I/UCRC Executive Summary - Project Synopsis	Date: April 2022
Center/Site: CANFSA/Colorado School of Mines	
Tracking No.:31: 36E: In-Situ Characterization of Microstructural Evolution During Simulated Additive Manufacturing in Model Alloys	**E-mail :** brodgers@mines.edu **Phone :** (720) 413–4542
Center/Site Director: CANFSA/M. Kaufman/P. Collins/A. Clarke	**Type: (Continuing)**
Project Leader: Brian Rodgers	**Proposed Budget**: $320K, Leveraged

Project Description: This project will start by conducting spot melts and rasters of Al-Ag and Ni-Al-Mo samples at the Advanced Photon Source (APS) with in-situ radiography imaging. These experiments will be coupled with ex-situ simulations of the melt pools correlated to the APS melts pools to verify solid-liquid interface velocities and obtain information about thermal gradients. Solidification velocities from APS radiography and thermal gradients obtained from simulations will be combined with microstructural characterization to assess solidification behavior of materials under different conditions. Analysis of Al-Ag samples will be augmented with DTEM.

Experimental plan: As-solidified samples of Al-Ag and Ni-Al-Mo following laser melting and solidification at the APS will be sectioned and imaged with SEM. TEM of FIB lift-outs and EBSD will serve as complementary analyses for regions of interest. TEM will also be used for DTEM samples.

Related work elsewhere: This project initiated as a part of an ONR MURI, with similar work is being conducted at other university sites, mainly on Ti-6Al-4V and alloys from the Inconel series. Other projects focus on electron beam additive manufacturing, while also using complementary APS experiments. This project also builds upon previous work performed by A. Clarke (Mines), A. Karma (Northeastern University), and J. McKeown (Lawrence Livermore National Laboratory) on in-situ visualization of metallic alloy solidification dynamics, with current emphasis on microstructure development under additive manufacturing conditions (supported by the US DOE Office of Science and NNSA LRGF).

How this project is different: Other studies emphasize the analysis of as-built parts in industrial alloy systems, while this project is centered around model alloys. The goal is to understand fundamental solidification behavior, rather than analyzing the performance of a single alloy under specific conditions.

Milestones for the current proposed year: Analyze sectioned material with SEM and EBSD, Further analysis of dendrite orientation transition (DOT) in Al-Ag and Al-Ge systems, publish results regarding DOT in Al-Ag and Al-Ge systems, and complete TEM necessary for publications.

Deliverables for the current proposed year: Assist in developing a ML interatomic potential for Al-Ag for follow-on phase-field simulations of Al-Ag DOT and Al-Ag alloys under complex thermal cycling.

How the project may be transformative and/or benefit society: Most solidification research explores slow solidification velocity scenarios such as casting. A deeper understanding of the phenomena uniquely seen at high velocities and large thermal gradients will facilitate advanced technologies, such as additive manufacturing, to expand into more alloy systems. These results may also facilitate concepts for alloy design for additive manufacturing. Control of solidification conditions may lead to opportunities for producing unique microstructures, such as additive manufacturing of highly textured, or 'single crystal', parts. Knowledge of dendrite orientation transition may be leveraged to create novel microstructures. The results from this work will also be used to inform phase-field model development for rapid solidification by Prof. A. Karma's group at Northeastern University.

Research areas of expertise needed for project success: Beamline access for in-situ experiments. TEM of FIB lift-outs and DTEM foils, SEM with EBSD, and post-processing to evaluate microstructure.

Potential Member Company Benefits: Enhanced understanding and control of metallurgical behavior under rapid solidification conditions, with applications in additive manufacturing and laser welding.

Progress to Date: At the APS, simulated additive manufacturing was performed on a matrix of Al-Ag and Ni-Al-Mo alloy samples with processing parameter variations. Top-down SEM imaging has been completed. A residency at LANL was also completed as part of laboratory residency graduate fellowship awarded Modeling of solid-liquid interactions with molecular dynamics in LAMMPS software was learned and performed. Brian also supported the creation of a semi-automated software package for molecular dynamics simulations in LAMMPS called LAVA.

Estimated Start Date: Fall 2019	**Estimated Knowledge Transfer Date**: Spring 2023

The Executive Summary is used by corporate stakeholders in evaluating the value of their leveraged investment in the center and its projects. It also enables stakeholders to discuss and decide on the projects that provide value to their respective organizations. **Ideally, the tool is completed and shared in advance of IAB meetings to help enable rational decision making.**