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Title: Characterizing Polymer Powders used in Additive Manufacturing

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Characterizing Polymer Powders used in Additive Manufacturing

Working with Engineers



Sendin Bajric

16 November 2017



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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.lansllc.com/>



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



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

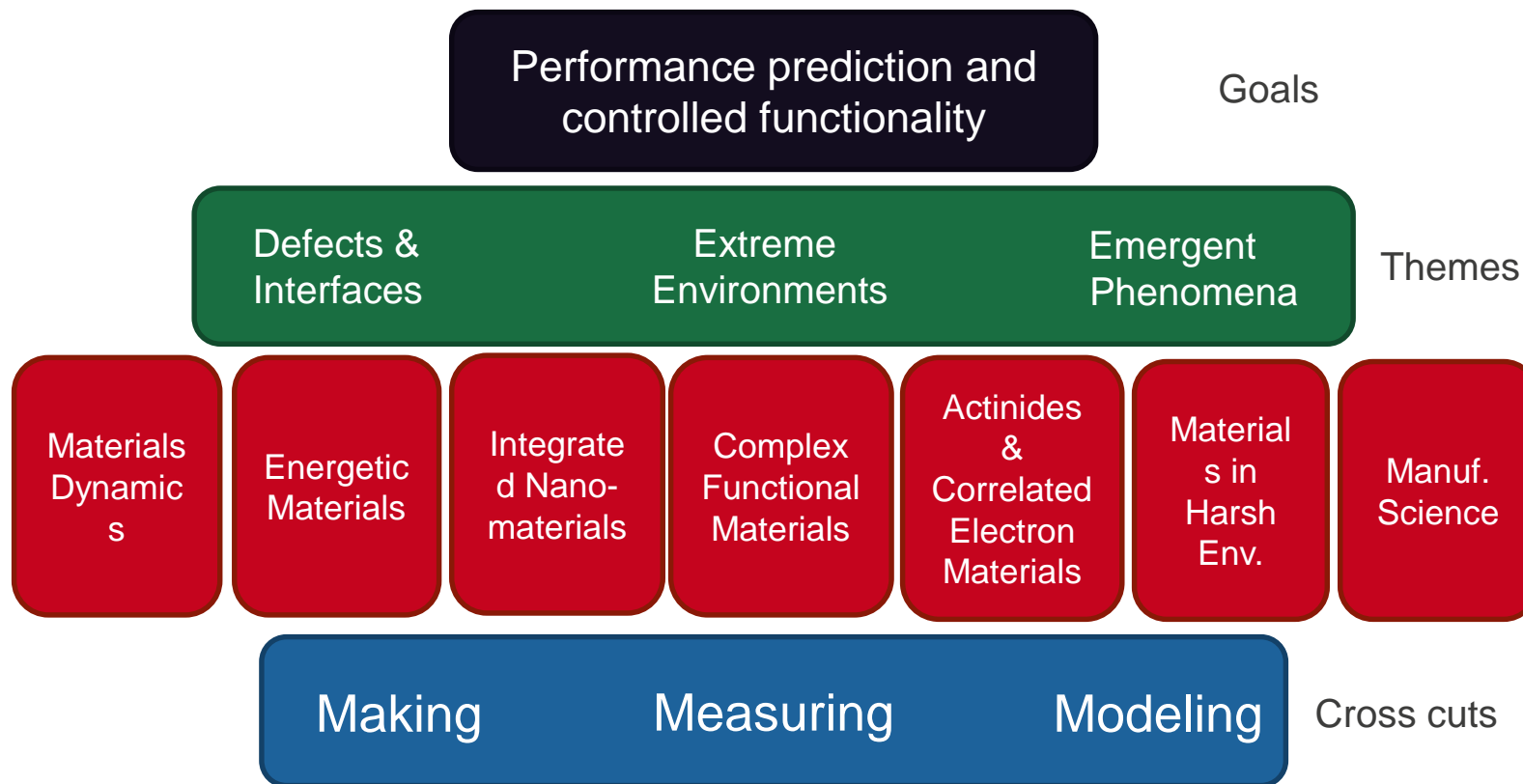


Reduction of threats of WMD and terrorism are critical to our national security

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

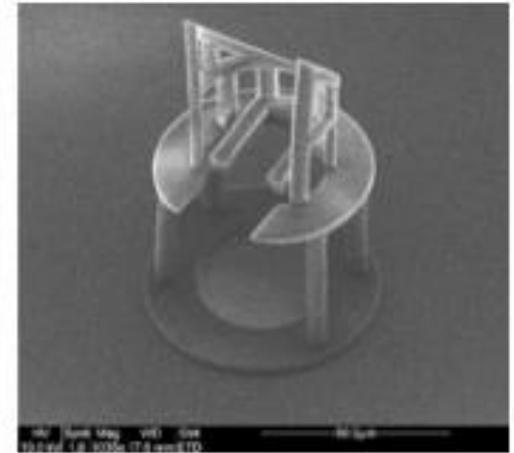
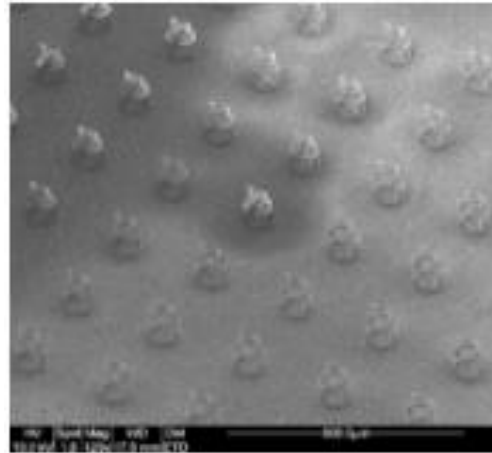
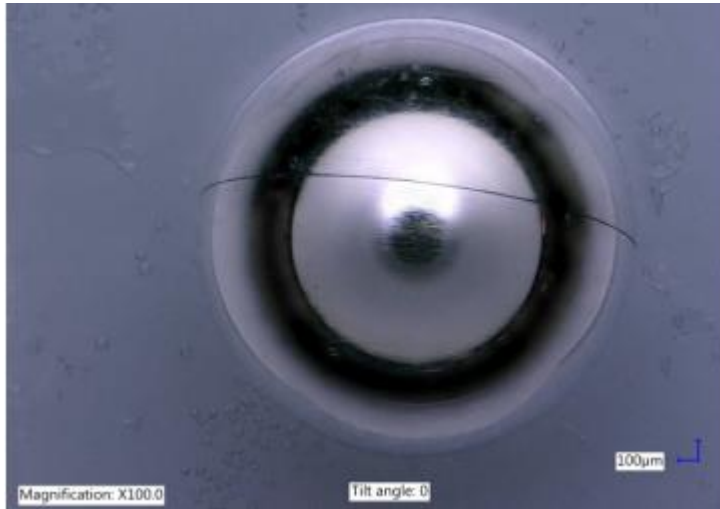


Materials strategy framework



My LANL Organization – MST-7

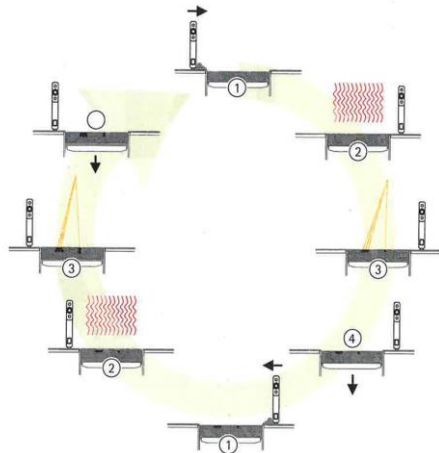
- **MST = Materials Science and Technology**
 - Provides materials science and technology solutions for national security missions



- **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



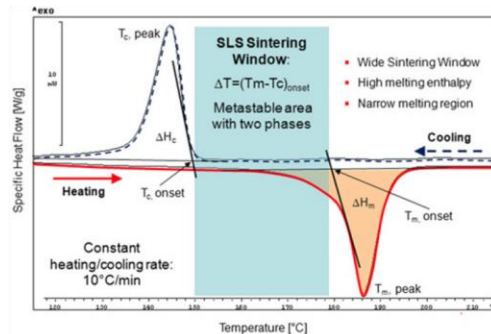
Formiga P110

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

- | | | |
|-----|---------|--|
| (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

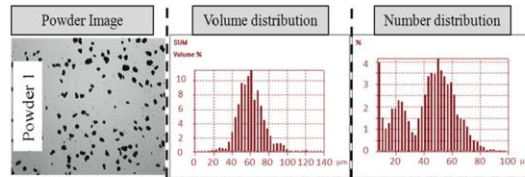
➤ Thermal “Sintering Window”



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

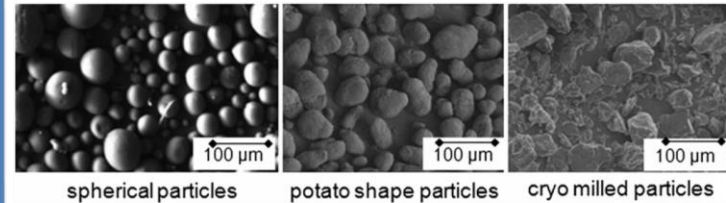
Reference: Schmid, M.; Amado, A.; Wegener, K., Materials perspective of polymers for additive manufacturing with selective laser sintering. *J. Mater. Res.* **2014**, 29 (17), 1824-1832.

➤ 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.

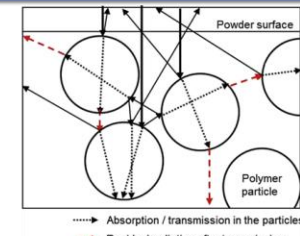
➤ Powder packing efficiency and flowability



- 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.

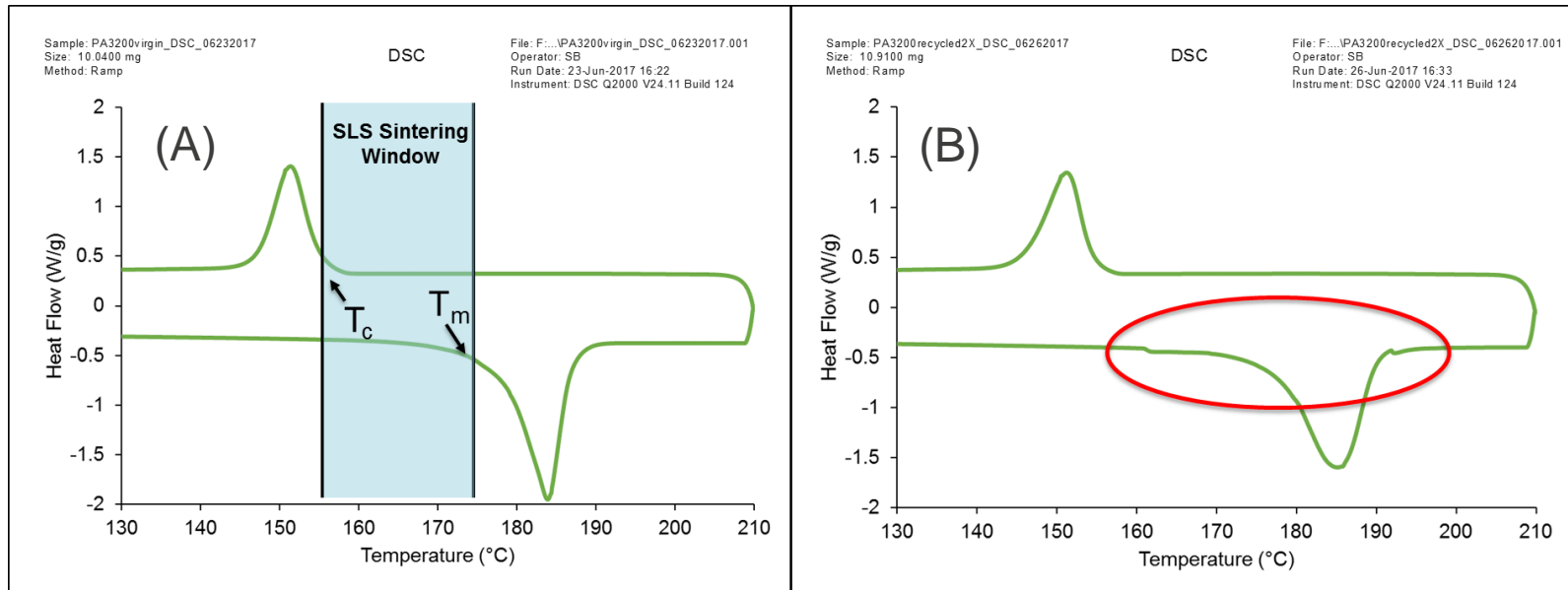
➤ Optical Absorption



Reference: Laumer, T.; Stichel, T.; Nagulin, K.; Schmidt, 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

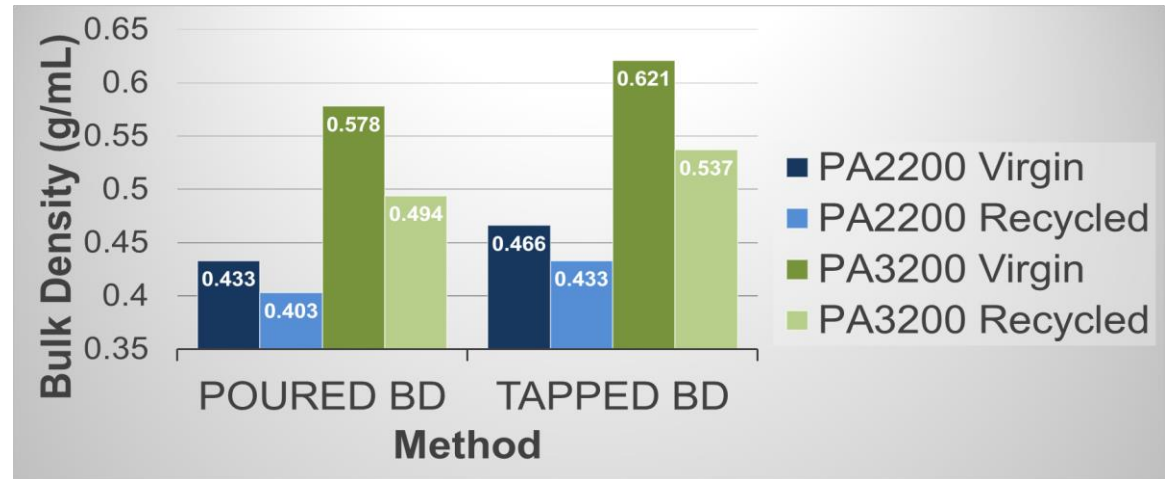


Region between the melting and crystallization onsets for (A) PA3200 Virgin and degradation signs for (B) PA3200 Recycled SLS powders.

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