Testimony of

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Advanced Composites for Infrastructure

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Introduction

Chairwoman Comstock, Ranking Member Lipinski, and Members of the Committee, I am Dr. Joannie Chin, Deputy Director of the Engineering Laboratory at the Department of Commerce's National Institute of Standards and Technology (NIST). The NIST laboratory programs work at the frontiers of measurement science to ensure that the United States (U.S.) system of measurements is firmly grounded in sound scientific and technical principles. With the unique facilities at the NIST laboratories, we address complex measurement challenges on every scale, from nanoscale devices for the next generation of electronics, to vehicles, buildings, and the resilience of whole communities. We work in the physical realm on advanced manufacturing, and in the virtual world of cybersecurity and cloud computing. As new technologies are developed and evolve, NIST's measurement research and services remain central to innovation, productivity, trade, and public safety. Thank you for the opportunity to appear before you today to discuss NIST's role in accelerating the adoption of advanced composites for new infrastructure, and for enhancing the resilience of American communities.

NIST and Advanced Materials

NIST's work on advanced composites, which, for our purposes today, I will define as polymers strengthened with fibers or other additives, is part of NIST's work in the advanced manufacturing and materials measurements area—a broad portfolio of research that includes work to help computer chips continue to shrink while becoming more powerful, to make additive manufacturing a widespread capability, and to accelerate the discovery of new materials through the NIST-led Materials Genome Initiative. Through NIST, the Nation has world-leading measurement capabilities, in both expertise and equipment, that no individual company or sector could amass. The authorities granted to NIST by Congress enable us to respond to the needs of American companies across the manufacturing landscape, working on difficult problems to the benefit of entire sectors.

Why do measurements matter? Measurements give us a common language for the performance of materials and help us have confidence in them, which is particularly important for buildings, bridges, jet engines, and medical devices, and for acceptance of new technologies like wearable electronics and tissue engineering. Since it was established in 1901 by Congress as the National Bureau of Standards, NIST has been developing new ways to measure materials with ever-increasing precision and accuracy, and to characterize novel materials for use in research and commerce. These measurements are critical inputs to the growth of the Nation's economy.

In addition to our programs in the NIST laboratories, we provide members of industry, academia, and other government agencies with access to two unique, powerful user facilities for investigating advanced materials. The first, the NIST Center for Neutron Research, provides unmatched thermal and cold neutron measurement capabilities to U.S. industry and the research community. The second of our user facilities, the NIST Center for Nanoscale Science and Technology, supports the U.S. nanotechnology enterprise from discovery to production by providing access to measurement and fabrication methods and technology. NIST also partners with a Department of Energy user facility, the National Synchrotron Light Source II at Brookhaven National Laboratory, which produces X-rays so bright that researchers can actually see individual atoms in materials. The National Synchrotron Light Source II contributes to the development of new semiconductors for computers and other applications, batteries and solar and fuel cells, superconducting materials, catalysts for chemical production, and materials that can assemble into complex structures by themselves.

To meet increasingly complex materials challenges in many diverse areas such as safety and security, health care, infrastructure, and other national needs, America needs new materials with special properties. Typically, discovering and proving out a new material is a decades-long process. NIST is a leader in a new approach that makes materials property data accessible and usable so that researchers and manufacturers working in pre-competitive arenas can leverage each other's efforts to propel whole fields forward. The federal multi-agency Materials Genome Initiative is helping industry shave years off the traditional timeline for discovering, developing, and deploying new materials in commercial and clinical products. Applying the "materials genome" approach, researchers use data on the known properties of materials and computer modeling to inform how to combine or process substances to get the performance they need, avoiding time-consuming trial-and-error experiments. NIST supports the Materials Genome Initiative with tools that make materials data more easily publishable and discoverable, and decreases the barriers inherent to sharing large, complex materials science datasets.

NIST and Advanced Composites

NIST has conducted research on advanced composites since the 1980s. Currently, we run more than a dozen projects that use measurement science to investigate the properties of advanced composites for a variety of applications including auto body components, impact- and ballistic-resistant gear for athletes and first responders, dental repair and reconstruction, and flexible electronics and semiconductors. NIST also has active collaborations with the Institute for Advanced Composites Manufacturing Innovation (IACMI), part of the Manufacturing USA network of public-private institutes that advance American manufacturing capabilities through innovation and workforce development. IACMI's goal is to help industry make lower cost advanced composites that require less energy to produce, with better potential for being recycled.

Our research is driven by industry needs, which we learn about through scientific collaborations with market leaders, deep-dive workshops, and road mapping exercises. NIST has helped to generate road maps for the composites industry. The 2017 *U.S. Composites Manufacturing Industry Technical Roadmap*[1] identified challenges for composites manufacturing generally, including advancing material performance and new processing methods and materials. Another 2017 publication, *A Technology Roadmap for Joining and Repair of Advanced Polymer Matrix Composites,*[2] addressed the goal of reducing composite repair cost and cycle time by 50 percent in the aerospace industry, where taking an aircraft out of service can result in a substantial loss of revenue. A future AMTECH-funded road map will address challenges in the use of thermoplastics for automotive and other forms of transportation.

[1] https://www.nist.gov/amo/facilitating-industry-engineering-roadmapping-and-science-fibers-advance-us
[2] http://www.manufacturing.gatech.edu/sites/default/files/uploads/pdf/2017_caiiac_report_web.pdf

Advanced Composites in Infrastructure

NIST's most recent advanced composite road mapping efforts are focused on infrastructure. The American Society of Civil Engineers 2017 Infrastructure Report Card issued a D+ grade to U.S. infrastructure, stating that the U.S. would need to invest $2 trillion to raise our grade over four years, and calling for "new approaches, materials, and technologies to ensure our infrastructure is more resilient."[3]

Advanced composites are often stronger, lighter, and longer lasting than traditional building materials, thereby offering many cost savings. For example, compared to traditional materials, it takes less fuel to transport these lighter components. The equipment required to assemble advanced composite components into bridges or other structures can be lighter, and advanced composites can resist corrosion from weather and exposure to chemicals. The longer lifespans for infrastructure components that include advanced composites mean fewer service days lost to maintenance of the bridges, roads, dams, levees, highways, railroads, utility poles, and other elements that support movement of the goods and services that underpin our economy.

The American advanced composites industry comprises some 500 companies selling to customers worldwide, and contributes about $22 billion to the U.S. economy each year.[4] Although America currently leads the world in advanced composite technology, adoption of these materials has been slower in the United States than in Canada and Europe, where advanced composites have been used in hundreds of bridges. The benefits of advanced composites for both our infrastructure and economy are not being fully realized here in the United States. Knowing that NIST frequently provides a neutral forum where industry members can speak candidly about challenges, the American Composites Manufacturers Association (ACMA) asked us to help convene the community.

Accelerating Adoption of Advanced Composites for Infrastructure

Road Map for Overcoming Barriers

A February 2017 workshop at NIST brought together infrastructure designers, owners, manufacturers and researchers to identify barriers to the use of advanced composites. We learned that builders want materials that save time and minimize costs, but they need to know how long their roads, bridges, and other infrastructure elements will last. Designers and engineers need guidance so they can use composites with confidence, and provide appropriate safety margins while maximizing the weight- and cost-savings attributed to these materials. The workshop resulted in a road map of activities that will encourage wider and faster adoption of advanced composites for infrastructure. The *Road Mapping Workshop Report on Overcoming Barriers to Adoption of Composites in Sustainable Infrastructure*, published in December 2017, is available to the public.[5]

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[3] https://www.infrastructurereportcard.org/wp-content/uploads/2016/10/2017-Infrastructure-Report-Card.pdf
[4] https://acmanet.org/composites-industry-overview/
[5] http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1218.pdf

Durability testing and standards: Since the first composite utility poles were installed in the 1960s, the field has rapidly improved materials and processing methods. Some kinds of advanced composites are so new that we don't know how they age in natural conditions over the usual life span of a large structure like a bridge—expected to last more than a century. In the absence of data, designers and engineers concerned with durability and safety might conservatively require use of additional material, but this can needlessly increase both costs and weight of the structure. Uncertainty about the long-term performance of novel materials is a potential obstacle to adoption for use by designers, engineers, builders, and owners.

Workshop participants set a goal of predicting the wear on a structure over 100 years of service through testbeds that can simulate accelerated aging, which will generate data and predictive models, which, in turn, will be the basis for durability standards and design tools available to the whole community through an online portal. A five-year partnership among durability researchers and members of industry will help to ensure these resources are relevant to the rapidly evolving composites field. In addition, data will be needed on the performance of new composite materials when subjected to strong shaking (such as during an earthquake), high winds (during a hurricane, tornado, or severe thunderstorm), or abnormal loads, like accumulations of snow and ice. Such data will be critical to developing safe and resilient communities in a cost-effective manner.

NIST is well-positioned to lead this work: We have decades of expertise in measurement science for advanced composites, particularly in the fundamental and highly interdisciplinary science and engineering work needed to determine durability, fatigue, and resilience. As an example, a unique NIST device for accelerated weathering, known as SPHERE, or Simulated Photodegradation via High Energy Radiant Emission, can generate controlled temperatures, humidity, and ultraviolet exposure for more than 500 samples at a time, and simulate 50 days of sunlight in one day. We also have large-scale structural testing facilities that can evaluate the effects of strong loads on advanced composite infrastructure. At the small end of the scale, a NIST project has developed fluorescent-sensors and test methods for quantifying and visualizing damage in composites.

As a non-regulatory agency, NIST has a long history of partnering with industry to develop voluntary consensus standards. NIST staff members provide leadership and technical expertise through more than 1800 positions on technical committees and work groups organized by ASTM, the International Organization for Standardization, and numerous other standards development organizations.

Design data clearinghouse: Although the U.S. is not yet leading the world in adopting advanced composites, there are successful infrastructure applications that can be shared with the community. A central clearinghouse of curated design guides and data tables from completed projects can help engineers and designers use the materials to their best advantage, and provide confidence in the materials' performance and life span. NIST, in partnership with the ACMA, will hold a workshop on the data clearinghouse in August 2018. The workshop goal is to generate an authoritative source of data and standards, with the ultimate goal of harmonizing standards globally. Uniform global standards will make it easier for American advanced composites manufacturers, engineers, and designers to compete in foreign markets.

Training and education: The Composites Roadmapping Workshop identified a need for more awareness of and confidence in advanced composites at all levels of the industry, from current designers, engineers, and owners, to students. Information that NIST and other researchers and practitioners generate from testing, standards, and data tables and design guides will inform curricula for industry certification of engineers and designers, and guide creation of apprenticeships for aspiring engineers and designers—who will have the power to specify and design for these materials in the future, increasing their use.

NIST and Community Resilience

The 2017 U.S. hurricane season reminded us that natural hazards take a high toll on communities with impacts that can last long after the event. To address these impacts, NIST manages a multi-faceted Community Resilience Program, a part of our broader disaster resilience work, assisting communities and stakeholders on issues related to the built environment and the interdependencies of physical infrastructure systems.

Resilience planning that includes making optimum choices of construction materials can improve a community's quality of life and economic well-being, as well as its ability to recover faster and better. Advanced materials such as composites may help mitigate the effects of natural and man-made disasters and contribute to more rapid post-disaster rebuilding. Disaster recovery and re-building activities will involve important decisions that weigh the strengths and weaknesses of different material systems, and the multiscale and multidisciplinary materials science research conducted at NIST-gives architects, design engineers, and, ultimately, community leaders the proper information to make these critical decisions.

<u>Research Needs for Resilient Buildings and Infrastructure</u>

NIST will host the road mapping workshop, "Research Needs Concerning Performance of Externally-Bonded Fiber Reinforced Composite Systems in Resilient Buildings and Infrastructure," in May 2018. Over the past decade, advanced composites have been used to reinforce concrete structures, masonry buildings, and bridges so they are more resilient to the demands of everyday use and weather, and to extreme events like earthquakes and hurricanes, but there is a lack of data to inform the choices infrastructure owners make about these relatively new materials and applications. The upcoming workshop will ensure NIST's future research on the reliability of advanced composites is valuable at all levels of industry and meets national needs. Once the performance and health of advanced composite systems have been grounded in measurement science, the resilience of infrastructure elements can be modeled and evaluated.

NIST and Data

A common thread through the many challenges that need to be addressed to expand the use of composites in infrastructure is advanced data and modeling. One of the products of the Materials Genome Initiative, the Materials Data Curation System, is a standardized way for engineers and designers to capture and share data on the properties of materials, including advanced composites. NIST has already begun training ACMA staff members to use the Materials Data Curation System. NIST will continue this work and host another workshop in August.

The materials genome approach has accelerated materials discovery for metals and glass, but has been slower for advanced composites, for which there is less available data. New advanced composite materials are typically made using slow, costly trial-and-error experiments. The Center for Hierarchical Materials Design (ChiMaD), a center of excellence in advanced materials funded by NIST and led by Northwestern University and the University of Chicago, is addressing this gap through Nanomine, a database of polymer nanocomposite properties, and a partnership with SpaceX that focuses on aerospace composites. We envision that these same data-driven approaches will soon be applied to discovery of new advanced composites for infrastructure.

Conclusion

Advanced composites can help us renew and repair the nation's infrastructure with lighter, more durable materials that require less maintenance, ensuring the movement of goods, services, and citizens. NIST is a leader in characterizing the performance and properties of advanced materials, including composites, on all scales, and in making data widely available and useful to the benefit of whole industries. Enabled by NIST programs, design engineers will be able to apply the full range of materials to enable cost-effective and innovative solutions to the Nation's infrastructure challenges with the benefit of knowing the strengths and weaknesses of all available options. NIST's work to accelerate the adoption of advanced composites is part of our broad program, informed by the needs of industry, that helps companies develop and reliably manufacture new products made with advanced materials, making American industries more competitive globally, and enhancing our quality of life.

Thank you for the opportunity to testify today. I am happy to answer any questions you may have.

JOANNIE W. CHIN

Dr. Joannie W. Chin is the Deputy Director of the Engineering Laboratory (EL) at the National Institute of Standards and Technology (NIST), one of seven research laboratories within NIST. As Deputy Director, she provides programmatic and operational guidance for EL, which has an annual budget of $90 million and nearly 500 federal employees and guest researchers from industry, universities, and research institutes. EL's mission is to promote the development and dissemination of advanced manufacturing and construction technologies, guidelines, and services to the U.S. manufacturing and construction industries through activities including measurement science research, performance metrics, tools and methodologies for engineering applications, and critical technical contributions to standards and codes development. EL focuses on high-leverage, high-impact infrastructural measurements and standards efforts to foster U.S. manufacturing and construction industry innovation, productivity, and competitiveness, improve building and fire safety, and reduce the environmental impact of buildings and manufacturing activities. EL is a source of unbiased measurement standards, data, and cutting-edge methods and technologies that promote innovation, market readiness, and quality control in vital economic sectors.

Prior to her appointment as Deputy Director, Dr. Chin previously served as leader of the Polymeric Materials Group in the Materials and Structural Systems Division of EL. She has published more than 100 scientific papers and holds a U.S. patent on a unique device for accelerated weathering of materials. She is a member of the ASTM Board of Directors and the American Chemical Society.

Education

Ph.D. in Materials Engineering Science from Virginia Polytechnic Institute and State University

M.S. in Chemistry from Virginia Polytechnic Institute and State University

B.S. in Polymer Science and Engineering from Case Western Reserve University