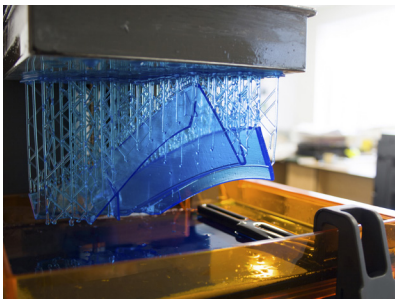
PHOTOPOLYMER ADDITIVE MANUFACTURING WORKSHOP

Roadmapping a Future for Stereolithography, Inkjet, and Beyond



Workshop Panels

Sustainable, Hybrid and Emerging Material Systems

Novel Characterization

Industry Applications and Developing Markets

Health, Safety and Regulations

Moonshot Ideas

Workshop Summary

Objectives

The Photopolymer Additive Manufacturing (PAM) Workshop, held October 29-30, 2019 at the National Institute of Standards and Technology in Boulder, Colorado, was organized to identify common problems and solutions specific to photopolymers, ultraviolet curing, manufacturing processes, and performance of materials in PAM commercial products. The workshop's technical focus was on the design, synthesis, and production of PAM printed products, particularly with respect to setting standards and establishing measurement science needs.

Overarching Challenges to Advancing PAM Technology

1. Limits in materials and chemistry
2. Lack of advanced characterization and standards
3. Rapidly evolving and dynamic hardware, software, and scalability needs
4. Lack of clarity and specificity in environmental, health, and safety regulations

Recommended Research Directions

I. **Material science and engineering to characterize PAM materials**, including in-situ and multimode, of the PAM process, such as simultaneous modulus and crosslinking density measurement

II. **Advanced computing for materials discovery and process modelling** of PAM parts to accurately predict performance of photopolymers on multiple length- and time-scales

III. **Measurement science and standards development for reliable, high-performance PAM** to overcome throughput and quality barriers, such as varying light intensity and exposure dose combined with increasing build volume capacity

IV. **Environmental, health, and safety regulations for safe and responsible PAM adoption** in coordination with industry and regulatory institutions

V. **Industry collaborations to enhance PAM utility**, such as shared test facilities for pilot programs and computing capabilities

The forthcoming workshop report provides a synthesis of these ideas, as well as further concepts, including barriers to the top scientific priorities for PAM. Twenty-three specific roadmapped solutions generated by the focus panels are summarized here and detailed in the full report.

MATERIAL MEASUREMENT LABORATORY

301-975-8300 | mmlinfo@nist.gov | http://www.nist.gov/mml

NIST National Institute of Standards and Technology U.S. Department of Commerce

Roadmapped Solutions for Advancing Photopolymer Additive Manufacturing (PAM)

Priority

Material Science and Engineering to Characterize PAM Materials	Advanced Computing for Materials Discovery and Process Modelling	Measurement Science and Standards Development for Reliable, High-Performance PAM	Environmental, Health, and Safety Regulations for Safe and Responsible PAM Adoption	Industry Collaborations to Enhance PAM Utility
• Define properties of and relationships between bulk and printed materials • Enhance in situ process control and monitoring with feedback • Characterize dispersion and chemistry at nanoscale to inform part performance	• Build a model to correlate printing conditions and final properties • Launch major efforts in computing and informatics to predict print process • Develop empirically-informed theory, modeling, and simulations of PAM • Improve computational models for UV-resin interactions • Create database of existing renewable photopolymers	• Develop PAM-specific standards and calibrations • Advance measurement science and tools to optimize quality control • Develop resin standards for sustainability market needs • Optimize UV sources for PAM Applications • Expedite material characterization via machine learning	• Support data systems for PAM registries and regulations • Reframe perception of PAM by overcoming throughput barrier • Define minimal dataset for risk assessment, exposure • Develop framework for product stewardship • Design education material on green photopolymers	• Translate commercial needs into R&D efforts • Support collaborations between small- and large-scale PAM industry adopters • Advance manufacturing capabilities in PAM • Build value proposition to meet customer needs • Pursue precision engineering and manufacturing

Recommended Research Directions

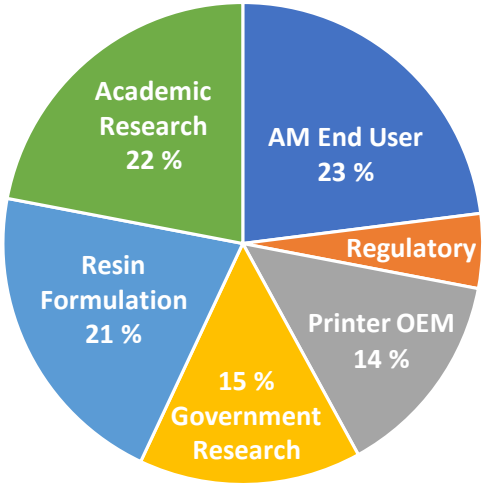
Paths Forward

1. Host webinar on workshop output and update community on current PAM challenges and opportunities
2. Establish environment, health, and safety data to support educational outreach and regulation development
3. Convene annual meetings for ongoing engagement between industry, regulatory and research institution stakeholders
4. Institute flexible government and academic research programs to address stakeholder needs

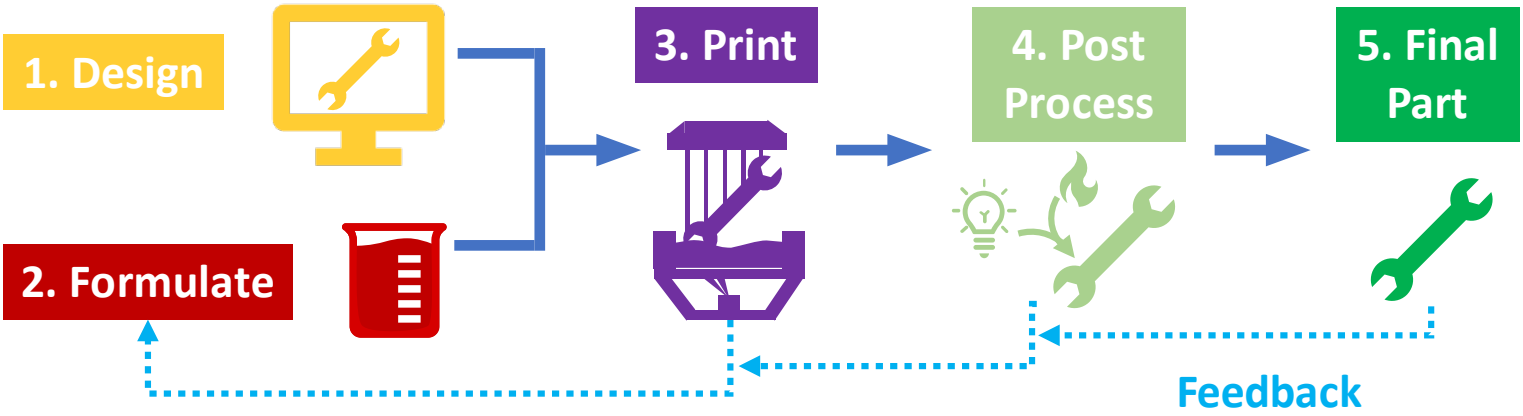
Participants

The PAM workshop was sponsored by the NIST Material Measurement Laboratory and organized in collaboration with RadTech North America, an ultraviolet and electron beam (UV+EB) photopolymer chemistry international nonprofit organization.

The workshop drew more than 80 participants spanning all sectors of the PAM community.



Photopolymer Additive Manufacturing (PAM) Process Flow and Priorities



Printer OEMs

- Engineered, stakeholder-defined final properties — 1 2 3 5
- Basic science for process engineering — 1 2 3 4 5
- Next-generation test file — 1 4 5

Raw material and resin suppliers

- Develop materials database — 1 2 5
- Sustainable materials — 1 2
- Advanced healthcare — 1 2 5

Research institutions

- In situ nano- and macro-scale characterization — 3 4 5
- Data science solutions — 1 2 3 4 5
- Predictive property modeling — 1 2 3 4 5

Regulatory institutions

- Collaborative standards — 2 3 4 5
- Regulation for garage-to-factory level manufacturing — 2 3 4 5
- Environment, health, and safety — 2 3 4 5

End users

- Increased print volume and throughput — 1 3 4 5
- Education on PAM — 1 2 3 4 5
- Defined material properties — 2 5

Workshop Organizers

NIST Material Measurement Laboratory	Callie Higgins	Chairs
	Jason Killgore	
	Dianne Poster	Advisor
NIST Physical Measurement Laboratory	Cameron Miller	
RadTech North America https://www.radtech.org/	Mike Idacavage	
	Mickey Fortune	
	Neil Cramer	
	Gary Cohen	

For More Information

http://go.usa.gov/xf66p photopolyAM@nist.gov

Credit: James Burrus