Advanced Materials and Manufacturing

Designing unique materials and fostering innovation in advanced manufacturing to fabricate structures with the properties and performance needed to address national security missions.

Introduction

Lawrence Livermore National Laboratory (LLNL) brings a multidisciplinary approach to address our nation's need for rapid development of advanced materials and manufacturing (AMM) processes. Scientists and engineers develop innovative materials with tailored properties that can be used for energy absorption, dissipation, generation, or storage; bioinspired structures for use in drug delivery; advanced optics used in satellites and telescopes; quantum materials; and components that can function effectively in extreme environments.

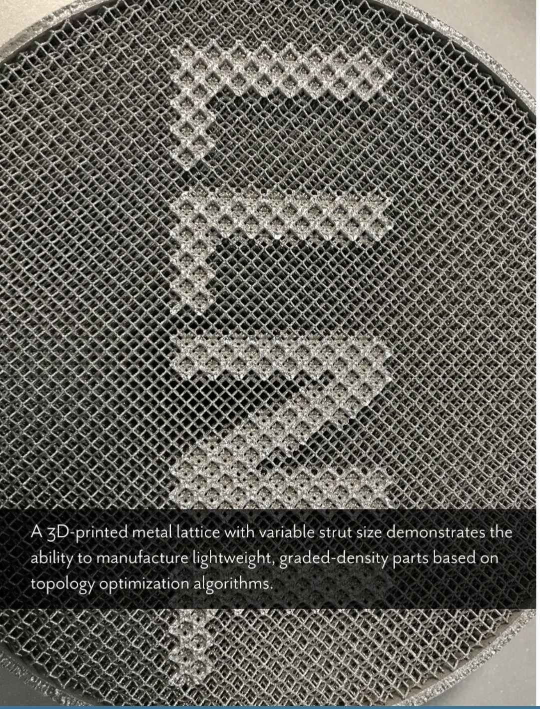
Livermore continues to advance manufacturing technology, enabling the development of customized feedstocks and inventing unique fabrication techniques. Novel diagnostic methods are developed and implemented to test and evaluate components during manufacturing, which accelerates the Laboratory's ability to deliver timely solutions.

AMM creates a more agile, responsive material development and manufacturing ecosystem to meet the needs of national security stakeholders. The team explores ways to enhance performance of materials and components, cut manufacturing costs, minimize supply chain vulnerabilities, reduce material and energy waste, and accelerate discovery, development, scalability, and deployment timelines.

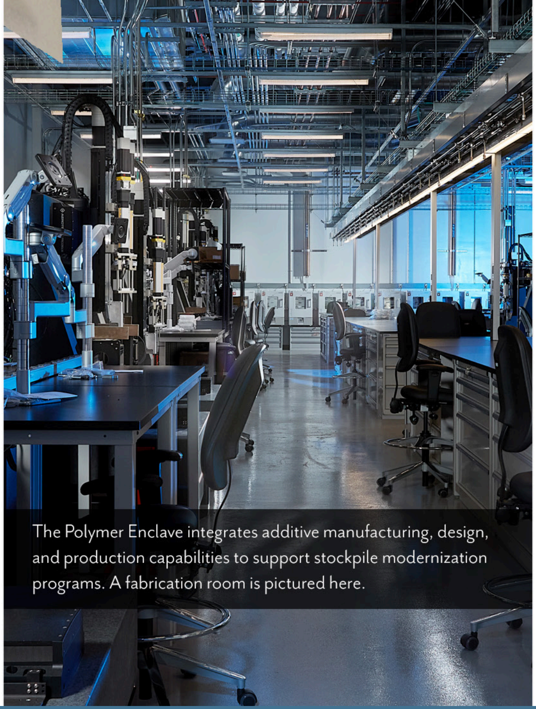
Applications

LLNL's research leverages decades of experience studying materials, manufacturing technologies, and mission-relevant applications. Livermore's expertise spans the design-development-deployment cycle, including materials that can meet emerging mission needs, capabilities to produce materials at scale, advanced manufacturing methods, and structures tailored to meet specific performance requirements. AMM expertise is evident across the Laboratory:

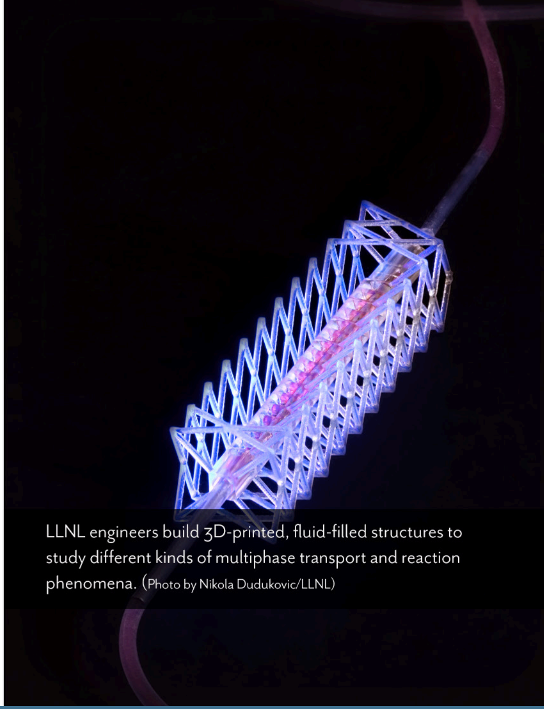
- The Advanced Manufacturing Laboratory (AML) facilitates industrial and academic partnerships to address challenges across commercial and government projects.
- The Polymer Enclave enables rapid design and development of polymer parts for stockpile modernization programs, offering a unique space where design activities and production enhancements can be rapidly tested and evaluated.
- The Laboratory for Energy Applications for the Future (LEAF) fosters cross-cutting research aimed at accelerating development of scalable, optimized structures for energy production, storage, and transmission, such as batteries, supercapacitors, hydrogen energy systems, desalination, and carbon capture and conversion.
- LLNL's high-performance computing resources and artificial intelligence expertise accelerate solutions through multiscale, high-fidelity modeling of material synthesis and manufacturing processes, enabling scientists to design new materials and feedstocks.
- A suite of advanced, in-situ diagnostics and non-destructive characterization tools, including 3D imaging, spectroscopy, x-ray computed tomography, and ultra-fast electron microscopy enable researchers to assess a material's properties and identify defects.
- Facilities designed to handle advanced radiological materials, where researchers deploy customized actinide processing techniques and deliver high-purity, actinide-based materials for mission-critical applications.
- At the Center for Engineered Materials and Manufacturing (CEMM), researchers develop new advanced and additive manufacturing techniques, new feedstock materials, multi-material and multiscale structures, fabricate materials with previously unachievable properties, and apply these advances to LLNL missions in national security and energy.
- At the Center for Design and Optimization, staff use computational methods to optimize systems governed by nonlinear, dynamic, multiphysics, or multi-scale phenomena.
- Testing of medical countermeasure is greatly accelerated by 3D printed biological cells and matrices to develop organ-on-a-chip systems.



A 3D-printed metal lattice with variable strut size demonstrates the ability to manufacture lightweight, graded-density parts based on topology optimization algorithms.



The Polymer Enclave integrates additive manufacturing, design, and production capabilities to support stockpile modernization programs. A fabrication room is pictured here.



LLNL engineers build 3D-printed, fluid-filled structures to study different kinds of multiphase transport and reaction phenomena. (Photo by Nikola Dudukovic/LLNL)

Accomplishments

LLNL integrates expertise in engineering, materials science, physics, chemistry, data science, modeling and simulation, and manufacturing to create innovative solutions. For example, material scientists study the chemical, electronic, structural, and kinetic properties of materials—including polymers, alloys, ceramics, foams, and biomimetic materials. Researchers also explore ways to enhance feedstock development, fabrication techniques, and characterization methods, while studying material aging and degradation that can impact long-term performance. Livermore experts leverage the power of artificial intelligence and data science to optimize designs and achieve rapid advances in materials science. A broad suite of LLNL resources contribute to these accomplishments, such as:

- Microcapsules containing carbon-trapping sorbents that can rapidly absorb chemicals and make them available for reuse in a range of applications, such as capturing carbon dioxide or biogas to be removed and reused or compressed and stored underground.
- A new method to 3D-print microbes in controlled patterns, expanding the potential for using engineered bacteria to recover rare-earth metals, clean wastewater, and detect actinides.
- Invention of a Volumetric Additive Manufacturing (VAM) technique, which can be used to fabricate 3D objects with complex architectures in a matter of seconds to minutes by projecting a combination of tomographic images into a photosensitive resin.
- Additively manufactured transparent glass with customized composition and structure to create a gradient index of refraction optical components.
- Customized alloys for extreme environments, with thermally stable microstructures that are lightweight, corrosion-resistant, and radiation tolerant, and use of predictive models to identify age-resistant designs—with applications such as hypersonic vehicles, space science, high-power lasers, and nuclear reactors.
- A groundbreaking method for fluid transport using 3D-printed open-cell lattice structures and capillary action phenomena. These micro-architected structures could impact many fields, including electrochemical or biological reactors used to convert carbon dioxide or methane to energy, advanced microfluidics, solar desalination, air filtration, heat transfer, transpiration cooling, and the delivery of fluids in zero-gravity environments.

The Future

The long-term vision of the Advanced Materials and Manufacturing team involves leveraging LLNL's newest resources to expand our collaborative research space. For example, we will explore new partnerships with industry and other research institutions at the Advanced Manufacturing Lab and the Polymer Enclave, which will boost our ability to rapidly deliver solutions.

LLNL will continue to take a leadership role in DOE-sponsored research activities involving hydrogen research, including new materials to enable compact and efficient storage and delivery of hydrogen. LLNL experts will also continue participating in the DOE Energy Materials Network and the DOE Critical Materials Institute.

Additionally, the team will explore ways to adapt innovative solutions for new environments, including biosecurity, water security, space science and security, and materials for environmental remediation. LLNL will support efforts to ensure the long-term performance of our energy production and delivery infrastructure as they face risks to material used in pipelines, turbines, and nuclear power plants. At the same time, the Laboratory will continue to focus on accelerating delivery of solutions that support the reliability of our nuclear deterrent.

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