.1%, US 16.7%, Argentina 6.3%, Germany 6.1% **Exports:** China 21.8%, US 12.5%, Argentina 8.1%, Netherlands 4.3%
Canada	$1.774 trillion $48,400 er capita	$442.1 billion	Machinery and equipment, motor vehicles and parts, crude oil, chemicals, electricity, durable consumer goods.	$423.5 billion	Motor vehicles and parts, industrial machinery, aircraft, telecommunications equipment; chemicals, plastics, fertilizers; wood pulp, timber, crude petroleum, natural gas, electricity, aluminum.	**Imports:** US 51.5%, China 12.6%, Mexico 6.3% **Exports:** US 76.4%, China 4.3%
Chile	$452.1 billion $24,600 per capita	$61.31 billion	Petroleum and petroleum products, chemicals, electrical and telecommunications equipment, industrial machinery, vehicles, natural gas.	$69.23 billion	Copper, fruit, fish products, paper and pulp, chemicals, wine.	**Imports:** China 23.9%, US 18.1%, Brazil 8.6%, Argentina 4.5%, Germany 4% **Exports:** China 27.5%, US 14.5%, Japan 9.3%, South Korea 6.2%, Brazil 5%
Colombia	$711.6 billion $14,400 per capita	$44.24 billion	Industrial equipment, transportation equipment, consumer goods, chemicals, paper products, fuels, electricity.	$39.48 billion	Petroleum, coal, emeralds, coffee, nickel, cut flowers, bananas, apparel.	**Imports:** US 26.3%, China 19.3%, Mexico 7.5%, Brazil 5%, Germany 4.1% **Exports:** US 28.5%, Panama 8.6%, China 5.1%
Mexico	$2.463 trillion $19,900 per capita	$420.8 billion	Metalworking machines, steel mill products, agricultural machinery, electrical equipment, automobile parts for assembly and repair, aircraft, aircraft parts, plastics, natural gas and oil products.	$409.8 billion	Manufactured goods, electronics, vehicles and auto parts, oil and oil products, silver, plastics, fruits, vegetables, coffee, cotton. Mexico is the world's leading producer of silver.	**Imports:** US 46.4%, China 17.7%, Japan 4.3% **Exports:** US 79.9%
Panama	$104.1 billion $25,400 per capita	$21.91 billion	Fuels, machinery, vehicles, iron and steel rods, pharmaceuticals.	$15.5 billion	Fruit and nuts, fish, iron and steel waste, wood.	**Imports:** US 24.4%, China 9.8%, Mexico 4.9% **Exports:** US 18.9%, Netherlands 16.6%, China 6.5% Costa Rica 5.4%, India 5.1%, Vietnam 5%
Peru	$430.3 billion $13,300 per capita	$38.65 billion	Petroleum and petroleum products, chemicals, plastics, machinery, vehicles, TV sets, power shovels, front-end loaders, telephones and telecommunication equipment, iron and steel, wheat, corn, soybean products, paper, cotton, vaccines and medicines.	$44.92 billion	Copper, gold, lead, zinc, tin, iron ore, molybdenum, silver; crude petroleum and petroleum products, natural gas; coffee, asparagus and other vegetables, fruit, apparel and textiles, fishmeal, fish, chemicals, fabricated metal products and machinery, alloys.	**Import:** China 22.3%, US 20.1%, Brazil 6%, Mexico 4.4% **Export:** China 26.5%, US 15.2%, Switzerland 5.2%, South Korea 4.4%, Spain 4.1%, India 4.1%
United States	$19.49 trillion $59,800 per capita	$2.361 trillion	Agricultural products 4.9%, industrial supplies 32.9% (crude oil 8.2%), capital goods 30.4% (computers, telecommunications equipment, motor vehicle parts, office machines, electric power machinery), consumer goods 31.8% (automobiles, clothing, medicines, furniture, toys).	$1.553 trillion	Agricultural products (soybeans, fruit, corn) 9.2%, industrial supplies (organic chemicals) 26.8%, capital goods (transistors, aircraft, motor vehicle parts, computers, telecommunications equipment) 49.0%, consumer goods (automobiles, medicines) 15.0%.	**Imports:** China 21.6%, Mexico 13.4%, Canada 12.8%, Japan 5.8%, Germany 5% **Exports:** Canada 18.3%, Mexico 15.7%, China 8.4% Japan 4.4%

involves how rubber tire waste on Colombia's roads was reused in flexible tiles produced by both large corporations and smaller businesses.

The environment is both a beneficiary of Colorado's research and the origin of some of his fields of study. "With respect to materials science, I am very interested in continuing my work in the amazing structure and properties of some plants and natural fibers from the Amazonia," he says. In addition to continuing to teach engineering, he plans to pursue further research in the circular economy of ceramics and composites, cultural and art materials, and sustainable manufacturing.

More climate-friendly ceramics

The push for increased sustainability in ceramics is not restricted to university labs. The multinational Corona is among Colombian companies that have adopted improved environmental practice as a corporate value. The company's business divisions include bathrooms and kitchens; surfaces, materials and paints; tableware; and industrial minerals and energy, and its operations include 20 plants in Colombia, two in the U.S., and three each in Mexico and Central America, as well as a global procurement office in China.



Credit: Henry Colorado

Henry Colorado, professor at the University of Antioquia, Colombia, likes to work with industry because it is "one of the ways research becomes a real solution."

"In terms of the design and development of refractories with regard to environmental concerns, the key driver is the reduction of heat loss in order to reduce fuel consumption and emissions," says Carlos Mesa, Latin America sales director of the

From the Andes to the Amazon to the Panama Canal, plans to establish a research triangle for nanotechnology

June marked 10 years since researchers from Argentina, Bolivia, Colombia, Costa Rica, Ecuador, Peru, and Venezuela founded the Nanoandes Network to promote nanotechnology programs in each country, initially by launching schools of nanoscience. Within five years, the organization notes on its ResearchGate page, 12 Latin American countries were home to more than 300 undergraduate, master's, doctoral, and post-doctoral researchers. Today, there are Nanoandes schools in Cartagena, Colombia; Quito, Ecuador; La Paz, Bolivia; Merida, Venezuela; and San Jose, Costa Rica, that offer theoretical and practical nanoscience workshops.

Each country seeks to make its imprint on nanotechnology advances.

The Argentine government's Nanoscience and Nanotechnology Institute, an arm of the National Atomic Energy Commission, houses a Micro and Nano Manufacturing lab for development of nanostructured films and materials, particularly for nuclear applications, as well as MEMS and nanosensors. Its application focus extends to use in medicine, industry, robotics, and agriculture.

Another prominent player is the Argentine Nanotechnology Foundation, which promotes both research and ventures by providing labs, equipment, and staff in support of "high-level nano developments." It also sponsors programs to foster entrepreneurship in this arena. These initiatives are in keeping with the Argentine government's focus on business development: the Foundation notes on its website that the National Agency for the Promotion of Research, Development and Innovation has "launched a new call for development and innovation projects that provide technological solutions" and is offering funding between 4–16 million Argentine pesos (US $55,000–220,000) for projects in "nanotechnology, modern biotechnology, biomedical engineering, mechatronics, and artificial intelligence."

In Panama, the company Empresas Carbonea is branching out from its traditional business of tempered glass hardware and tools to a nanotechnology-based coating for new glass or the restoration of old glass as well as concrete, metal, electronics, wood, and ceramics.

Nanotech+b is another Panamanian company working in materials development. It supplies Coltan (columbita–tantalite) to customers in the microelectronics, telecommunications, and aerospace industries. "Tantalite is the primary source of Tantalum (Ta), an element with high volumetric efficiency and electrical stability in a wide temperature range (-55 ºC to 125 ºC)," the company's website states, while "Columbita is the source of Niobium (Nb), used in metal alloys with applications in aeronautics" and is valued for its superconductivity. Nanotech+ sources Coltan from mines in the Democratic Republic of Congo, Venezuela, Bolivia, and Brazil and is seeking strategic partners for the establishment of a Coltan refinery in Panama for production of tantalite and niobium dioxides.

Meanwhile, Peru is working to establish a means of converting Amazon waste into nanomaterials. CONCYTEC (the National Council of Science, Technology, and Technological Innovation) and the World Bank are supporting a research project at the Pontificia Universidad Católica del Perú whose aim is to develop "a technological process that allows the production of graphene from Amazon forest waste."

In an announcement in June, CONCYTEC said the project "will develop an ad hoc technology to use waste from the Madre de Dios forest industry as a carbon source to produce graphene." The announcement quoted the project's principal researcher, Omar Troncoso Heros: "This technology will contribute to the modification of the basically extractive model of the region to a model of high added value, the forestry industry is one of the most important in the Peruvian Amazon, therefore increasing its productivity is vital for its development. Our initiative aims to develop a process that makes it possible to take advantage of forest waste, thus starting a nanotechnology industry in Peru."

Nanotechnology may be in its infancy in Latin America, but scientists, government agencies, and commercial enterprises are committed to investing in the region's resources to pursue innovation in this field.

Footnotes
a Empresas Carbone's website is available at https://www.empresascarbone.com/en/products/nanotechnology.
b Nanotech+'s website is available at https://nanotechnology.com.pa.

company's ERECOS refractories subsidiary. He adds the company applies circular economy principles to its manufacturing process. "Refractories that are uninstalled from a kiln or other equipment are thoroughly cleaned and used as a key input in the production of new refractories. This [process] helps reduce the dependence on virgin raw materials that have to be sourced from mines," he says.

Corona's mining practices include storing topsoil and organic layers for restoration after the mining activity is concluded, after which it gives local farmers access to land that is now being used for dairy cattle grazing and to raise strawberry and potato crops.

In partnership with the Spanish company Cementos Molins, Corona began operations at a new cement plant in the second half of 2019. The plant was constructed adjacent to the company's high-grade limestone quarry to reduce transportation costs and emissions. Its design incorporates filters that minimize emissions of dust, nitrogen oxide gases, sulfur oxide gases, and its equipment's energy consumption is 15% lower than that of other cement plants in the region. Water treatment plants and closed-circuit systems facilitate reuse of water.

The company also adopted use of noise-reducing technologies "to mitigate the impact of the cement plant on the surrounding natural environment and native animals" and conducted biodiversity studies that led to "the development of wildlife corridors (or green corridors) aimed to protect native and endangered species."

Chile: Transforming copper into an element of global trade

Chile's industrial sector is built quite literally from the ground up. Copper, the country's top export, is the source of 20% of government revenue.[3] (The state-owned CODELCO—the National Copper Corporation—is the world's largest producer of copper and molybdenum.) And copper's economic impact extends across the ceramic sector spectrum, from refractories to nanotechnology.

Founded more than 60 years ago, Refractory Iunge works in such sectors as copper, steel, cement, lime, and oil refineries and has licensing or partnership agreements with Allied Mineral, HarbisonWalker International, and Refractorios Peruanos SA (REPSA).

As in other countries, the industry is conscious of its responsibility to address environmental impacts. Pablo Valenzuela, one of the company's owners and a member of the board, notes recycling is a company tradition. "The copper industry uses mainly magnesia chrome bricks," he says. "Chrome may be in certain shapes and forms dangerous to the health. We have been trying to work very closely with copper producers in Chile to try to recycle those products and not end with them hidden or dumped in a place where they may harm human and animal health and the environment."

A copper-based nano process

Copper's antibacterial, antifungal, and antiviral properties provided Chile with a point of entry into nanotechnology research and development. Nanoprocess, one enterprise that emerged as a result, has "the infrastructure to produce 500 kilograms of copper nanoparticles in aqueous suspension per year, dispersed and stabilized in deionized water, free of solvents and synthetic additives."

The company adds: "The validated nanotechnology is modular, each module is capable of producing 10 kg of nano particles of high purity per day, and we can expand the number of modules according to the market requirement. We have the logistics to send concentrations of nano particles dispersed in water, in drums of 120 or 200 Lt, in sealed containers, anywhere in the world."

See the directory for information about additional companies in Chile that are using copper as a launchpad for

Credit: Corona

Quality control and testing at GAMMA Insulators, the utility products manufacturing subsidiary of Corona in Sabaneta, Colombia.

nanotechnology research and development as well as organizations that are cultivating advances in these areas as a means of promoting prosperity and social value.

Mining and mindset

Silica is another area of industry activity in Chile, where Minera Toro owns and oversees an estimated 3,000 hectares of mining properties. Those sites have a combined monthly production capacity of 6,000 tons of washed, graded sand. The company has stated a commitment to CO_2 neutral operations and use of renewable energy. An additional goal of its sustainability model is promoting social and economic progress as a means of reducing regional inequalities in this increasingly urbanized country.

What else does Chile have to offer to prospective research or commercial partners in the U.S.? Valenzuela stresses the importance of integrating this market and other Latin American markets

Credit: Corona

The multinational Corona is among Colombian companies that have adopted improved environmental practices as a corporate value.

Directory of companies, government agencies, associations, institutes, and universities in Latin America

ARGENTINA

Fundación Argentina de Nanotecnología
Phone: +54 11 2033-1455
Email: info@fan.org.ar
Website: https://www.fan.org.ar

Universidad Nacional de San Martin
Instituto de Nanosistemas
Phone: +54 11 2033-1400 ext. 6113
Email: ins@unsam.edu.ar
Website: http://www.unsam.edu.ar/institutos/ins/eng/index.asp

Website for porphyrin nanomaterials design and development: http://www.unsam.edu.ar/institutos/ins/eng/research/porphyrin.asp

BRAZIL

ABCERAM
Associação Brasileira de Cerâmica
Brazilian Ceramic Society
Phone/Fax: +54 11 3768-7101 / 11 3768-4284
Email: abceram@abceram.org.br
Website: http://abceram.org.br

ANFACER: Associação Nacional dos Fabricantes de Cerâmica Para Revestimentos, Louças Sanitárias e Congêneres

National Association of Manufacturers of Ceramics for Coverings, Sanitaryware, and Related Products
Phone: + 55 11 3192-0600
Email: info@anfacer.org.br
Website: http://ceramicsofbrazil.com/en

Centro Multidisciplinar para o Desenvolvimento de Materiais Cerâmicos

Multidisciplinary Center for Development of Ceramic Materials
Website: http://www.cmdmc.com.br/conheca/quem.php

The Center is a joint research venture of teams at the Universidade Federal de São Carlos, Universidade Estadual Paulista, Universidade de São Paulo, and Instituto de Pesquisas Energéticas.

Eirich Group
Phone: +55 11 4619-8900
Email: eirich@eirich.com.br
Website: https://eirich.com.br/en/industries/ceramics (Dedicated ceramics page in English)

https://eirich.com.br/categoria_download/ceramica (Downloadable brochures in English about services for specific ceramic sectors)

Products and services encompass raw materials, mixes, ceramic bodies and finished products such as clay bricks. Process expertise spans press bodies, granules, plastic bodies, slurries, and fiber materials. Industry experience includes glazings, refractories, structural ceramics, sanitary ceramics, oxide and non-oxide ceramics and ferrites.

Instituto de Pesquisas Energéticas e Nucleares
Nuclear and Energy Research Institute
Phone: +55 11 2810-5000
Website: https://www.ipen.br/portal_por/portal/default.php

Dedicated webpages for research in biomaterials, materials characterization, composites, crystals and monocrystalline fibers, ceramic materials, photonic materials, metallic materials, nuclear materials, polymeric materials, extractive metallurgy, physical metallurgy, material transformation processes, surface treatment, and glass and glass-ceramic.

LNNano
Brazilian Nanotechnology National Laboratory
Phone: +55 19 3517-5088
Email: lnnano.dir@lnnano.cnpem.br
Website: https://lnnano.cnpem.br

A research lab open to academia and industry, LNNano conducts applied and basic research designed to develop sustainable products and processes for the domestic and international markets. Among its areas of focus is developing "sophisticated techniques for joining, preparing, processing and characterizing metallic and ceramic alloys," the website notes, as well as "production of advanced materials from renewable sources and residues from industrial and agricultural activities." LNNano is also the headquarters of the Binational Brazil-China Center of Nanotechnology, a joint venture of the Brazilian Ministry of Science, Technology and Innovation and the Chinese Academy of Sciences.

Refratarios Paulista
Phone: +55 19 3019-1250
Website: https://www.rpa.ind.br/home/Default.asp?v=en

Production capabilities include cordierite, mullite, high alumina refractories, and hybrid refractory materials whose ceramic structure is reinforced with silicon carbide.

Sao Paulo University
Phone: +55 11 3091-6706 (Department of Applied Physics)
Email: secfap@if.usp.br
Website: https://www5.usp.br/#english
Website: http://web.if.usp.br/cristal

Universidade Estadual Paulista
Phone: +55 11 3170-3700
Website: https://www.unip.br/?lang=en

Universidade Federal de São Carlos
Phone: +55 16 3351-8111
Email: Anselmo Ortega Boschi, daob@ufscar.br
Areas of research interest: Ceramic coatings, technological development, processing of ceramic materials, ceramic tile floors

Email: Márcio Raymundo Morelli, morelli@ufscar.br
Areas of research interest: Synthesis of ceramic powders, combustion reaction, formulation and processing of ceramic materials, sintering, ceramic substrates, solid oxide fuel cells, use of inorganic residues in ceramic matrices

Universidade de São Paulo
Webpage, Materials Engineering Research Group: http://dgp.cnpq.br/dgp/espelhogrupo/8444026717250923

Verdés
Email: contato@verdes.com.br
Phone: +55 11 4024-8211
Website: http://www.verdes.com.br/en/equipments/Ceramic

into a more global outlook and cautions against being "too localist" in business. Relative to the U.S., Canada, and Mexico, the remainder of the Americas market is small today. "But it's not always going to be that way," he says. "It's important to understand what's going on, especially with local players, and be prepared to develop business relations in Latin America."

In economically and politically volatile times, no enterprise can afford to overlook a country or region in the global marketplace. To learn more about opportunities in this region, consult the resources available through the Association of American Chambers of Commerce in Latin America and the Caribbean,[4] the umbrella organization of the American Chambers of Commerce in 23 countries. Its membership extends to 20,000 companies that account for more than 80% of U.S. investment in the region.

References

[1]Cilluffo, A., and Ruiz, N.G. "World's population is projected to nearly stop growing by the end of the century." *Pew Research Center*. Published 17 June 2019. https://www.pewresearch.org/fact-tank/2019/06/17/worlds-population-is-projected-to-nearly-stop-growing-by-the-end-of-the-century

[2]Dieppe, A. "Global productivity: Trends, drivers, and policies." *The World Bank*. https://www.worldbank.org/en/research/publication/global-productivity

[3]"South America: Chile." *The World Factbook*. https://www.cia.gov/library/publications/the-world-factbook/geos/ci.html

[4]Association of American Chambers of Commerce in Latin America and the Caribbean. https://www.aaccla.org ■

Directory of companies, government agencies, associations, institutes, and universities in Latin America (cont.)

CHILE

Credit: Alex Talavera

CEDENNA/Centro para el Desarrollo de la Nanociencia y la Nanotecnología
Center for the Development of Nanoscience and Nanotechnology
Contact form: https://cedenna.cl/en/contact-us
Website: https://cedenna.cl/en

CEDENNA conducts research in nanoscience and nanotechnology and the manipulation of materials at the atomic, molecular, and macromolecular scales. Its work encompasses simulations, magnetic nanostructures, chemistry of nanostructures, chemical physics, packaging technology, and nanobiomedicine.

IMEX JCN
Phone: +56 2 2699-6623
Sales email: ventas@jcn.cl
Contact form: https://www.jcn.cl/contacto
Website: https://www.jcn.cl

The company produces and markets Nano Copper that is free of contaminants (99.9% pure) and available in all particle sizes.

Leitat
Phone: +56 2 321-0500
Website: https://www.leitat.cl

A private nonprofit technology center, Leitat's mission is to create and transfer economic, social, and sustainable value to companies and entities through applied research and technology processes, including production of nanocapsules and development of materials.

Minera Toro
Phone: +56 9 5608-7990 / 3376-7422
Email: Patricio Fierro pfierro@mineratoro.cl
Website: https://www.mineratoro.cl

Nano7
Phone: +56 9 9697-4723
Email: ingrid.carcamo@nano7.cl
Website: http://nano7.cl

The company's products target glass and ceramic requirements in the mining and construction industries, including abrasive glass, electrical and electronic equipment and panels, solar panels, and heavy machinery and mining CAT trucks.

NANOPROCESS
Phone: +56 55 2 865-008 or +56 9 7388-7657
Email: contact@nanoprocess.tech
Website: https://nanoprocess.cl

The company manufactures copper nanoparticles for incorporation in a wide variety of technological developments and production processes.

NANOTEC
Phone: +56 22 5106000 - +56 98 2302187
Email: info@nanotecchile.com
Website: http://www.nanotecchile.com/eng

The company collaborates with clients on joint R&D projects to develop new copper-based nanotechnology processes and products.

Recsol
Phone: +56 72 249-1555 / +56 72 249-1416
Contact form: http://www.recsol.cl/contacto.php (also includes the names and email addresses of the general manager and the commercial and product managers)
Website: http://www.recsol.cl

The company creates solutions related to wear in steel, cement, and thermoelectric plants. Its production line includes bimetallic plates and casting, impact elements, ceramics, and fabrication of mining equipment.

Universidad de Concepción
Contact page: http://www6.udec.cl/pexterno/contacto (address and phone details for all campuses plus email contact form)
Website: http://udec.cl/pexterno

Directory of companies, government agencies, associations, institutes, and universities in Latin America (cont.)

COLOMBIA

3D Solutions
Phone: +57 1 743-8434
info@3dsolutions.com.co
https://www.3dsolutions.com.co

The company develops additive manufacturing systems for dentistry and medicine.

Grupo Corona
Contact page: https://empresa.corona.co/contacto
Website: https://empresa.corona.co

This Colombian multinational serves clients in the home, construction, industry, agriculture, and energy sectors. It manufactures and sells products organized under four business divisions—bathrooms and kitchens; surfaces, materials, and paints; industrial supplies; and energy management—and is developing a new line of business in the production and sale of cement in collaboration with Cementos Molins de España. The company's subsidiary, Gamma, manufactures such refractory products as bricks, concrete, mortar, and thermal insulation.

ITM Institución Universitaria
Phone: +57 4 440-5100
Website: https://www.itm.edu.co

Here is where the Research Group on Advanced Materials and Energy works on the design of biofunctionalized gold nanoparticles stimulated by electromagnetic fields.

QuadCarbon
Phone: +57 318 795-6098
Email: info@quadcarbon.com.co
Website: https://www.quadcarbon.com.co/index.php

The company's business centers on the import and commercialization of raw materials, such as carbon fiber reinforcements, glass and aramid fibers, and resins used in shaping materials.

Universidad Autónoma de Occidente
+57 2 318 8000
Email: Faruk Fonthal Rico, ffonthal@uao.edu.co
Website: https://www.uao.edu.co/la-universidad/summary-uao

The University is home to the Research Group on Advanced Materials for Micro and Nanotechnology, whose lines of investigation include optoelectronics materials.

Universidad de Antioquia, Colombia
+57 4 219-8332
Email: Henry Colorado, henry.colorado@udea.edu.co
Website: http://www.udea.edu.co/wps/portal/udea/web/home

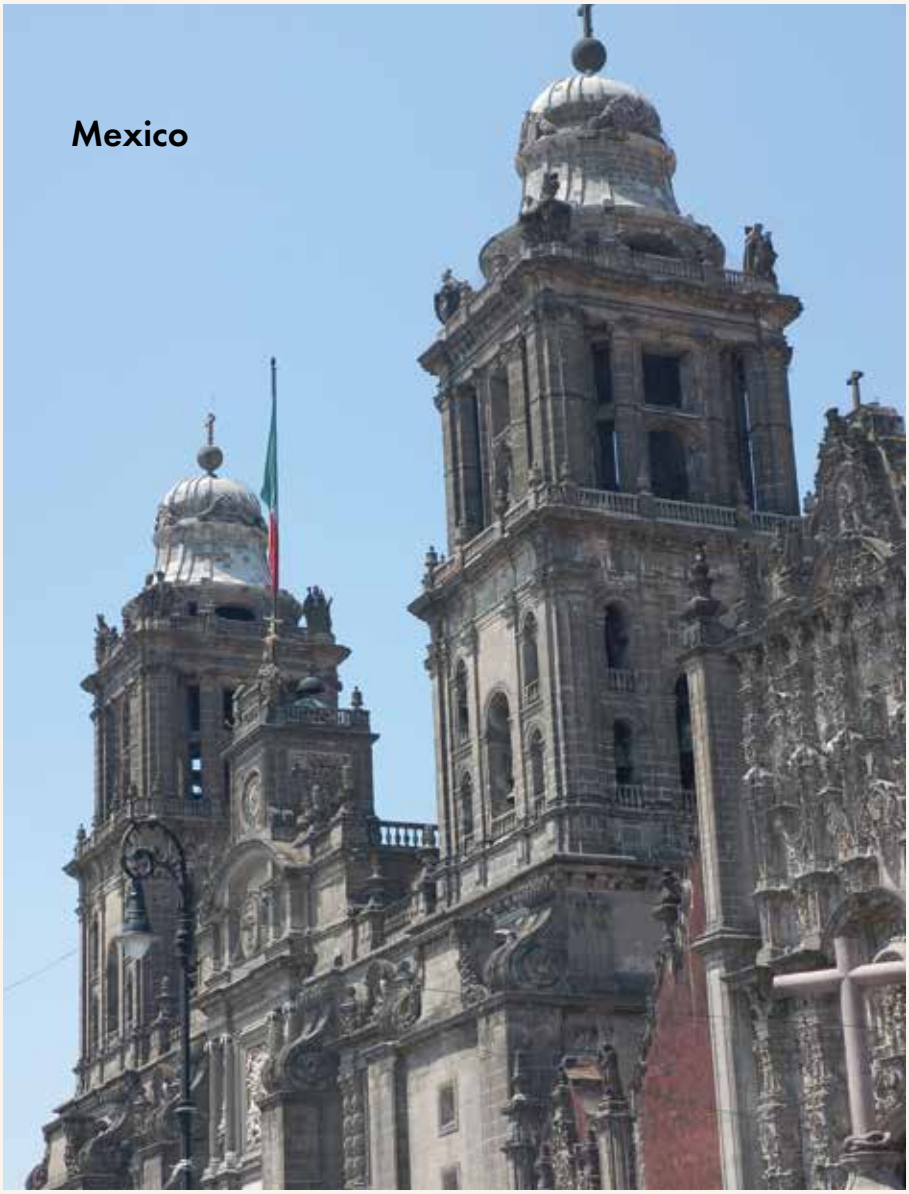
See our main article for our interview with professor Colorado, an ACerS member.

Universidad de Los Andes
Phone: +57 1 339-4999
Website: https://uniandes.edu.co

The University houses a Microelectronics Center for the characterization and manufacture of micro and nanoscale devices. Its clean room conforms to controlled environment class 1000 standards.

Universidad Nacional de Colombia, Manizales
Phone: +57 6 887-9300
Email: arosalesr@unal.edu.co
Website: https://www.manizales.unal.edu.co

Among the team's lines of investigation are simulation of magnetic systems, growth of magnetic materials, semiconductor nanostructures, and thermal materials.



Credit: Randy B. Hecht

COSTA RICA

Instituto Tecnológico de Costa Rica TEC
Phone: +506 2550-2213
Email: infome@tec.ac.cr
Website: https://www.tec.ac.cr/en

The School of Materials Science and Engineering houses a Materials Research and Extension Center whose lines of inquiry include degradation and protection of materials, characterization of materials and nondestructive tests, materials mechanics, and advanced technologies for the development and application of materials. The Center offers a variety of services to industry, including thermal and thermochemical treatments, metallography and macrography, X-ray diffraction, electron microscopy, mechanical tests, and nondestructive tests.

LANOTEC
National Laboratory of Nanotechnology
Phone: +506 2519-5832
General email: lanotec@cenat.ac.cr
Director: Jose R. Vega-Baudrit jvegab@gmail.com
Website: https://www.lanotec.org

The Center provides services in microscopy, spectrophotometry and thermal measurements, and physical–chemical measurements. An English-language digital brochure of its recent projects is available for download at https://www.lanotec.org/research.

Universidad de Costa Rica
Phone: +506 2511-1330 / 2511-1350
Website: https://www.ucr.ac.cr

The University houses the Materials Science and Engineering Research Center, which engages in "multidisciplinary scientific and technological research … dedicated to the study at the microscopic level of physical and chemical properties of materials, for their development and adaptation in industrial processes."

Center phone: +506 2511-6573
Center email: cicima@ucr.ac.cr

Directory of companies, government agencies, associations, institutes, and universities in Latin America (cont.)

ECUADOR

Centro de Nanociencia y Nanotecnología
Center for Nanoscience and Nanotechnology
Phone: +59 3 2398-9492
Email: cencinat@espe.edu.ec
Website: http://www.espe-innovativa.edu.ec/cencinat

The Center, which operates under the auspices of the Universidad de las Fuerzas Armadas (Armed Forces University), houses a nanomaterials characterization lab and engages in the following areas of research and capabilities: transmission electron microscopy, scanning electron microscopy, atomic force microscopy, X-ray diffractometry, sunlight simulator, and mechanical profilometry.

MEXICO

Note: Our 2013 international report was a dual profile of Mexico and Canada. Access the earlier report about Mexico, including that year's directory, at https://bulletin-archive.ceramics.org/2013-10.

CIMAV
Center for Research in Advanced Materials
Phone: +52 81 1156-0800
Email: Servando Aguirre, servando.aguirre@cimav.edu.mx
Website: https://cimav.edu.mx/en

A product of collaboration between government, academia, and industry, CIMAV encompasses 10 public and 14 private research centers, two incubators, and eight institutions of higher education (domestic and international). Its areas of focus include the design, synthesis, modification, and characterization of micro and nanometric-level materials. Research teams' advanced materials projects are developed for energy, environmental, and medical applications.

CIMAV Laboratorio Nacional de Nanotecnología
Website: https://ntch.cimav.edu.mx

Among the nanostructured materials and applications being researched at the lab are technology for production of carbon nanotubes; development of composite materials (metals–CNTs and ceramics–CNTs); production of silica aerogels; electrocatalysts for fuel cells, aerogels, and activated carbon; and micro and nanostructured polymeric sensors. A more extensive overview of all areas of research can be found at https://ntch.cimav.edu.mx/lineas-de-investigacion.

Consejo Nacional de Ciencia y Tecnología
National Science and Technology Council
Phone: +55 5322-7700
Website: https://www.conacyt.gob.mx/index.php

This government agency fosters and provides funding for "the development of scientific research, technological development and innovation in order to promote the technological modernization of the country." Its Advanced Materials Research Center carries out technological research and development as well as training in such areas as materials chemistry and physics, functional materials, coatings, nanostructured catalytic materials, polymer-based composite materials, and computational simulation of materials and processes. A more extensive overview of its programs and capabilities can be found at https://www.conacyt.gob.mx/index.php/comunicacion/comunicados-prensa/10-contenido-estatico/70-centro-de-investigacion-en-materiales-avanzados.

The government agency also oversees the Center of Advanced Technology (CIATEQ), whose work in the formulation and synthesis of polymers is a key area of focus in plastics and advanced materials. A more extensive overview of this work can be found at https://www.ciateq.mx/index.php/oferta-tecnologica/plasticos-y-materiales-avanzados.html.

Instituto Potosino de Investigación Científica y Tecnológica
Phone: +55 444 834-2000
Website: https://www.ipicyt.edu.mx

The Division of Advanced Materials engages in synthesis, characterization, and use of new materials and nanostructures for emerging applications. Areas of research focus include generation of alternative energy sources, organic electronics, gas sensors, and nanomedicine. The National Laboratory for Nanoscience and Nanotechnology Research and the National Supercomputing Center (used to conduct molecular simulations related to physiochemical, electronic, and magnetic properties) also operate under the auspices of IPICYT.

Credit: Randy B. Hecht

NANOCRON NANOTECNOLOGIA SA
Contact page: http://nanocron.com/index.php/contacts
Website: http://nanocron.com

The company specializes in "research, development, and production of nanoparticles with dimensions less than 200 nm, among which are metals, metal oxides and nanocomposites" as well as manufacture of nanopowders and nanodispersions for a variety of applications used in diverse industries.

PANAMA

Universidad Tecnológica de Panamá
Phone: +507 560-3061
Email: maytee.zambrano@utp.ac.pa, carlos.medina@utp.ac.pa
Website: http://gitts.utp.ac.pa/en

In addition to offering materials science, materials manufacturing, and nanotechnology courses, the University operates the Research Group on Advanced Technologies of Telecommunications and Signal Processing, where teaching and research follow four primary fields: applied information theory, wireless communication systems, signal processing for communication systems, and electrical engineering.

INDICASAT-AIP
Phone: +507 517-0700
Email: Rolando A. Gittens rgittens@indicasat.org.pa
Website: http://indicasat.org.pa/home

The Institute for Scientific Research and High Technology Services of Panama operates under the auspices of the National Secretariat of Science, Technology and Innovation. Its areas of priority are biodiversity, biotechnology, and biomedicine. Rolando Gittens' areas of research specialization include biomaterials, orthopedic and dental implants, and osseointegration of titanium.

ECOROADSA
Phone: +507 6832-2829 / 343-0897
Email: info-panama@ecoroadsa.com
Website: www.ecoroadsa.com

The company develops and commercializes technologies for environmentally friendly and sustainable road construction. Its nanotechnology-based product Zycotherm enables a chemical bond with asphalt cement that promotes adhesion and allows lower mixing temperatures.

NANOTECH+
Phone: +507 787-5322
Website: https://nanotechnology.com.pa

PERU

Universidad Nacional de Ingeniería
National Engineering University
+51 1 481-1070
Website: https://www.uni.edu.pe

The materials science research priority is nanoscience and nanotechnology—including nanomaterials and metallurgy and nanostructured materials—with the goal of establishing nanoscience strategies for Peru. Additional areas of focus include thin films, renewable energy, and advanced magnetic materials.

Universidad San Ignacio de Loyola
+51 1 317-1000
Email: Dra. Mercedes Puca Pacheco, Nanotechnology and Advanced Materials Research Unit, mercedes.puca@usil.pe
Website: https://www.usil.edu.pe/en/node/118 (English-language home page)

University research is focused on development of next-generation nanometric materials for technology, electronics, and medicine. Among its areas of investigation are synthesis and characterization of magnetic and metallic nanoparticles, nanostructure polymers, and graphene/graphene oxide as well as synthesis of polymeric nanocomposites reinforced with graphene.

Universidad Nacional Mayor de San Marcos
Mail: sanmarcosaldia@unmsm.edu.pe
Website: http://www.unmsm.edu.pe

Universidad Nacional De Trujillo
Phone: +51 44 633-952
Email: materiales@unitru.edu.pe
Website: https://www.unitru.edu.pe