

LA-UR-17-30483

Approved for public release; distribution is unlimited.

Title: Characterizing Polymer Powders used in Additive Manufacturing

Author(s): Bajric, Sendin

Intended for: Presentation to UC-Merced students

Issued: 2017-11-15

Disclaimer:

Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the Los Alamos National Security, LLC for the National Nuclear Security Administration of the U.S. Department of Energy under contract DE-AC52-06NA25396. By approving this article, the publisher recognizes that the U.S. Government retains nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy. Los Alamos National Laboratory strongly supports academic freedom and a researcher's right to publish; as an institution, however, the Laboratory does not endorse the viewpoint of a publication or guarantee its technical correctness.

Characterizing Polymer Powders used in Additive Manufacturing

Working with Engineers



Sendin Bajric

16 November 2017



Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

Agenda

16 November 2017



- Personal background
- My LANL organization
- Internship project at LANL
- Mentor relationship
- Cultural adjustments

Personal Background

- Born in Bosnia-Herzegovina, raised in St. Louis, Missouri.



- Bachelor's degree in Chemistry
- Worked 1 year following graduation in industry
 - Quality Control
- Pursued Master's degree in Polymer Science at UO
- Obtained 9-month internship at LANL
- Currently in Post-Masters position with MST-7 at LANL.



Los Alamos, New Mexico, and the National Lab



<http://www.laaor.org/>



<http://www.eqnm.org/>



<http://www.lansllc.com/>

LANL Mission

Our core mission is to ensure the U.S. nuclear deterrent

- Ensure safety, reliability and performance of stockpile
- Design agency for four out of seven warhead systems constituting nation's deterrent



How could you ensure this worked, *without starting the engine?*

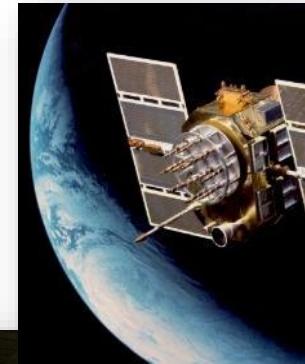


The United States faces a much more complex challenge in caring for its nuclear stockpile

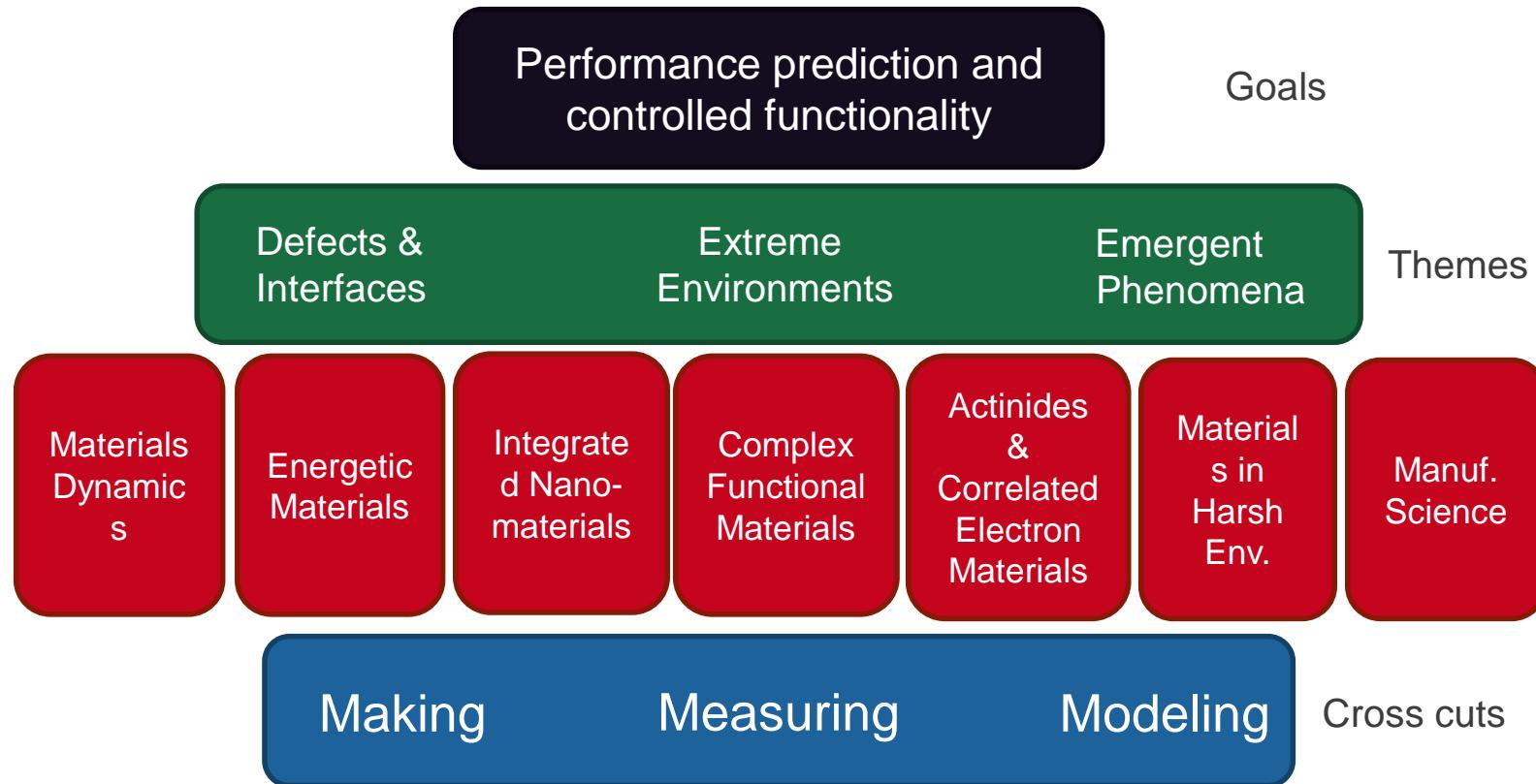


Reduction of threats of WMD and terrorism are critical to our national security

- Reduce proliferation threats
- Safeguard and detect radiological material
- IAEA inspector training
- Counterterrorism
- Critical infrastructure modeling
- Disaster response

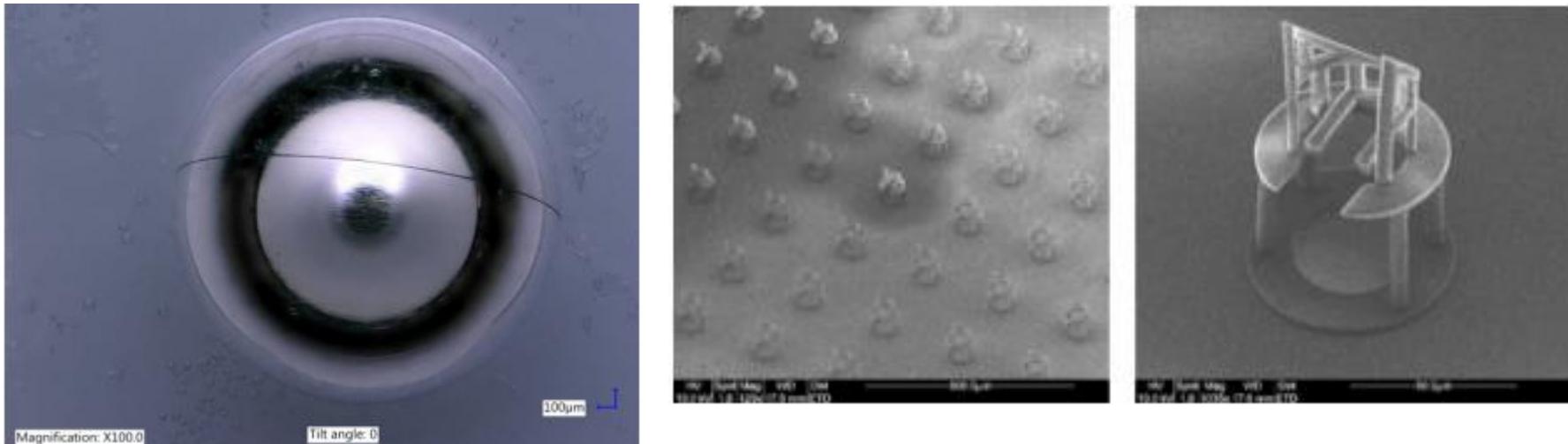


Materials strategy framework



My LANL Organization – MST-7

- **MST = Materials Science and Technology**
 - Provides materials science and technology solutions for national security missions



- **MST-7 = Engineered materials**
 - Expertise in target fabrication and assembly, polymer science and engineering, and materials characterization

Additive Manufacturing

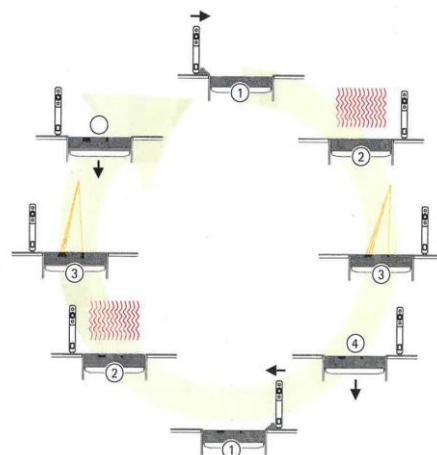
- The manufacture of 3D objects using layer-by-layer addition.

- **Selective Laser Sintering (SLS)**

- Uses a laser to sinter polymer powders to produce mechanically strong structures.

- **Motivation:**

- To build highly complex designs with less waste
 - Expand material selection

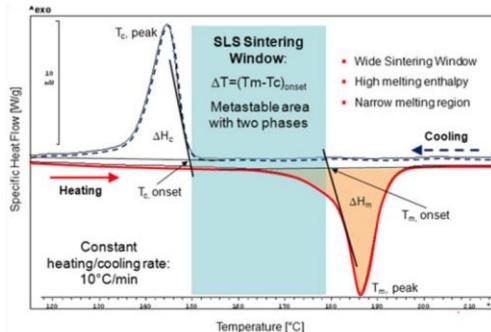


Reference: EOS Formiga P110, Training Manual, Article #: 9236-3511, Edition: 07.13, 2013
EOS GmbH, D-82152 Krailling/Munchen.

| | | |
|-----|---------|--|
| (1) | Apply: | Polymer powder layer is applied. |
| (2) | Heat: | Layer is heated and maintained below melting. |
| (3) | Sinter: | Patterned laser melts the powder. |
| (4) | Lower: | Melted layer is lowered for next layer and cycle is repeated |

Key Material Properties for SLS Success

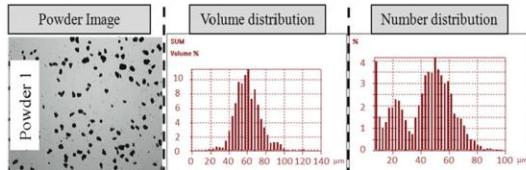
➤ Thermal “Sintering Window”



- Wide SLS window is important to postpone crystallization and enable full coalescence of particles

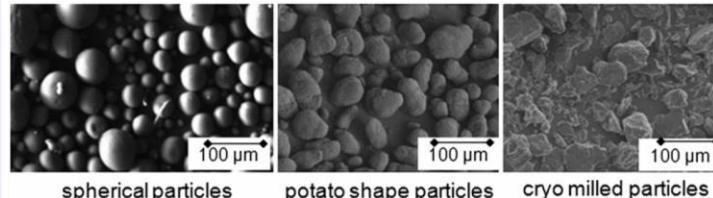
Reference: Schmid, M.; Amado, A.; Wegener, K., Materials perspective of polymers for additive manufacturing with selective laser sintering. *J. Mater. Res.* **2014**, 29 (17), 1824-1832.

➤ Particle Size and Distribution



Reference: Schmid, M.; Amado, A.; Wegener, K., Materials perspective of polymers for additive manufacturing with selective laser sintering. *J. Mater. Res.* **2014**, 29 (17), 1824-1832.

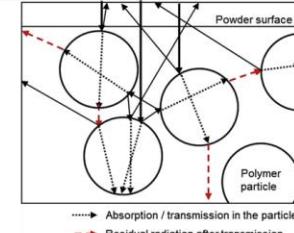
➤ Powder packing efficiency and flowability



- High density and high flowability are vital to effectively sinter powder particles

Reference: Schmid, M.; Amado, A.; Wegener, K., Materials perspective of polymers for additive manufacturing with selective laser sintering. *J. Mater. Res.* **2014**, 29 (17), 1824-1832.

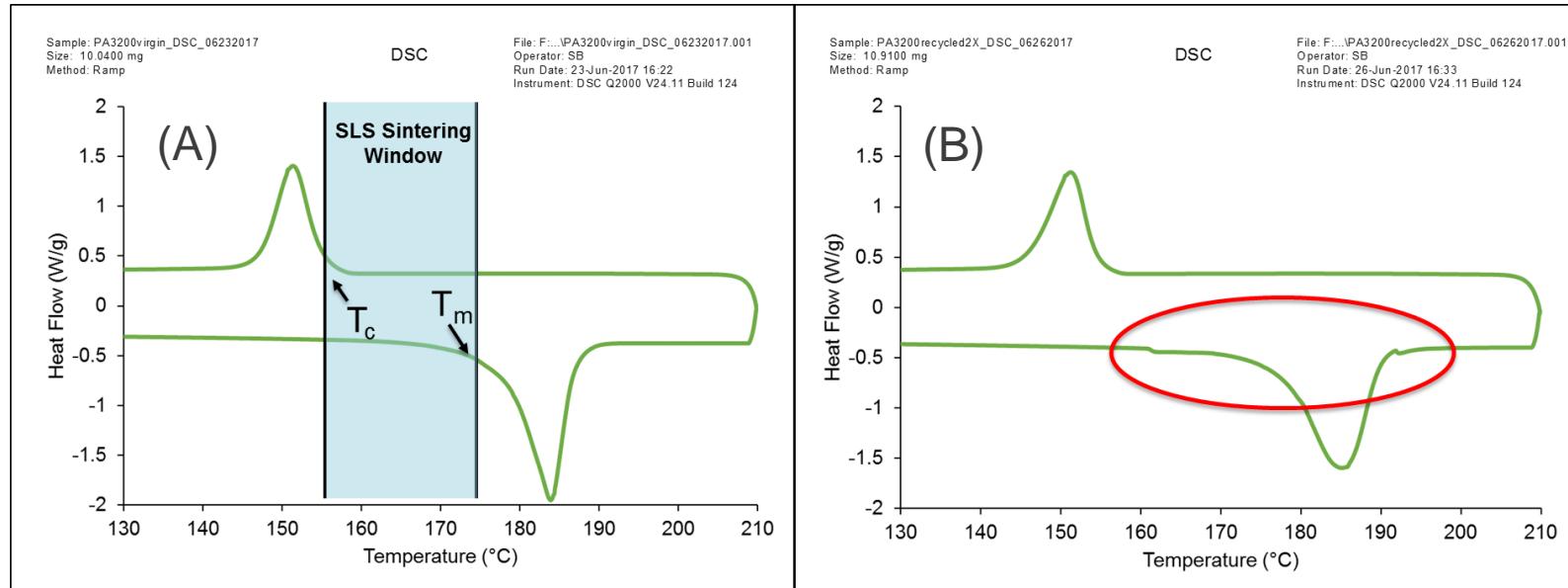
➤ Optical Absorption



Reference: Laumer, T.; Stichel, T.; Nagulin, K.; Schmid, M., Optical analysis of polymer powder materials for Selective Laser Sintering. *Polymer Testing* **2016**, 56, 207-213.

Results

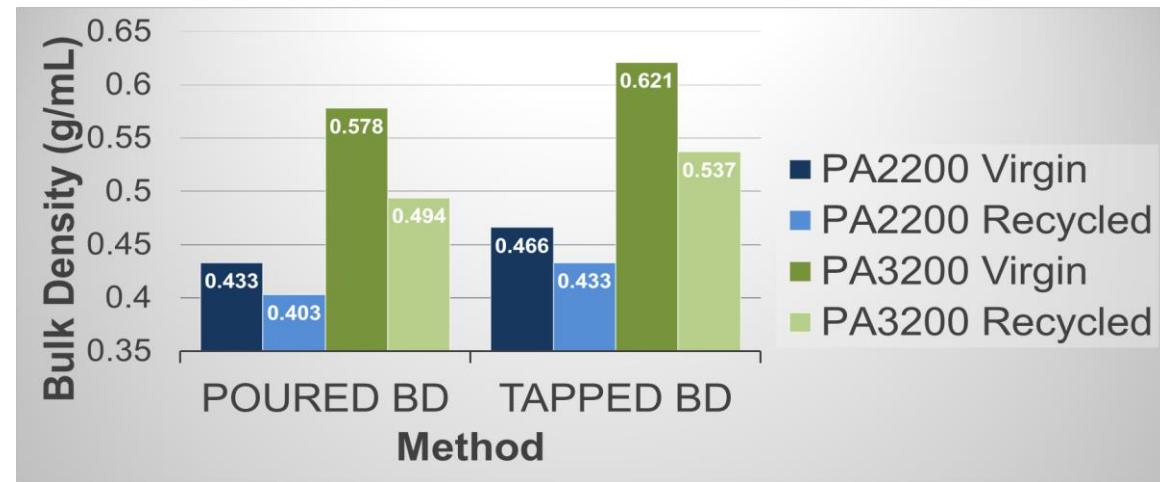
- **Differential Scanning Calorimetry (DSC)**
 - Identifies the thermal sintering window of SLS powder materials



Region between the melting and crystallization onsets for (A) PA3200 Virgin and degradation signs for (B) PA3200 Recycled SLS powders.

Results

- **Bulk Density (BD)**
 - Indirect measure of the powder's packing efficiency
 - High BD values indicate more efficient packing



| Powder Comparison | Poured BD (%) | Tapped BD (%) |
|-----------------------------|---------------|---------------|
| PA2200 - Virgin vs Recycled | 6.91 | 7.19 |
| PA3200 - Virgin vs Recycled | 14.52 | 13.53 |
| Virgin - 2200 vs 3200 | 25.07 | 24.94 |

Project impact and Future Directions

- **Why does what I did matter to the Lab?**

- Need for capability to create complex designed objects for use in national security missions. Freedom of design for materials enables the Lab to have controlled functionality of materials.

- **Why does what I did matter to me?**

- Firm believer and supporter of national security cause. To be at the heart of innovation at the Lab, knowing that the more effort I put into the work, will be meaningful to the national security mission of the country.

- **Future Directions**

- Characterizing novel powders with other desirable properties
 - Acquiring particle size analysis, melt flow analyzer, to better understand behavior of materials during SLS processing
 - Pushing towards expertise and leadership in Additive Manufacturing

Mentor's Role and Cultural Adjustments

- **Mentor: Joseph Torres, MST-7**
 - Full support
 - Good communication
 - Interesting and difficult projects
 - Good workload
 - Informs how to be successful
- **Cultural Adjustments to Northern New Mexico:**
 - Open to traveling and new experiences
 - Different handshakes/shake-ups
 - Cool experience overall if open to different cultures