MANUFACTURING SCIENCE

Despite the decline of traditional manufacturing in the United States, the sector is still responsible for around 12% of the total gross domestic product, with 8% of total employment in 2013, and is the most important part of the U.S. economy according to total output. Los Alamos National Laboratory manufacturing capabilities support our national security customers and the core National Nuclear Security Administration (NNSA) mission. These capabilities support developing innovative and cost-effective manufacturing solutions for our applied energy programs in partnership with other national laboratories and industry. Our global security program customers rely on our manufacturing science capabilities to develop innovative solutions for their missions and to deliver expert assessments of the capabilities of our adversaries. Los Alamos has a natural role to play in providing innovations in manufacturing science, which can be utilized in our national security mission as well as in enabling knowledge transfer to industry via strategic partnerships and spin-off companies.

The scope of the Manufacturing Science area of leadership spans the application of fundamental science research and development activities to understand the critical steps in the manufacturing process to achieve control and optimization. This leadership area does not include the challenges of supply chain logistics, plant configuration and control, quality control, and many other engineering aspects of a highly tuned manufacturing plant. Although manufacturing is very much an applied area of research, fundamental science underpins our knowledge of many traditional manufacturing processes such as casting and welding and modern approaches such as additive manufacturing. However, even in widely used traditional methods such as casting, the detailed physics involved in the solidification process is not well understood. The science challenges in the manufacturing process can be usually described by the process-structure-properties-performance paradigm. This implies that a given manufacturing process produces a well-characterized materials structure, which then exhibits a specified set of properties resulting in the intended performance. The challenge lies in attaining a detailed understanding of the correlations in each of these steps to achieve controlled functionality in the final manufactured part. This knowledge can help us better understand legacy manufacturing processes and assess

Given the Laboratory's responsibility for design authority for the nuclear explosives package and the manufacturing mission of pits and detonators, manufacturing science is critical to our mission. Here, researchers use an extruder in the Lab's Sigma Complex.

Materials for the Future

The Los Alamos National Laboratory Materials for the Future strategy derives from our vision to support the Laboratory's national security mission drivers.

We pursue the discovery science and engineering for advanced and new materials to intentionally control functionality and predict performance relevant to ensuring the success of the Lab's missions.

To deliver on our missions, our materials strategy builds on materials science and engineering, enabling the necessary Laboratory leadership in seven key areas:

- Complex Functional Materials
- Material Resilience in Harsh Service Conditions
- Manufacturing Science
- Actinides and Correlated Electron Materials
- Integrated Nanomaterials
- Energetic Materials
- Materials Dynamics

whether a new manufacturing process—that may be more cost-effective and efficient—still produces a material of high quality meeting performance requirements.

Los Alamos Leadership in Manufacturing Science

Given the Laboratory's responsibility for design authority for the nuclear explosives package and the manufacturing mission of pits and detonators, manufacturing science is critical to our mission. For materials within the nuclear explosives package, Los Alamos is unique in the NNSA complex for supporting research on the entire spectrum of manufacturing—from fundamental scientific studies of the manufacturing process to production of parts for systems. Deep materials manufacturing expertise at the manufacturing plants has declined. The Laboratory must retain this nuclear explosives package materials manufacturing expertise to adequately support our design authority making future changes and decisions relative to the stockpile. Traditionally the Lab has focused on the manufacture of metal parts, but there is also considerable experience in manufacturing of both polymer and high-explosives-based products. Los Alamos has expertise in casting and welding and has deployed several new instruments for additive manufacturing focused on directed-energy processes such as laser engineered net shaping. Los Alamos possesses unique high-resolution characterization capabilities for studying the structure of manufactured parts such as the Spectrometer for Materials Research at Temperature and Stress at the Lujan Neutron Scattering Center, which is particularly useful for probing the residual stress and preferred orientation in manufactured parts. The Advanced Simulation and Computing program has invested in the development of modeling and simulation tools to treat both traditional casting and additive manufacturing processes via our TRUCHAS code and has developed microstructural models that are able to predict residual stress and performance of manufactured materials.

Key Science Questions

- How do we develop predictive tools that allow manufacturing for particular functionality and structure, and also address the issue of scaling-up of processes from the bench to production scale covering a wide range of processing and performance conditions?
- How do we tie processing to qualification and quantify limits and uncertainties and their influence on performance?
- How do we understand which physics ultimately dominate the material properties in the manufacturing process?
- How can we control and quantify the introduction of materials defects into manufactured parts while retaining desired performance?
- How can we produce validated modeling tools and in situ diagnostics that ultimately enable rapid feedback to allow for on-the-fly adjustment of manufacturing parameters?

10-year End State

Los Alamos National Laboratory will have implemented a robust, well-understood manufacturing process for several materials in the stockpile using new in situ diagnostics and characterization tools that fully elucidate the manufacturing process. An advanced manufacturing facility with experimental and simulation capabilities in an unclassified setting will serve to provide new staff experience while awaiting training and clearance approval. As an example, this facility will have catalyzed the advanced manufacture of a part qualified for use in the stockpile and delivery of an integrated and validated code that realizes the process-structure-properties-performance pathway for manufacturing.

For more information, please see materials.lanl.gov or send email to materials@lanl.gov.

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