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High Pressure Response of Additively Manufactured AlSi10Mg

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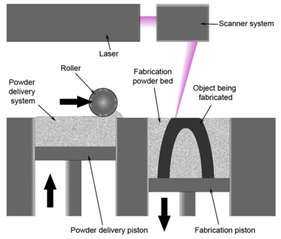
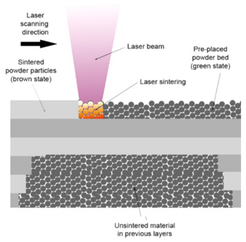
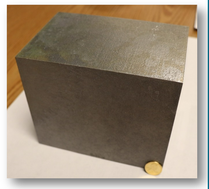
Laser Powder-Bed Fusion (LPBF) AM Al-Si10-Mg





- Large billet printed at CalRAM Inc., a Carpenter Additive Company
  - SML 280HL machine (SML Solutions)
- Build parameters
  - Nominal Hatch Spacing: 150 µm
  - Nominal Layer Thickness: 30 µm
  - Raster Speed: 1100 mm/s
  - Laser Power: 350 W
  - Nominal Beam Diameter: 75 µm
  - Mean Power Diameter: 20 µm
  - Powder Condition: Virgin
- Stress relief anneal at 287 °C for 2 hours



Composition

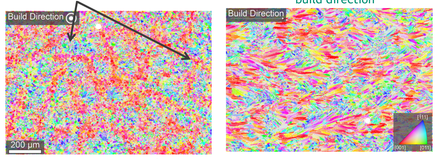
	Al	Cu	Fe	Mg	Mn	N	Ni	O	Pb	Si	Sn	Ti	Zn
Powder	**89.57**	0.01	0.07	**0.3**	0.01	0.01	0.01	0.05	0.01	**9.78**	0.01	0.01	0.01
Build	**89.17**	0.01	0.07	**0.31**	0.00	0.00	0.01	0.07	0.00	**10.30**	0.00	0.01	0.01

(ICP-MS and LECO)

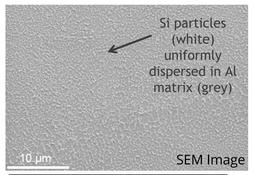
Microstructure

- Highly anisotropic, bi-modal grain structure
  - Small grains form at melt pool boundaries
  - Larger grains form at the center of the melt pool and elongate in the build direction
  - Elongated grains show a preference for the [001] orientation
- Uniformly distributed Si-rich precipitates
  - Heat treatment breaks up cellular structure

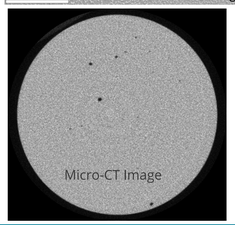
Bimodal grain structure → Thermal history aligned with build direction



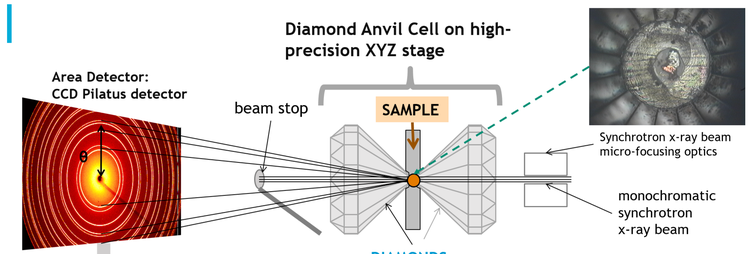
Inverse Pole Figure (IPF) maps

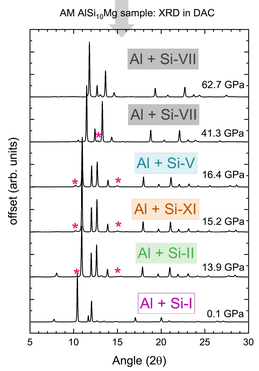


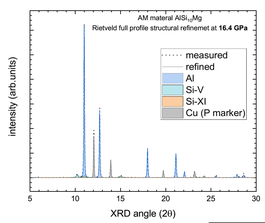
- Print achieved a density of 99.4% theoretical maximum density (TMD)
- Porosity was characterized using micro-computed tomography (micro-CT)
  - Porosity was consistent throughout the build with an average equivalent spherical diameter of roughly 35 µm



Static DAC compression & XRD at APS-ANL

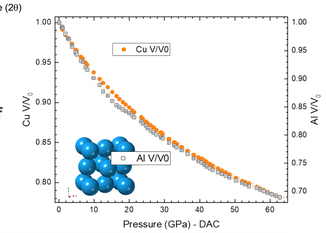




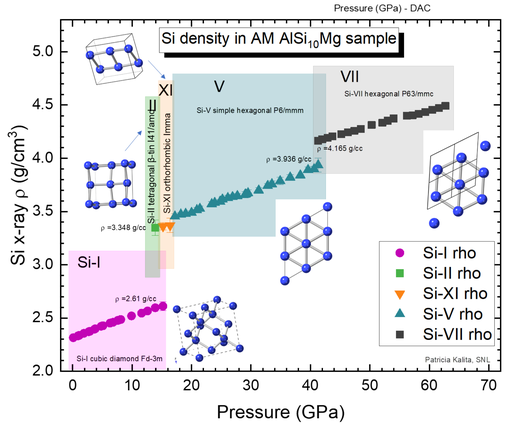


Example of full-profile Rietveld structural refinement of XRD of AlSi10Mg.

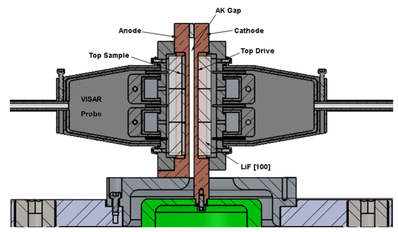
Pressure evolution of the unit cell volume of the Al phase and of the Cu pressure marker

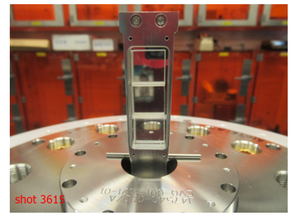


- Static compression up to **62 GPa**
- **~100 XRD** patterns collected, processed, analyzed
- Cu pressure marker, no P medium
- **Steady** compression in **Al**
- **4 phase transitions in Si**
- Stars mark new lines due to phase transitions in Si
- Difficult to see phase transitions by visual inspection → need for **Rietveld** structural refinements!
- Challenging experiment because of only 10 wt.% of Si



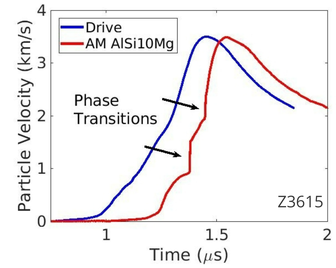
Ramp-Release Experiment at SNL Z Machine

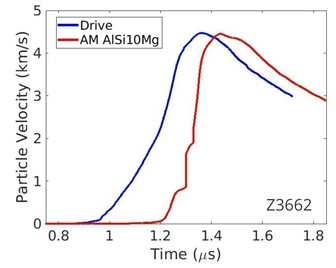




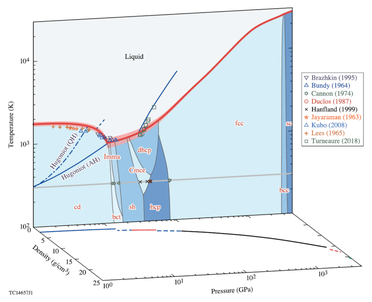
- Ramp compression loads near the isentrope
- Two Z experiments
  - Z3615 – Peak stress of ~ 100 GPa
  - Z3662 – Peak stress of ~ 200 GPa

- **Two Low pressure phase transitions were observed in the bulk AM AlSi10Mg response**
  - Unusual for an Al-based alloy





- Dynamic compression to **~200 GPa**
- **Two phase transitions** observed in bulk AlSi10Mg response
  - The **large volume collapse of the Si phase transitions** generates the observed bulk response in AlSi10Mg
- First transition occurs **~ 16 GPa**
  - Attributed to Si-I cubic diamond (cd) to Si-II tetragonal β-tin (bct) and Si-XI orthorhombic (Imma)
- Second transition occurs **~ 40 GPa**
  - Attributed to Si-V simple hexagonal (sh) to S-VII double hexagonally closepacked (dhcp)



Si Phase Diagram from R. Paul et al. *PRL* **122**, 125701 (2019)