CANFSA

Center for Advanced Non-Ferrous Structural Alloys
An Industry/University Cooperative Research Center

Project 59-L: In-situ Visualization of Microstructure Evolution in Metallic Alloys under Additive Manufacturing Conditions

Semi-annual Spring Meeting

April 2022

- Student: Oliver Hesmondhalgh (Mines)
- Faculty: Amy Clarke (Mines)
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- Student: Oliver Hesmondhalgh (Mines)
- Advisor: Amy Clarke (Mines)

Project Duration
PhD: August 2021 to May 2025

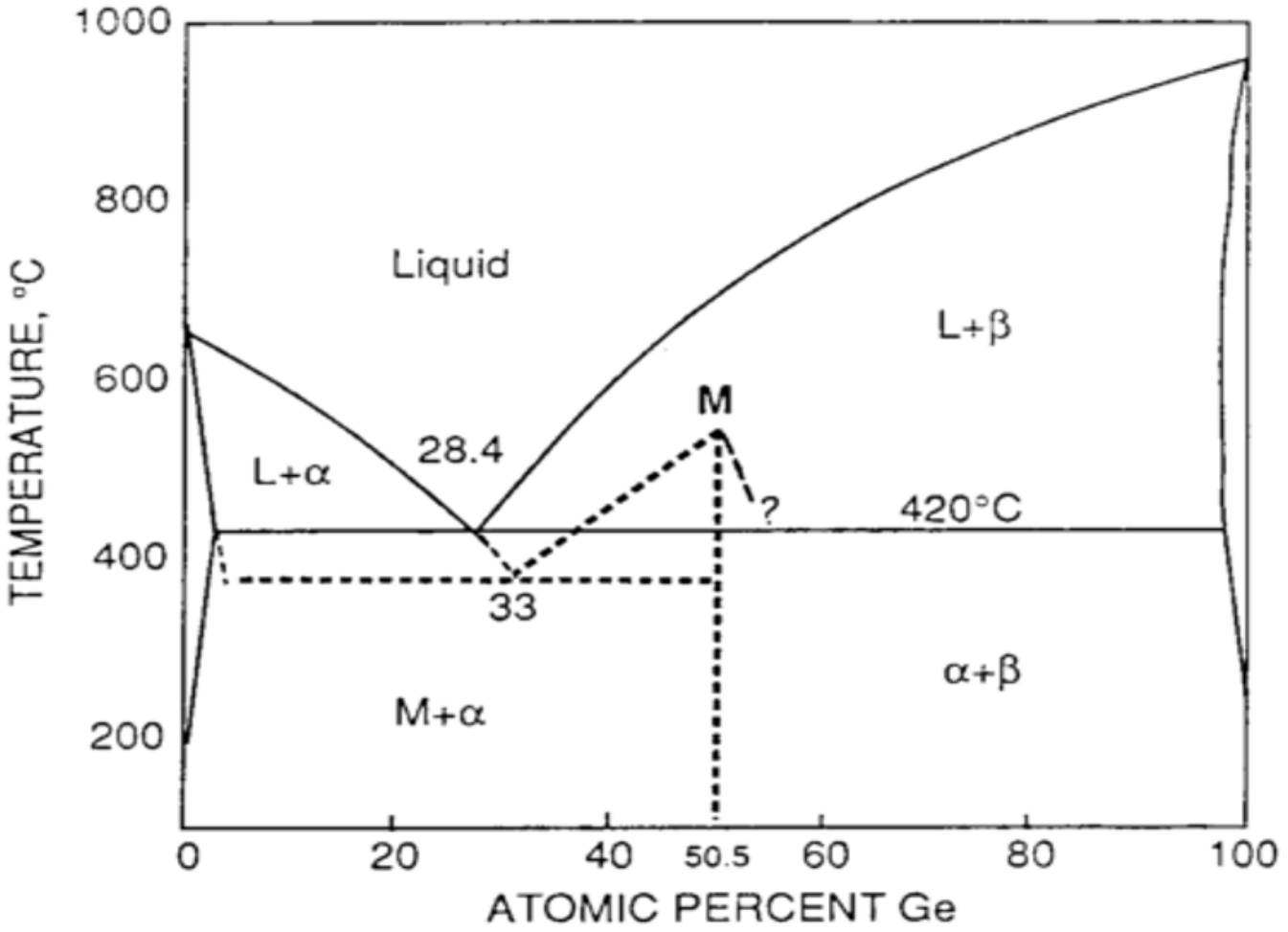
- Problem: Microstructure evolution during metallic additive manufacturing (AM) is not well understood, making alloy design and control of material properties difficult.
- Objective: Characterize microstructures during simulated AM and after complex thermal cycling. Inform phase field modeling of rapid solidification dynamics.
- Benefit: Microstructure predication and control under AM conditions and insights into alloy design for AM matched to AM processes.

Recent Progress

- Developed manual image analysis process to estimate solidification velocities from dynamic transmission electron microscopy (DTEM) data.
- Al-Si solidification velocities measured to inform phase field modeling of grain competition.
- Al-Ge DTEM and ex-situ microscopy analyzed to understand metastable phase formation.

Metrics		
Description	**% Complete**	**Status**
1. Literature review	25%	●
2. In-situ imaging of Al alloys during simulated AM with DTEM and/or at the Advanced Photon Source (APS) at Argonne National Laboratory (ANL)	0%	●
3. Microstructure characterization of Al alloys after simulated AM	20%	●
4. Complex thermal cycling of Ti alloys and heat-treatments with dilatometry	10%	●
5. Electron microscopy of novel Ti alloy microstructures produced under AM conditions	0%	●

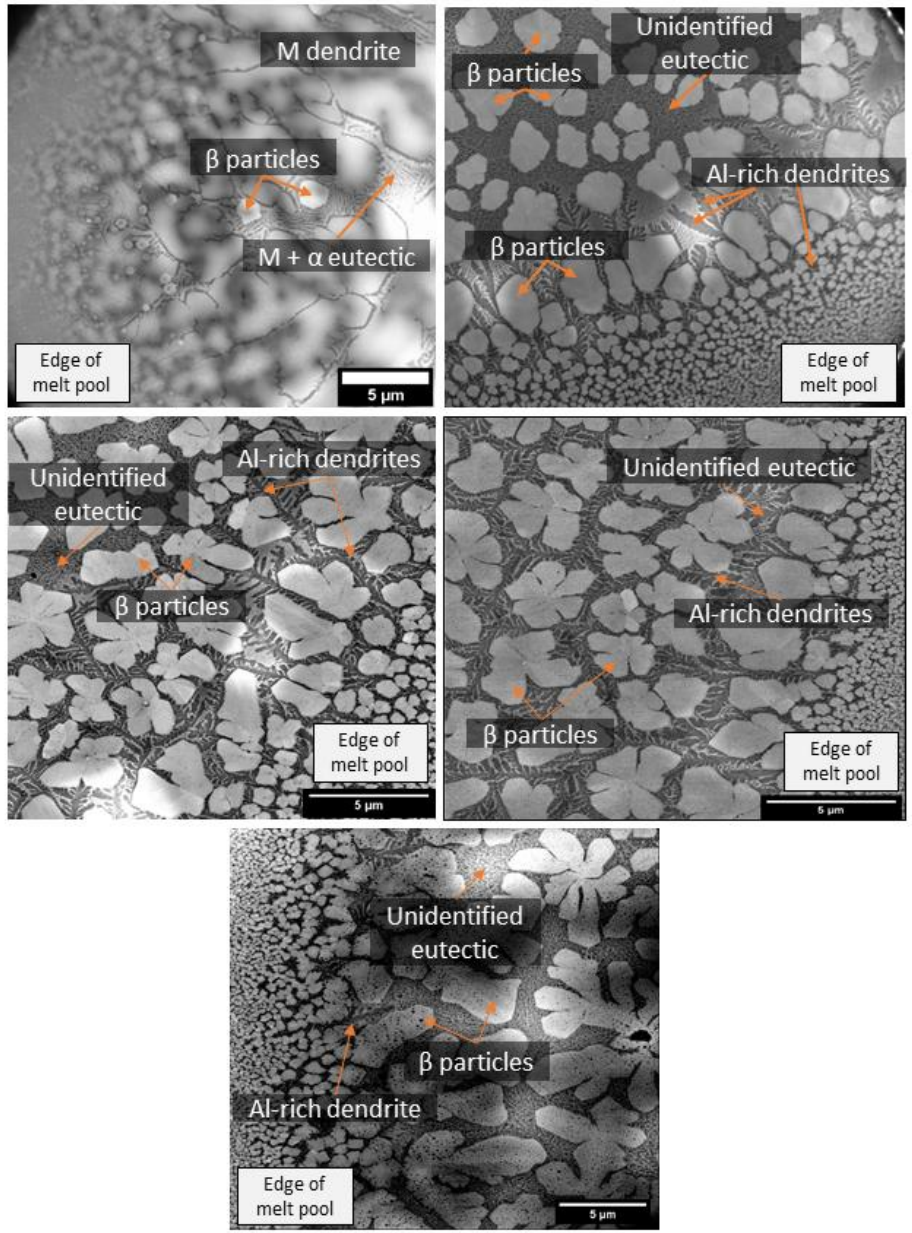
Proposed Metastable Phase Diagram for Al-Ge with Rapid Solidification



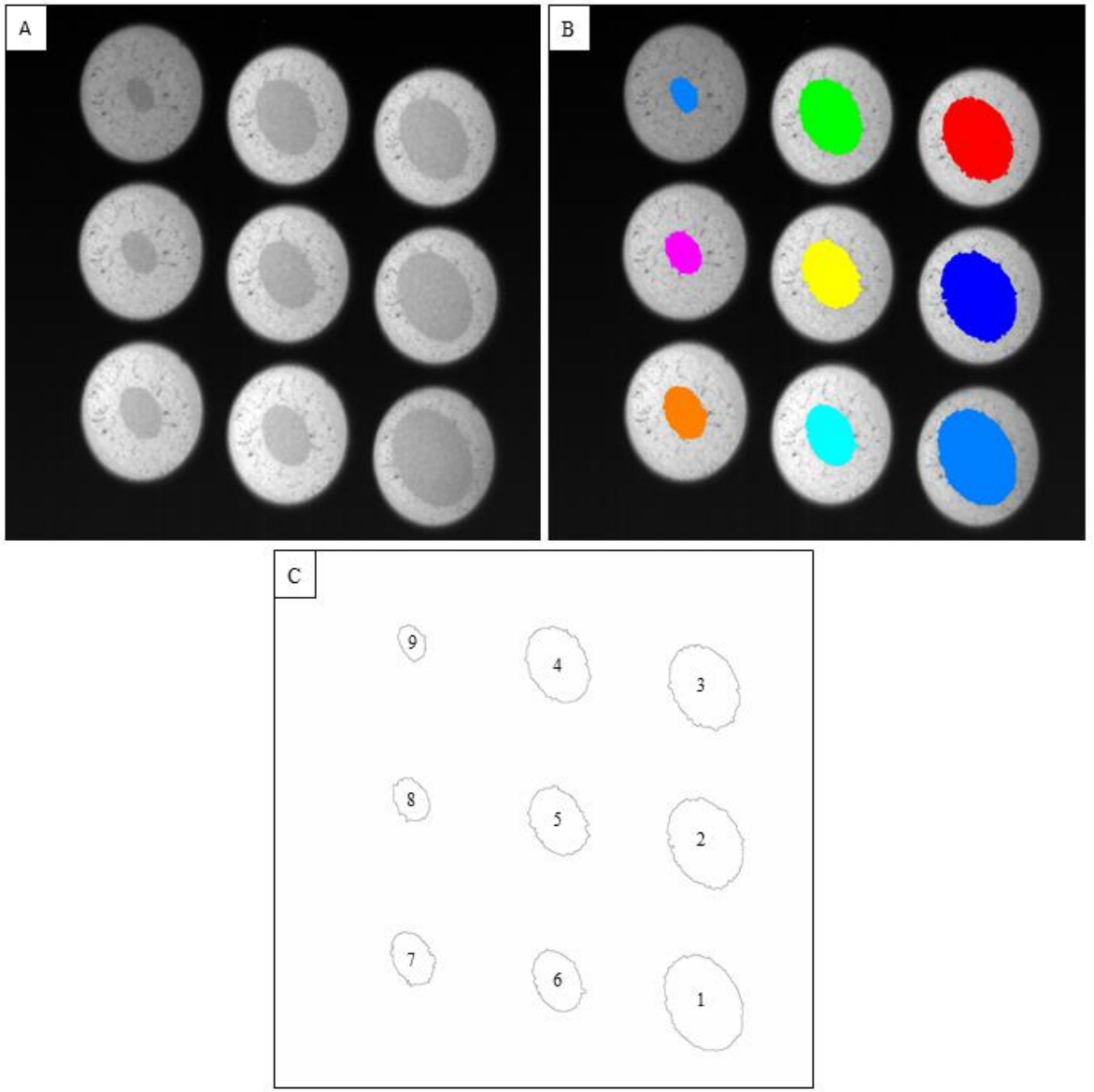
Proposed metastable Al-Ge phase diagram [1].

Ex-situ Analysis of Al-Ge after Rapid Solidification

- Ex-situ HAADF TEM images of melt pools from Al-Ge DTEM samples of differing compositions (~46-76 at.% Ge)
- Metastable monoclinic phase found as dendrites and as a eutectic with α-Al.
- Additional work required to identify some regions of interest.



Grain Competition in Al-Si during Rapid Solidification



A) Non-local means filter (Avizo).

B) Segmented melt pools using adaptive threshold tool (Avizo).

C) Outlines of melt pools used to measure solidification velocity (ImageJ).

Challenges & Opportunities

- TEM with nanoscale crystallographic mapping with ASTAR at Mines
  - Will provide additional microstructure characterization

- Manual image analysis process provides estimates of solidification velocities
  - Automate and improve the accuracy of these measurements

- Prepare first peer-reviewed journal manuscript

Thank you!

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References

[1] T. Laoui, M.J. Kaufman. Nonequilibrium Behavior in the Al-Ge Alloy System: Insights into the Metastable Phase Diagram, Metallurgical Transactions A. 22 (1991) 2141-2152.