Topics for Materials Genome Initiative (MGI) Challenges

Accelerating the introduction of new materials will have profound impacts in areas that support economic prosperity, human health, the environment, energy, and national security. As described in its [2021 Strategic Plan], the MGI will utilize challenges to help unify and accelerate adoption of the Materials Innovation Infrastructure through expansion and exploitation of capabilities in autonomous experimentation, artificial intelligence and machine learning, and robotics and automation to identify solutions to issues of national interest. These challenges will inspire and help grow an MGI-ready workforce. The MGI Challenges will be organized under the following areas:

Protecting and improving human health

In order to advance initiatives to bolster the Nation's health and wellbeing, new materials are required to provide alternative and affordable solutions to extend health span for all Americans. Advances in drug delivery include use of nano and bioinspired materials to target infections, damage, and diseases across of the human body. Other topics for consideration include artificial cartilage; soft materials for women's health (reconstructive breast materials, nano drug delivery systems for women's cancers, pelvic floor, osteoporosis, etc.); materials for medical devices, nerve guides and novel dental materials; nanomedicine design; and personalized implant materials. Materials for portable or wearable devices that can monitor exposure to toxic substances and pollutants are additional areas of interest. Use of autonomation to quickly design around supply chain disruptions and opportunities to utilize existing infrastructure from other fields to advance biomedicine are also included in this category.

Delivering sustainable and resilient energy

With continued strain of natural resources and critical materials, new materials are required to ensure the nation's energy infrastructure remains resilient, affordable, and accessible. Challenge topics of interest include advanced materials and materials systems for increased performance, longer lifetime, higher reliability, reduced environmental impact, and lower cost compared with incumbent energy technologies. Examples include: optimized energy conversion from renewable sources such as wind, solar, geothermal, hydro-power, and biomass; portable, and cleaner nuclear energy, including safe handling and reuse of nuclear waste. Additional examples include high-performance, and fit-for-use energy storage and transmission at scale, such as: low-cost secure grid storage and transmission solutions; energy-rich synthetic fuels derived from renewable resources such as solar energy, including clean hydrogen and electrofuels such as methanol and ammonia, among others; and new battery solutions for diverse applications such as ultra-long range electric vehicles, portable devices, and high-power density, modular units for aerospace.

Thriving in extreme environments

Human innovation and exploration have, and will continue, to push the boundary of survivability and sustainability. From developing a new space economy to exploring the bottom of the ocean, new affordable materials are required to ensure structural, thermal, chemical, and radiation resiliency. Extreme environments include high or low temperatures, rate of temperature change (thermal shock), exposure to radiation, chemicals, corrosive environments (including seawater), pressure, impact, shock, and most critically combinations of such stressors that non-linearly combine to cause failure. Potential topics for consideration span multifunctional materials, coatings, or sealants that can withstand exposures to temperature fluctuations, radiation, and corrosive chemical exposures; survive blast and shock; or harden functional devices such as electronics, sensors, and memory. The ability to forecast performance degradation is crucial. These materials can open new vistas in diverse end uses such as nuclear and concentrated solar power; propulsion; thermal and thermochemical energy storage; cryogenic applications including superconductivity and liquid hydrogen transport; space exploration; and national defense.

Enhancing structural performance

Structural materials are often overdesigned to ensure performance and avoid failure during the system's lifetime. Also, infrastructures (such as transportation, telecommunication, and other key sectors) are susceptible to high costs of sustainment. Finally, most of these applications require substantial volume of materials that stresses the supply chain. In all cases, certification and qualification of new materials and manufacturing processes are crucial for engineering decisions. Taken together, these factors make new material insertion expensive. The MGI can help optimize trade-offs and reduce cost of scale-up and validation. Potential topics for consideration include strengthening and extending life of infrastructure; improving failure resistance via composite design, advanced joining technologies, and self-healing concepts; light-weighting to enhance structural efficiency, expand design space, and reduce cost; modular material systems methods to improve performance and repairability; and accelerated certification approaches.

Protecting the environment

New materials are needed to remediate existing environmental damage, including to break down forever chemicals and capture greenhouse gases. MGI approaches can also accelerate the intentional development and design, manufacture and use of materials and chemicals that promote circularity and are more environmentally benign. Potential topics for consideration include designing for reuse, direct mineral to application transformations, lower temperature synthesis and processing, new materials for catalysts, low-carbon concrete, sequestration, direct air capture technologies, membrane technologies for energy efficient separations (including clean water and industrial processes), reusable materials for separation, refinement, and replacement of critical minerals and elements.

Propelling the information and communications technology revolution

The information and communications technology (ICT) revolution has transformed society. Nearly all aspects of modern life are now dependent on semiconductor technology, including communications, computing, entertainment, health care, energy, and transportation. As a result, these technologies are essential to the economic and national security of the United States. MGI approaches to accelerate the deployment of new materials will be critical to the continued race to increase the performance and functionality of ICT systems, while reducing cost and power requirements.

On June 13, 2024, the Office of Science and Technology Policy released its AI Aspirations. For materials, there is a vision to develop new, high-performance, sustainable materials in years rather than decades for globally competitive semiconductor manufacturing.

Additional topics for consideration include materials and manufacturing processes for devices, components and packages for advanced electro-optical, infrared, and radio frequency sensor capabilities, energy efficient microelectronics, compact optical & photonic systems, quantum technologies, hybrid and unconventional computing (analog, neuromorphic, beyond von Neumann architectures, etc.), ultra-dense memory, wireless communication (6G and beyond), flexible packaging, and high-power electronics.

Advancing Critical and Emerging Technology

Earlier this year, OSTP released an update to the Critical and Emerging Technologies list. The MGI is in a position to deliver leap-ahead impacts in many of these areas, creating jobs, delivering economic prosperity, mitigating threats from adversaries, and ensuring asymmetric strategic advantage and dominance. Examples of critical and emerging technologies and subfields that cross many sectors include convergent manufacturing methods; remote assembly and repair such as in space or under the ocean; approaches to material scale-up to enable validation, certification, and manufacturing development; metrology and non-destructive techniques for quality control and inspection; "gold" standard data sets of materials and processes for specifications and standards; standard and interoperable representations of materials data and performance for digital engineering tools; and approaches to balance material data sharing while addressing security and integrity.