I/UCRC Executive Summary - Project Synopsis	**Date**: April 2022

Center/Site: CANFSA/Colorado School of Mines

Tracking No.: 36A Microstructural Evolution in Titanium Alloys Under Additive Manufacturing Conditions	**Phone:** (303)-990-0939	**E-mail:** asaville@mines.edu

Center/Site Director: M. Kaufman/P. Collins/A. Clarke	**Type: (Continuing)**
Project Leader: Alec Saville	**Proposed Budget**: $320K, Leveraged

Project Description: This project focuses on understanding the microstructure and crystallographic texture development in electron beam melted (EBM) and Wire-Arc Additive Manufacturing (WAAM) Ti-6Al-4V with changes in build parameters and build processes and understanding the genesis of microstructural evolution in other AM titanium alloys. Neutron diffraction, large-scale electron backscatter diffraction (EBSD) measurements, and solidification simulations of AM Ti-6Al-4V as a function of specimen build height and scan strategy will create a complete picture of processing-microstructure links. Links to mechanical properties by crystal plasticity modeling will be pursued through collaboration. Thermal processing of new titanium alloys will also be completed to evaluate microstructural evolution in an emerging class of titanium alloys designed to produce ultrafine grained, as-built AM microstructures.

Experimental plan: Bulk and local neutron diffraction texture measurements will be performed at Los Alamos National Laboratory (LANL) and processed using the MAUD software package and MATLAB-MTEX plugin. Large scale EBSD maps will be collected (e.g. ~ 5 x 5 mm) to correlate local texture to microstructural features and enable reconstruction of as-solidified microstructures/orientations. New alloy specimens will be thermally cycled with dilatometry to simulate the complex thermal cycling experienced during AM. Evaluations of grain refinement will be obtained by short-term heating into the β regime, quenching to room temperature, and EBSD measurements followed by β-Ti reconstructions.

Related work elsewhere: Less comprehensive, smaller scale explorations of texture and microstructure have been completed on EBM and WAAM Ti-6Al-4V. "Designer" titanium alloys for AM have grown in interest, and are increasingly being reported in literature.

How this project is different: Corroborative exploration of microstructure and texture from EBSD and neutron diffraction has not been completed previously in literature for EBM or WAAM Ti-6Al-4V, let alone when comparing different AM processes and modelling of solidification conditions. New titanium alloy AM work has shown knowledge deficits in understanding the genesis of microstructural refinement of various alloys, which is an important area for future work.

Milestones for the current proposed year: Collation of dilatometry and characterization data for emerging AM titanium alloys is anticipated, along with reconstruction of fully transformed Ti-10-2-3 microstructures and in depth explorations of a newly calculated orientation relationship.

Deliverables for the current proposed year: Publication of WAAM Ti-6Al-4V findings on crystallographic markers for microstructural condition and solid state grain refinement for emerging titanium alloys in AM. Several talks are also being given at various conferences over the next few months. Alec Saville also plans to defend his PhD in August of the upcoming reporting period.

How the project may be transformative and/or benefit society: By understanding crystallographic texture and microstructural evolution as a function of build parameters and processes, predictive capabilities can be developed for AM. This will enable new levels of microstructure and property control and increase the deployment of AM to a broader range of structural applications. Understanding the origins of microstructural refinement will provide new insights into titanium AM alloy design and enhance as-built materials for structural, biomedical, and high strain rate applications.

Research areas of expertise needed for project success: Rietveld refinement, neutron diffraction, solidification, crystallographic texture, crystallography, phase transformations, thermodynamics, and titanium metallurgy.

Potential Member Company Benefits: Neutron diffraction measurements of metal AM builds is of direct interest to LANL, Sandia National Laboratories, Lawrence Livermore National Laboratory, and the Air Force Research Laboratory. ATI is also interested in the processing of novel Ti alloys. The texture results, solidification modeling, and phase reconstructions generated from this work are also of interest to the aerospace, biomedical, and defense industries, particularly regarding the qualification and certification of parts built by AM.

Progress to Date: All Ti-6Al-4V specimens have been characterized, including EBSD, neutron diffraction, reconstruction, and solidification modelling of the EBM-PBF Ti-6Al-4V specimens. Ti-10-2-3 reconstructions are in progress, with initial validation tests completed. Dilatometry heat treatments of emerging Ti-Cu alloys are also completed, with data processing in-progress.

Estimated Start Date: Fall 2018	**Estimated Knowledge Transfer Date**: Fall 2022

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.**