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Ceramic & Glass MANUFACTURING

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WHEN SMALLER IS BETTER: THE PROMISE OF NANOMATERIALS

NANOPARTICLES WILL CHANGE THE WORLD, BUT WHETHER IT IS FOR THE BETTER DEPENDS ON DECISIONS MADE NOW

LOOKING TO THE PAST AND THE FUTURE OF NIOSH NANOTECHNOLOGY GUIDANCE

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Computational Methods for Glass & Ceramics
When: July 15 – 18, 2024
Instructors: Dr. Collin Wilkinson, Assistant Professor of Glass Science at Alfred University and Rebecca Welch, Visiting Scholar at Alfred University.

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1836 Alfred University OUTSIDE of ORDINARY

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Vol. 5, No. 1, pp 1–16.

INDUSTRY NEWS

JOINT VENTURE OF GERMAN TRADE FAIR COMPANIES

Two of Germany's biggest trade fair companies, Messe Düsseldorf and Deutsche Messe AG, agreed to pool their expertise in the Turkish market and will each hold a 50% share in Hannover Messe Ankiros Fuarcılık A.S. in Ankara. The venture organizes Ankiros/Turkcast, a large trade fair for the metallurgy and foundry industries, and Aluexpo, the largest aluminum trade fair for the Eurasian region. Messe Düsseldorf acquired 50% of the shares in Hannover Messe Ankiros Fuarcılık A.S., making both German trade fair companies equal business partners.

Ankiros/Turkcast is a leading Eurasian trade fair.

The Lithoz 3D printer uses laser slurry drying, or net shaping, technology.

LITHOZ, ORNL AGREE TO EXPLORE ADDITIVE MANUFACTURING TECH

Lithoz GmbH (Vienna, Austria) and Oak Ridge National Laboratory in Tennessee signed a research and development agreement to use Lithoz's 3D printing technology to explore the processing and additive manufacturing of nonoxide ceramics. The goal of the agreement is to develop technology to shape nonoxide ceramics with high-refractive indexes, such as silicon carbide, for use in extreme temperature applications and to scale up production of ultrahigh-temperature ceramic parts to an industrial level.

A HYDROGEN FIRST: MASS PRODUCTION OF A GLASS SPIRITS BOTTLE

Family-owned spirits company Bacardi (Hamilton, Bermuda) says it completed the world's first commercial production fueled by hydrogen of a glass spirits bottle. Bacardi worked with Slovenia-based glassmaker Hrastnik1860 to develop the technology that powered a glass furnace with hydrogen as its primary energy source. The trial produced 150,000 70cl glass bottles for spirits maker St. Germain. Hydrogen contributed more than 60% of the fuel for the glass furnace, cutting greenhouse gas emissions by more than 30%.


Bacardi operates production facilities in 11 countries and territories.


ReElement uses chromatographic refining equipment for separating and purifying rare earth elements. *Credit: ReElement Technologies*

PARTNERSHIP MAKES USE OF PURDUE RARE EARTHS TECHNOLOGY

Fishers, Ind.-based ReElement Technologies is partnering with Purdue University to use the university's patented rare earths technology. The technology uses ligand-assisted chromatography for separation and purification of rare earths and other critical elements from coal, coal byproducts, ores, recycled permanent magnets, and lithium-ion batteries. ReElement says the partnership will enable it to develop a domestic supply chain of critical materials for U.S. producers of recycled and ore-sourced rare earth metals.

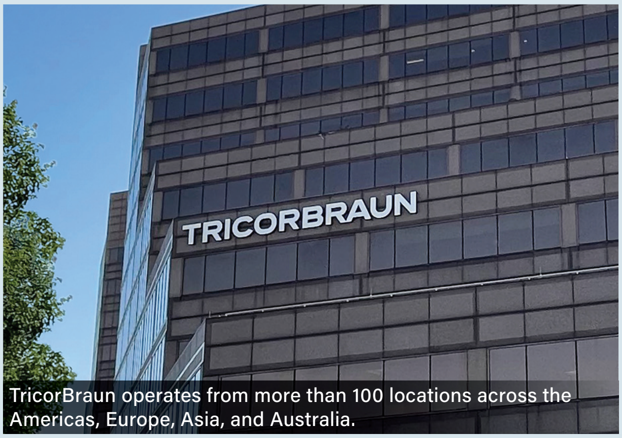
ORNL AND CITY-OWNED POWER COMPANY COLLABORATE ON RESEARCH

EPB, a Chattanooga, Tenn.-based municipal energy and telecommunications company, and Oak Ridge National Laboratory announced a joint research effort called Collaborative for Energy Resilience and Quantum Science. It will focus on using Chattanooga's energy and communications infrastructure to develop technologies for improving the resilience and security of the national power grid and accelerating the commercialization of quantum technologies.

Officials of the Department of Energy, U.S. Congress, Oak Ridge National Laboratory, and the city of Chattanooga announced the joint research project on energy and quantum science. *Credit: EPB*

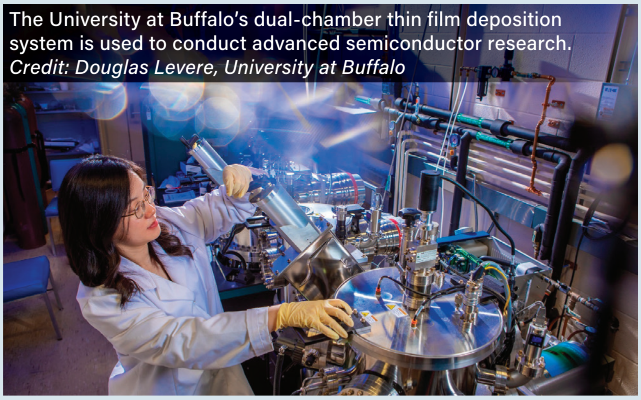
TRICORBRAUN ACQUIRES GERMAN GLASS MAKER

Packaging company TricorBraun acquired Bonn, Germany-based glass packaging provider Glassland. The acquisition grows the German footprint of St. Louis-based TricorBraun's glass packaging business, Vetroelite, and broadens the company's European presence. Glassland serves spirits makers and other customers in Germany and Switzerland with high-end glass bottle and closure designs. Since its founding in 1902, TricorBraun has acquired 41 packaging companies globally.



TricorBraun operates from more than 100 locations across the Americas, Europe, Asia, and Australia.

The University at Buffalo's dual-chamber thin film deposition system is used to conduct advanced semiconductor research. *Credit: Douglas Levere, University at Buffalo*



NEW YORK COLLEGE LAUNCHES CENTER FOR ADVANCED SEMICONDUCTOR TECHNOLOGIES

The University at Buffalo launched the Center for Advanced Semiconductor Technologies to continue its microelectronics and research innovation for the semiconductor industry. The center's director will be Jonathan Bird, professor and chair of the UB Department of Electrical Engineering. In October 2023, the Buffalo-Rochester-Syracuse region was designated a federal technology hub following the passing of the CHIPS and Science Act in 2022—a $280 billion effort to boost microchip research and production in the United States.

Representatives from the Jagodina, Serbia region attended Schott Pharma's groundbreaking ceremony. *Credit: Schott Pharma, Sasa Krstic*

SCHOTT BREAKS GROUND FOR PLANT IN SERBIA

Schott Pharma invested in a new production site in Jagodina, central Serbia, for pharmaceutical drug containment solutions and delivery systems. The site will produce ampoules for storing injectable drugs, including painkillers, inflammation inhibitors, and anesthetics. Other product groups might follow based on market demand, the company says. In the first phase, Schott will create 130 jobs, and 350 are planned for the expansion phase.

WHEN SMALLER IS BETTER: THE PROMISE OF NANOMATERIALS

By David Holthaus

In a world where bigger often equates to better, nanotechnology flips that on its head: smaller is superior. The relatively young science makes use of rapidly evolving research to exploit the unique properties that materials display when they are in the nanoworld, far too small to be seen by the naked eye.

A nanometer is one-billionth of a meter. Imagining something that small can be difficult, so it helps to describe this measurement in everyday terms. A sheet of paper is 100,000 nanometers thick. A human hair is about 80,000 nanometers wide. One inch equals 25.4 million nanometers.

Nanomaterials can come in different sizes and shapes, as long as at least one dimension is on the nanoscale (< 100 nm). For example, nanoparticles and quantum dots have all their dimensions on the nanoscale, while nanorods and nanofibers are confined to the nanoscale in two dimensions but can be longer in the third.

Some trace the advent of nanotechnology to a groundbreaking lecture in 1959 by Nobel Prize-winning physicist Richard Feynman at the California Institute of Technology.

"Atoms on a small scale behave like nothing on a large scale, for they satisfy the laws of quantum mechanics," he said during the lecture. "So, as we go down and fiddle around with the atoms down there, we are working with different laws, and we can expect to do different things. We can manufacture in different ways."

At the atomic level, Feynman said, scientists will see "new kinds of forces, new kinds of possibilities, and new kinds of effects." But, he noted, "The problems of manufacture and reproduction of materials will be quite different."

FROM RESEARCH TO APPLICATION

Although Feynman's lecture was delivered nearly 65 years ago, it was in the 21st century that the promise of nanotechnology began to materialize in many industrial sectors, including medicine, energy, information technology, and environmental science. That is when researchers and manufacturers gained the tools and techniques necessary to image and manipulate materials on the nanoscale.

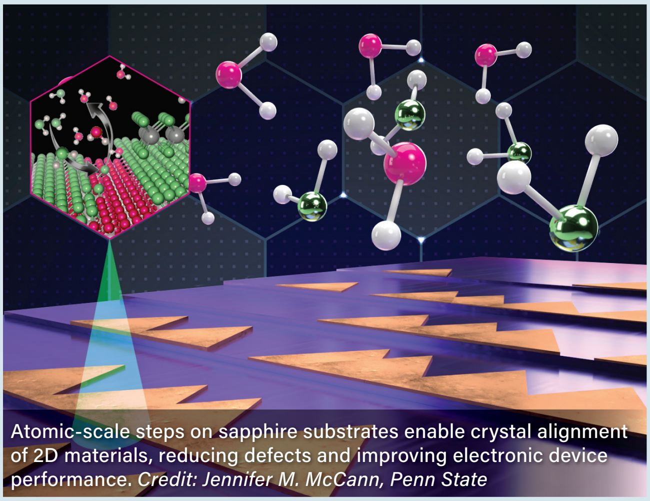
Nanomaterials allow for products to be made lighter, stronger, more durable, more reactive, and/or more conductive, among other properties. For example, nanoscale additives in personal body armor can make it lighter yet more protective. Nanoscale films on glass can make eyeglasses, computer screens, and cameras more water-repellent, anti-reflective, and self-cleaning. Nanoengineered materials in cars are found in high-power, rechargeable battery systems; thermoelectric materials for temperature control; and tires that improve fuel mileage. Nanostructured ceramic coatings improve wear resistance for machine parts, while nanoscale lubricants and engine oils can extend the lifetimes of moving parts in everything from power tools to industrial machinery.

In the United States, the National Nanotechnology Initiative (NNI) was launched in 2000, bringing together more than 30 federal departments, independent agencies, and commissions to work together on understanding and controlling matter on the nanoscale. Its main areas of focus include leveraging nanotechnology to improve water sustainability, sensors, and electronics.

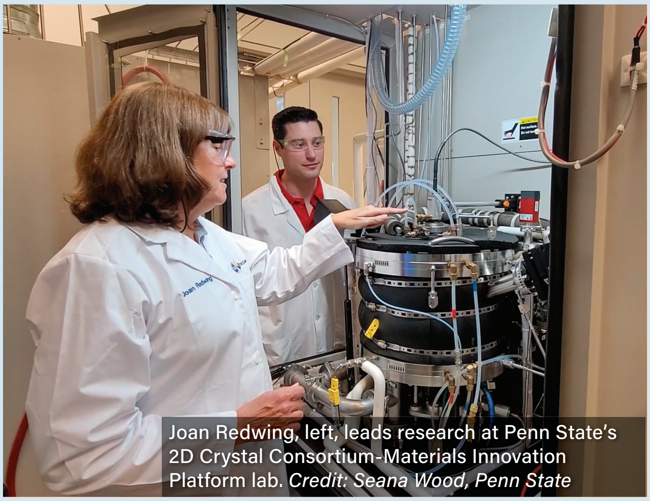
The NNI coordinates investments in nanoscale research and development across the U.S. government. Cumulatively, the participating government agencies and departments have invested more than

A nanomaterial sample from a large-scale reactor in Cerion's industrial-scale manufacturing facility. *Credit: Cerion*

A large-scale reactor mixes nanomaterial product at Cerion's manufacturing plant. *Credit: Cerion*



Atomic-scale steps on sapphire substrates enable crystal alignment of 2D materials, reducing defects and improving electronic device performance. *Credit: Jennifer M. McCann, Penn State*



Joan Redwing, left, leads research at Penn State's 2D Crystal Consortium-Materials Innovation Platform lab. *Credit: Seana Wood, Penn State*

$38 billion over the past 20 years to realize the potential of nanoscience, the agency says.

One company that produces nanomaterials is Cerion, a Rochester, N.Y.-based firm that designs, scales, and manufactures metal, metal oxide, and other ceramic nanomaterials for companies that are developing products and systems that will use them.

"We're one of the oldest and one of the largest in the United States for manufacturing nanomaterials," says CEO Landon Mertz. "We're about 16 years old now, which, at least in our industry, makes us a dinosaur. It's still a very young industry."

Although Cerion was founded in 2007, its history goes back much farther to Rochester-based photography pioneer Eastman Kodak Company, which developed the precipitation-based manufacturing processes for fabricating materials used in photographic film emulsions. Building on that work, Cerion researchers developed processes to create and scale up nanomaterials to satisfy customer specifications.

Some of the main challenges in the nanomaterials industry include being able to rapidly design custom materials specific to a product or system while preserving the material's technical attributes during scale-up and manufacturing. Plus, they must accomplish these goals in a cost-efficient manner.

Landon Mertz

Some manufacturers may customize off-the-shelf materials or invest in bringing nanomaterial expertise in-house, but this approach can be costly. Cerion focuses on designing and scaling nanomaterials to meet specific customer needs.

"We provide product development teams and commercialization teams with access to advanced expertise in precision design, scale-up, and manufacturing so that our customers can get access to nanomaterials at commercial scale," Mertz says.

In its earlier years, Cerion scientists saw demand for nanomaterials that can modify the refractive index in glass for use in mobile phone displays, television displays, and augmented reality. But over the last few years, Mertz says the demand in the ceramics market has shifted toward powders.

"What you tend to see is somebody's making a part that is either wholly or partially comprised of a nanomaterial that then gets incorporated into a larger system," he says.

Nanomaterials are a general-purpose technology, Mertz says, a technology that can be implemented across the entire economy throughout a wide range of industries.

"We tend to see demand across almost every major industrial sector, but it tends to be on the higher-value end of the spectrum," he says.

In the ceramics sector, the biomedical field is the most explored, as ceramic nanoparticles are considered good carriers for drugs, genes, proteins, and imaging agents, according to researchers at Jamia Hamdard University in New Delhi, India. They say nanoparticles have been successfully used as drug delivery systems against bacterial infections, glaucoma, and, most widely, cancer.

NEXT-GENERATION ELECTRONICS

The field of 2D materials is where some of the most leading-edge nanomaterials research is conducted today. 2D materials are a class of nanomaterials that are merely one or several atoms thick, but they have properties that include being exceptionally strong, lightweight, flexible, and excellent conductors of heat and electricity.

At The Pennsylvania State University's Materials Research Institute, Joshua Robinson and his team are working on creating 2D materials for applications in next-generation electronics beyond silicon for digital circuits and flexible electronics, as well as developing novel coating technologies and functionalities enabled by 2D materials.

"The 2D materials we focus on are made on a flat surface and grown over very large areas," Robinson says. "We can make these so that they're compatible with the standard electronics industry. Our aim is to manufacture them in a way that is useful for folks like Intel that are working hard on next-generation transistors and things like that."

Graphene, a 2D material consisting of carbon atoms arranged in a honeycomb-like structure, is made by researchers in Penn State's 2D Crystal Consortium-Materials Innovation Platform lab using a small furnace that heats elements to 2,400°C. Graphene is very strong but also super thin, which allows electrons to move much faster through it than they can through silicon, the basis of today's computer chips.

Replacing silicon with graphene may allow computers to transmit information much faster than they already do and make them even more energy efficient. But before they can be manufactured at industrial scale, they must be produced and perfected in places such as Robinson's lab.

Although the focus of Robinson's lab currently is semiconductors, there are many other applications for their research.

"There's use of these materials in things like catalysis and hydrogen evolution for energy," he says. "There's also materials for photovoltaics, like solar cells."

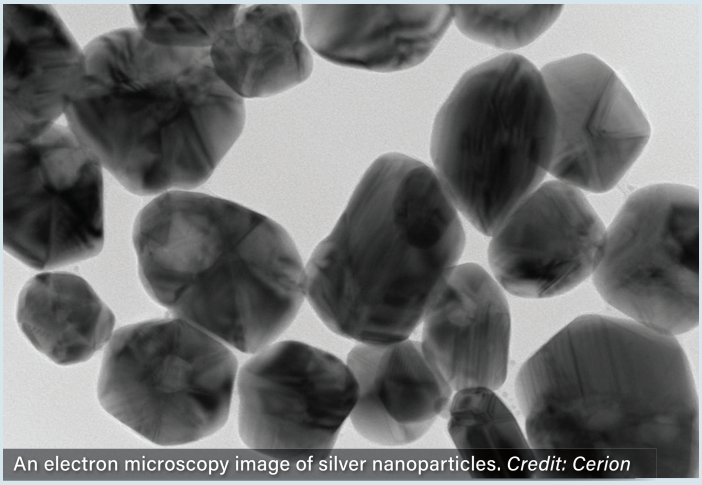
EUROPE'S INVESTMENT IN GRAPHENE

Graphene was first isolated in 2004 by two researchers at the University of Manchester, U.K. Since then, research on this ultra-thin and ultrastrong material has exploded, and it can be found in commercial products including lithium-ion batteries, motorcycle helmets, and lubricants in high-power electronics.

Several groups in Europe are leading the charge on graphene research. For example, the University of Manchester now houses the National Graphene Institute and the Graphene Engineering Innovation Centre. A team of scientists there in January 2024 announced they had received a 3-million-euro investment to help them develop a lithium-free energy storage solution.

Additionally, in 2013, the European Union formed a consortium of industry and academic partners called The Graphene Flagship. The initiative was one of three established by the European Commission to investigate major, long-term scientific and technological challenges. The others are a project on the human brain and one on quantum technologies.

The effort was initially funded with one billion euros from the European Commission and focused largely on academic research. It gradually evolved to industry-led projects using the research gained from its initial work, says Patrik Johannson, director of the Graphene Flagship.


An electron microscopy image of silver nanoparticles. *Credit: Cerion*

"Our overall vision over these years has been 'from lab to fab[rication],'" he says.

Research conducted through the Flagship has led to 83 patents, and 17 spin-off companies have been generated from it, according to the consortium's latest annual report. So far, the Flagship has convened 11 industry-led projects that are focused on real-world applications.

The Flagship's industry partners include Fiat-Chrysler (Amsterdam, Netherlands), which is working on a dashboard for vehicles that will feature conductive patterns, sensors, and other devices based on graphene. Sweden-based energy giant ABB is working on a maintenance-free circuit breaker that would replace grease in drive mechanisms with self-lubricating graphene. And aerospace company Lufthansa is working on a project to improve air filtration systems in aircraft using graphene foams.

The versatility of graphene and its potential to be used in such a broad range of applications led to the European Union's effort, Johannson says. But he notes the cost of the material varies depending on its application.

"Do you want it to be for wafer production? Or do you want it as a filler in concrete? You can imagine that's quite different," he says.

The costs of nanomaterials may adjust as their applications become more accepted in the marketplace, says Cerion's Mertz.

"The way we need to look at it is how do we get more volume into the marketplace, which helps bring some fixed costs down," he says. "The people that tend to adopt new technologies need some kind of new leading-edge performance. And they are willing to pay for it. You're first to market. Over time, as you ramp up volumes, you're able to make these materials more mass-market."

Significant challenges remain in converting research lab findings to industrial applications and in scaling up production, which includes controlling for cost. Other challenges, particularly with biomedical materials, include gathering long-term information on their safety. And standards for the industry are still under development, making it difficult to develop regulatory guidelines.

But thanks to more than two decades of basic research, investment, and application, it is almost certain that these challenges will be overcome, allowing nanotechnology to improve and even revolutionize many more technology and industry sectors.

Nobel Prize winners in nanoscience

By David Holthaus

Over the last decade-plus, the Royal Swedish Academy of Sciences has awarded several Nobel Prizes for groundbreaking research in nanomaterials.

In 2023, the Nobel Prize in Chemistry was awarded to a trio of scientists for the discovery and development of quantum dots, nanoparticles so tiny that their size determines their properties. Quantum dots now illuminate computer monitors and television screens based on QLED technology. They also add depth to the light of some LED lamps, and biochemists and doctors use them to map biological tissue.

Physicists had long known that, in theory, size-dependent quantum effects could arise in nanoparticles, but it was considered almost impossible to design materials on that scale with precision. So, few believed this knowledge could be put to practical use. But in the early 1980s, Aleksey Yekimov, now the chief scientist at U.S. company Nanocrystals Technology (New York, N.Y.), succeeded in creating size-dependent quantum effects in colored glass. The color came from nanoparticles of copper chloride. Yekimov demonstrated that the particle size affected the color of the glass via quantum effects.

A few years later, Louis Brus of Columbia University was the first scientist to demonstrate size-dependent quantum effects in particles floating freely in a fluid. Then in 1993, Moungi Bawendi of Massachusetts Institute of Technology revolutionized the chemical production of quantum dots, resulting in a high quality that was necessary for them to be used in applications.

"They planted an important seed for nanotechnology," the Royal Swedish Academy said in awarding the coveted prize.

In 2010, the Nobel Prize in physics was awarded to two scientists at the University of Manchester in the United Kingdom who first unambiguously produced and identified the 2D material graphene. Andre Geim and Konstantin Novoselov extracted a single-atom layer of carbon from a piece of graphite using ordinary adhesive tape. Their groundbreaking work was done at a time when many believed it was impossible for such thin crystalline materials to be stable.

Today, graphene is known to be a conductor of electricity that performs as well as copper. As a conductor of heat, it outperforms all other known materials. It is almost completely transparent, yet so dense that not even helium, the smallest gas atom, can pass through it. Because of these properties, it has applications in batteries, transistors, and computer chips, among others.

NANOPARTICLES WILL CHANGE THE WORLD, BUT WHETHER IT IS FOR THE BETTER DEPENDS ON DECISIONS MADE NOW

By Kristin Omberg

Kristin Omberg is group leader of the Chemical and Biological Signatures Group at Pacific Northwest National Laboratory. This article was originally published in The Conversation and can be found at theconversation.com/us. Republished with permission.

Technologies based on nanoscale materials—for example, particles that are more than 10,000 times smaller than the period at the end of this sentence—play a growing role in our world. Carbon nanofibers strengthen airplanes and bicycle frames, silver nanoparticles make bacteria-resistant fabrics, and moisturizing nanoparticles called nanoliposomes are used in cosmetics.

Nanotechnology is also revolutionizing medicine and pushing the boundaries of human performance. If you received a COVID-19 vaccine in the United States, it contained nanoparticles.

In the future, nanotechnology may allow doctors to better treat brain diseases and disorders like cancer and dementia because nanoparticles pass easily through the blood-brain barrier.

Nanoparticles in eye drops may temporarily correct vision. And strategically implanted nanoparticles in the eyes, ears, or brain may enable night vision or hearing that's as good as a dog's. Nanoparticles could even allow people to control their smart homes and cars with their brains.

This isn't science fiction. These are all active areas of research.

But frameworks for assessing the safety and ethics of nanoparticles have not kept pace with research. As a chemist working in bioscience, I am worried by this limited oversight. Without updated frameworks, it's hard to tell whether nanotechnology will make the world a better place.

NANO—WHAT AND WHY?

Any particle or material between 1 and 100 nanometers in one dimension can be classified as "nano." The period at the end of this sentence is 1,000,000 nanometers, and a human hair is about 100,000 nm in diameter. Both are much too large to be considered "nano." A single coronavirus is about 100 nanometers in diameter, and soot particles from forest fires can be as small as 10 nanometers in diameter—two examples of naturally occurring nanoparticles.

Nanoparticles can also be produced in a laboratory. The adenovirus vectors, nanolipoparticles and mRNA used in COVID-19 vaccines are engineered nanoparticles. The zinc oxide and titanium dioxide used in sheer mineral sunscreens are also engineered nanoparticles, as is the carbon nanofiber in airplanes and bicycle frames.

Nanoparticles are useful because they have different properties than larger materials, even when they have the same chemical composition. For example, large particles of zinc oxide cannot be dissolved in water and are used as pigment in white paint.

Nanoscale zinc oxide is also used in sunscreen, where it looks nearly transparent but reflects sunlight away from your skin to prevent sunburn.

Nanoscale zinc oxide also exhibits antifungal and antibacterial properties that could be useful for making antimicrobial surfaces, but the reason for its antimicrobial properties is not completely understood.

And therein lies the problem. While many scientists are interested in exploiting the positive properties of nanomaterials, my colleagues and I are concerned that scientists still don't know enough about their behavior.

NANOTECHNOLOGY SAFETY

Nanoparticles are attractive to biomedical researchers because they can slip through cell membranes. The antimicrobial properties of nanoscale zinc oxide are probably related to their ability to cross bacterial cell membranes. But these nanoparticles can cross human cell membranes as well.

In the United States, zinc oxide is "generally recognized as safe and effective" by the Food and Drug Administration for products like sunscreen because it's unlikely—in sunscreen—to be toxic to humans.

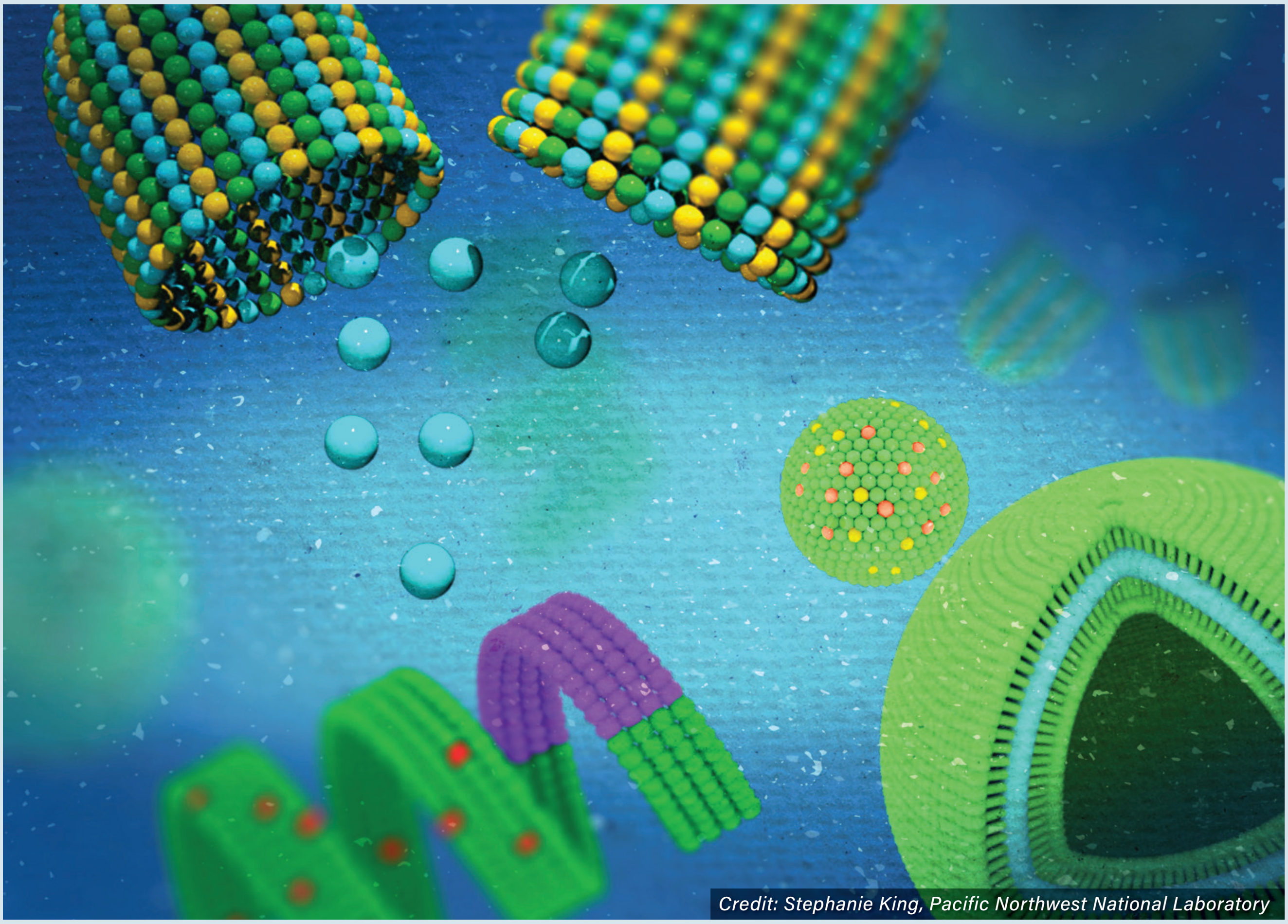
However, although scientists understand the health effects of large particles of zinc oxide fairly well, they don't fully understand the health effects of nanoscale zinc oxide. Laboratory studies using human cells have produced conflicting results, ranging from inflammation to cell death.

I'm a big believer in sunscreen. But I also worry about the environmental effects of particles that are known to cross cell membranes.

Hundreds of tons of nano-zinc oxide are produced each year, and it doesn't degrade easily. If we don't understand its behavior better, there's no way to predict whether it will eventually become a problem—though increasing evidence suggests nano-zinc oxide from sunscreen is damaging coral reefs.

NANOTECHNOLOGY ETHICS

Nanoparticles' ability to cross cell membranes does make them effective in therapeutics like vaccines. Nanoparticles show promise for regenerating skeletal muscles, and they could one day treat muscular dystrophy, or the natural atrophy that comes with age.



Credit: Stephanie King, Pacific Northwest National Laboratory

But COVID-19 vaccines provide a cautionary tale—nanoparticle-enabled COVID-19 vaccines were quickly adopted by the United States and Europe, but lower-income countries had far less access due to patent protections on the vaccine and a lack of production and storage infrastructure.

Nanoparticles may also allow for human performance enhancements, ranging from better eyesight to soldiers engineered to be more effective in combat.

Without an ethical framework for their use, performance-enhancing nanotechnologies that are accessible only in certain places could deepen wealth gaps between high- and low-income countries.

EMERGING OVERSIGHT

Today, different countries treat nanoparticles differently. For example, the European Union's Scientific Committee on Consumer Safety has banned the use of nanoscale zinc oxide in aerosol sunscreens across the E.U., citing their potential to get into lung cells and, from there, move to other parts of the body. The United States has not taken similar action.

The European Union established a nanobiotechnology laboratory to study the health and environmental effects of nanoparticles.

In the United States, the National Nanotechnology Initiative, a coordinated government-sponsored research and development effort, works to bring legal and ethical experts together with scientists. They weigh the benefits and risks of nanotechnologies and disseminate information to other scientists and the public.

Overcoming the disparity in nanoparticle-enabled vaccine distribution is another issue altogether. The World Health Organization's COVAX program sought to ensure fair and equitable access to COVID-related therapeutics. Similar measures should be considered for all nanotechnology-enabled medicine so everyone can benefit.

Synthetic biology is a field that is experiencing similarly rapid growth. For the past 20 years, the nonprofit iGEM Foundation has held an annual worldwide student competition, which it uses as a platform to teach young scientists to think about the broader implications of their work.

The iGEM Foundation requires participants to consider safety, security and whether their project is "good for the world." The nanotechnology research community would benefit greatly from adopting a similar model. Nanotechnologies that change the world for the better require coordinating science and ethics to shape how they are used and controlled long after we create them.

LOOKING TO THE PAST AND THE FUTURE OF NIOSH NANOTECHNOLOGY GUIDANCE

By Jay Vietas and Lilia Chen

Jay Vietas and Lilia Chen are co-manager and coordinator, respectively, of the Nanotechnology Research Center (NTRC) and branch chief and deputy branch chief, respectively, of the Emerging Technologies Branch in the NIOSH Division of Science Integration. This article was originally published on the NIOSH Science Blog at https://blogs.cdc.gov/niosh-science-blog. Republished with permission.

The National Institute for Occupational Safety and Health (NIOSH) has been at the forefront of research on engineered nanomaterials since the early 2000s. As the NIOSH Nanotechnology Research Center (NTRC) celebrates its 20th anniversary, we look back over two decades of NIOSH NTRC published guidance to help reduce worker exposures to engineered nanomaterials (ENMs).

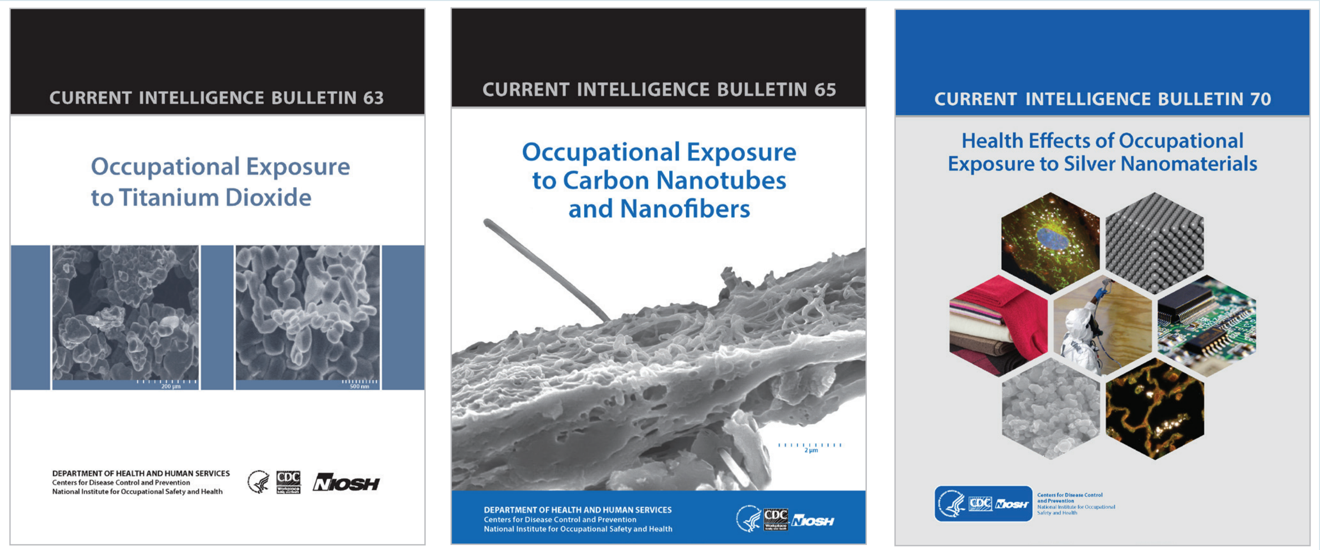
Both companies and workers use this guidance to keep workers safer. NTRC research has led to improved recommendations for controlling exposures during advanced manufacturing processes. Organizations have also used our guidance to base global standards.

Here, we reflect on how our guidance and publications have evolved through decades of research. We also discuss the needs for future research efforts.

THE NTRC STRATEGIC PLAN

In 2005, NIOSH became the first government agency to publish a strategic plan as a roadmap for nanotechnology research. This work, titled *Approaches to Safe Nanotechnology: An Information Exchange with NIOSH*, led to seminal guidance for the nanotechnology industry.

The strategic plan served multiple purposes. It offered a chance to collect safety and health concerns about nanomaterial exposures. It also outlined research needs and gave recommendations for workplace practices. International organizations and others used those workplace practices to create guidance documents. In 2009, the strategic plan was updated and published as "Approaches to safe nanotechnology: Managing the health and safety concerns associated with engineered nanomaterials."[1]



Examples of Current Intelligence Bulletins providing guidance on workplace exposure to engineered nanomaterials. *Credit: National Institute for Occupational Safety and Health*

To protect the nanotechnology workforce, NIOSH published the "Strategic Plan for NIOSH Nanotechnology Research and Guidance" in 2010.[2] Updated in 2014 and 2019, the plan currently describes the NTRC strategy into 2025.[3]

The strategic plan includes filling knowledge gaps in these priority areas:

- Researching the toxicology of available nanoparticles on the market
- Studying long-term effects of carbon nanotubes
- Developing exposure limits and control recommendations for fine and ultrafine titanium dioxide and carbon nanotubes
- Finding new nanomaterials coming into the market for mass production

ESTABLISHING WORKPLACE EXPOSURE LIMITS AND RECOMMENDATIONS

Occupational exposure limits are the "gold standard" for those working in occupational safety and health. NIOSH recommended exposure limits (RELs) are intended to prevent adverse health effects in workers from occupational inhalation exposures for up to a 10-hour shift, 40-hour work week, over a working lifetime. Researchers develop RELs from the best science available for a given material.

NIOSH was the first U.S. government agency to establish RELs for ENMs. In 2011, for the first time in its history, NIOSH released two RELs for the same chemical based on fine and ultrafine sizes. These were published in "Current Intelligence Bulletin 63: Occupational exposure to titanium dioxide."[4] Workplace guidance recommendations were also provided in this Current Intelligence Bulletin.

NIOSH also published two other ENM-related guidance documents:

- "Current Intelligence Bulletin 65: Occupational exposure to carbon nanotubes and nanofibers" (2013): https://www.cdc.gov/niosh/docs/2013-145/pdfs/2013-145.pdf
- "Current Intelligence Bulletin 70: Health effect of occupational exposure to silver nanomaterials" (2021): https://www.cdc.gov/niosh/docs/2021-112/pdfs/2021-112.pdf

TARGETED GUIDANCE FOR EMPLOYERS

In addition to exposure limits, employers need to know the best workplace practices to meet exposure targets. NIOSH has published guidance documents for these employers:

- "Medical screening and hazard surveillance for workers potentially exposed to engineered nanoparticles" offers interim guidance on controlling exposures with practical measures, conducting hazard surveillance, and using established medical surveillance methods (2009): https://www.cdc.gov/niosh/docs/2009-116/pdfs/2009-116.pdf
- "General safe practices for working with engineered nanomaterials in research laboratories" addresses ENM handling in research laboratory settings (2012): https://www.cdc.gov/niosh/docs/2012-147/pdfs/2012-147.pdf
- "Strategies for engineering controls in nanomaterial production and downstream handling processes" helps to find and describe methods for controlling ENM exposures using engineering controls (2014): https://www.cdc.gov/niosh/docs/2014-102/pdfs/2014-102.pdf
- "Building a safety program to protect the nanotechnology workforce" is targeted to small- and medium-sized businesses (2016): https://www.cdc.gov/niosh/docs/2016-102/default.html
- "Occupational exposure sampling for engineered nanomaterials" offers workplace sampling guidance for carbon nanotubes and nanofibers, silver, titanium dioxide, and other ENMs without exposure limits (2022): https://www.cdc.gov/niosh/docs/2022-153

TARGETED GUIDANCE FOR EMPLOYEES

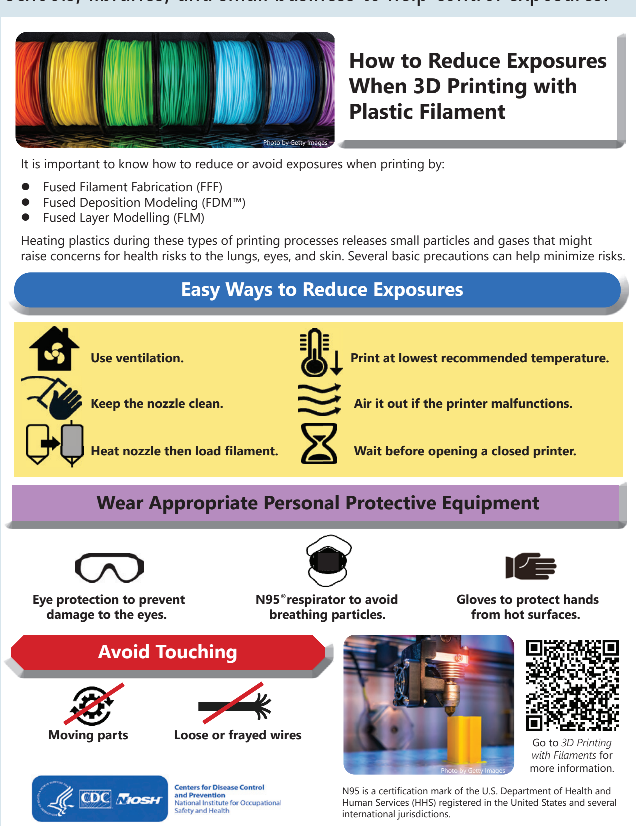
Ultimately, NIOSH aims to protect the health of the worker. When workers understand why and how to manage their exposures, they are more likely to take actions to protect their health. NIOSH published clear, concise, one-page guidance documents specifically for workers.

For example, three NIOSH posters present safety questions workers should ask before working with nanomaterials[5] and when 3D printing with filament[6] or metal powders.[7] The posters can help workers in recognizing possible hazards. The posters include the types of controls and personal protective equipment workers could use to protect themselves.

NIOSH also published an infographic on reducing exposures when 3D printing with plastic filament.[8] It highlights easy ways to reduce exposures during fused filament fabrication, fused deposition modeling, and fused layer modeling.

LOOKING AHEAD TO THE FUTURE

NIOSH NTRC remains committed to offering research-based guidance to meet the needs of the ever-changing field of nanomaterials and related emerging technologies. Researchers recently published "Approaches to safe 3D printing: a guide for makerspace users, schools, libraries, and small business to help control exposures."[9]



Example of a one-page guidance document published by NIOSH to help workers understand why and how to manage their exposure to engineered nanomaterials. *Credit: National Institute for Occupational Safety and Health*

They are also laying the groundwork to develop additional occupational exposure limits for ENMs.

NIOSH continues to seek and gather feedback from the advanced manufacturing industry and provide guidance. The aim is to bridge knowledge gaps and make actionable recommendations. If you have input or suggestions about guidance or research needs, contact nano@cdc.gov.

You can find a full list of NIOSH nanotechnology publications at Nanotechnology Guidance and Publications.[10]

To celebrate the 20th anniversary of the Nanotechnology Research Center, the National Institute for Occupational Safety and Health will focus on nanomaterials in its 2024 science blog posts. View the NIOSH Science Blog at https://blogs.cdc.gov/niosh-science-blog.

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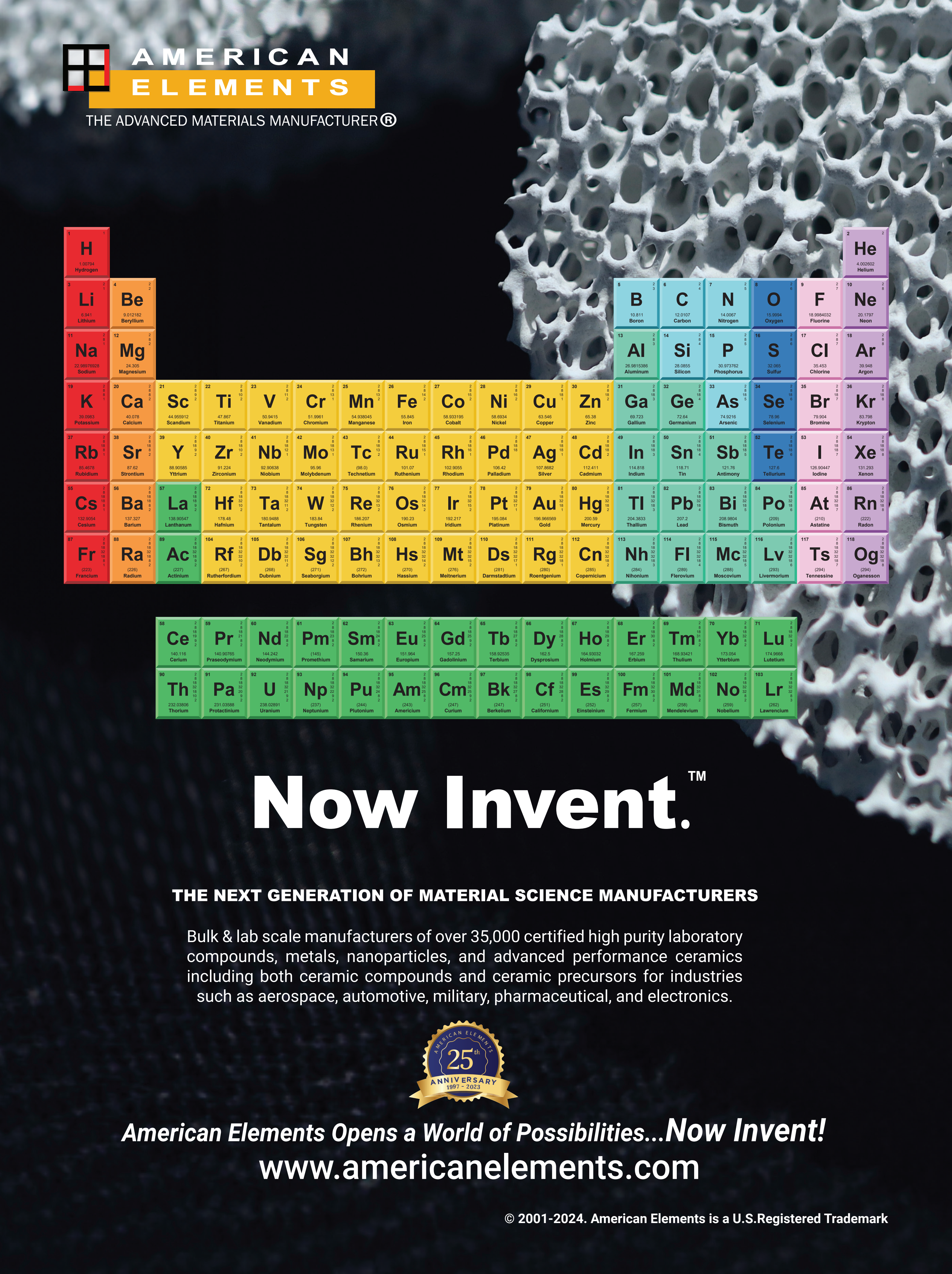

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