Measurement Science Roadmap for Polymer-Based Additive Manufacturing

Workshop Objectives

- Develop roadmap that identifies the measurement science research and standards needed to accelerate the commercialization and adoption of polymers-based additive manufacturing
- Build on prior AM roadmaps and other efforts that have identified technology challenges and R&D requirements
- Provide direction and input to standards development organizations and the Additive Manufacturing Standards Collaborative hosted by ANSI

Anticipated Roadmap Results and Impacts

- Influence the national research agenda for polymers-based additive manufacturing
- Influence the selection, priorities, and timing of new standards development
- Advance AM capabilities for U.S. manufacturers

Measurement Science Roadmap for Polymer-Based Additive Manufacturing

The term measurement science is used in the context of creating **critical-solution enabling tools – metrics, models, and knowledge** – for U.S. manufacturers.

This includes:

- Development of
    - Performance metrics
    - Measurement and testing methods
    - Predictive modeling and simulation tools
    - Knowledge modeling
    - Protocols
    - Technical data
    - Reference materials
    - Artifacts
- Conduct of inter-comparison studies and calibrations
- Evaluation of technologies, systems, and practices, including uncertainty analysis
- Development of the technical basis for standards, codes, and practices

Prior AM Measurement Science Workshop

- Measurement Science for Metal-Based Additive Manufacturing (Dec 2012) with 88 AM experts: follow up meeting in May 2016.
  - For roadmap report try web search on:

    NIST additive metals roadmap

Similar process and objectives:

- Build upon prior AM roadmaps
- Actionable plans: what's needed and how to get there – beyond just a list of research needs
- Foundation for ASTM F42 strategic plan
- Detailed input for America Makes national AM roadmap
- Consensus needs and priorities to influence the national research agenda

Sample Action Plan from Final Report of Prior NIST Workshop

Figure 2-2. Roadmap Action Plan: Robust In-Situ Process Monitoring Techniques

Barrier: In-situ process monitoring techniques for material and product defects are currently not robust and lack key capabilities (e.g., high-speed video and high-speed thermograph for deposition of materials, real-time measurement, and in-situ detection of processing anomalies leading to discontinuities, such as thermal gradients, voids, and inclusions). Feedback control for composition and microstructure, and sensor integration is not attainable with current black box controllers.

Approach Summary: Identify, develop, and implement process monitoring, NDE, and in-process measurement techniques to enable maximum detection of material defects.

	Roadmap Action Plan	Milestones and Results	Overarching Targets
1–2 years	• Identify and implement existing process monitoring technologies, identify constraints and limits, and resolve measurement capabilities • Collect and analyze critical data • Correlate process monitoring data to NDE measurements	• Implementation of process monitors on existing AM platforms • Identification of limits of existing sensor/process monitoring equipment • Correlation of NDE and mechanical testing to determine if sensor resolution is adequate	• Maximized detection capabilities to qualify production with batch size of one
3–5 years	• Correlate NDE data with destructive testing • Identify existing, alternate, and in-process measurement techniques not being investigated that are capable of scaling with AM processes • Identify and develop techniques for real-time and long-term collection, analysis, and storage of massive data sets	• Identification of alternatives that address the gaps of existing process monitoring technologies • Implementation of these new technology detection limits • Correlation to NDE and mechanical testing • Demonstration of the ability to collect and store the pertinent data	
5+ years	• Use data to drive modeling efforts • Correlate modeling with process measurement to enable robust process control (e.g., vision system identifies a defect/pore, process control system corrects and eliminates defects)	• Demonstration of direct correlation between process monitoring, control, and NDE	

Stakeholders & Potential Roles

- **Industry/AM Users:** Aerospace, biomedical, oil and natural gas industry: Identify needed material and mechanical properties
- **Industry/AM Providers:** Open up software and collaborate with researchers to implement and support these techniques
- **Academia:** Conduct basic research and analysis
- **Standards Committees:** Evolve standards along with the technology
- **Government:** Support standards development; Coordinate and facilitate cooperation among NIST, Oak Ridge, NASA, DOE, DOC, NSF, NIH, DARPA; Resources (i.e., neutral source)

Relative Impacts

Low—High	
♦♦♦	**Improves product quality:** Eliminate defects; Have an intimate and unprecedented understanding of component quality
♦♦♦	**Reduces costs:** Scrap, raw materials; Reduce capital investments in forming/shaping
♦♦♦	**Accelerates innovation:** For example, making available the data needed to develop techniques for designing micro-structuring
♦♦♦	**Enhances industry competitiveness:** Lower lead times (e.g., batch size one production)
♦♦♦	**Faster product development time:** Eliminate need for tooling
N/A	**Other:** Needed for AM to be a manufacturing tool

Panels

- Characterization of Materials Throughout Their Lifecycle
- Process Models
- In Situ Processing Measurements
- Performance
- Integration and Standards

Breakouts

- Future targets and Capabilities for Polymers-AM
- Challenges & Barriers
- Develop Action Plans

Put the *work* in the workshop

- Open discussion is encouraged throughout workshop
- Your perspectives and inputs are extremely important - everyone has the opportunity to contribute
- Consensus-building is difficult (and sometimes frustrating), but an essential part of roadmap development
- Thank you for your support and for your help

Contact Information

Kalman Migler:

http://www.nist.gov/mml/msed/polymers/kalman-migler.cfm