I/UCRC Executive Summary - Project Synopsis	**Date**: October 2020

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@mymail.mines.edu

Center/Site Director: M. Kaufman/P. Collins/A. Clarke	**Type: (Continuing)**
Project Leader: Alec Saville	**Proposed Budget**: $240-320K, 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 refinement in Ti-Cu alloys under AM conditions. Neutron diffraction and large-scale electron backscatter diffraction (EBSD) measurements of AM Ti-6Al-4V as a function of specimen build height and strategy will create a complete picture of processing-structure links. Studies on the texture memory effect in WAAM and EBM Ti-6Al-4V will also be completed using neutron diffraction and large scale EBSD to further develop a predictive basis for controlling crystallographic texture and microstructure. Thermal cycling of Ti-Cu alloys will also be completed to evaluate how microstructural evolution occurs 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. EBSD maps will be collected in 4 x 4 mm areas to correlate local texture to microstructural features and enable reconstruction of as-solidified microstructure/orientations. Ti-Cu specimens will be thermally cycled in a dilatometer to simulate complex thermal cycling experienced during AM. Evaluations of grain refinement will be obtained by short-term heating into the β regime, and quenching to room temperature.

Related work elsewhere: Less comprehensive, smaller scale explorations of texture and microstructure have been completed on EBM and WAAM Ti-6Al-4V. The texture memory effect has been seldom explored, apart from work completed at AFRL in the early/mid 2000's. Exploratory Ti-Cu work has been recently published in Nature, although the origin(s) of grain refinement are not well understood.

How this project is different: Corroborative exploration of microstructure and texture from EBSD and neutron diffraction has not been completed prior in literature for EBM or WAAM Ti-6Al-4V, let alone when comparing different AM processes. Previous Ti-Cu work did not unambiguously determine the genesis of microstructural refinement, and thus is an area of critical importance in advancing titanium alloy design for AM.

Milestones for the current proposed year: Completion of build height WAAM and texture memory effect EBM Ti-6Al-4V neutron diffraction measurements, and complementary large-scale EBSD measurements to enable reconstruction of as-solidified microstructures. Initial characterization of as-received Ti-Cu microstructures and the evaluation of grain refinement with thermal cycling will also be performed.

Deliverables for the current proposed year: Publication of EBM Ti-6Al-4V texture results using EBSD and neutron diffraction. Submission of a proposal to measure texture as a function of build height in WAAM Ti-6Al-4V and evaluation of the texture memory effect in EBM Ti-6Al-4V with the High-Pressure-Preferred-Orientation (HIPPO) beamline at LANL. And, publication of instructional material generated for processing neutron diffraction data into texture measurements using Rietveld refinement.

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, predicative capabilities can be developed for AM. This will enable new levels of microstructure and property control, and increase the deployment of AM into a broader range of structural applications. Understanding the origins of Ti-Cu microstructural refinement will provide new insights into AM alloy design.

Research areas of expertise needed for project success: Rietveld refinement, neutron diffraction, 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 and Sandia National Laboratories. The texture results generated from this work are also on interest to the aerospace industry.

Progress to Date: Evaluation of as-received EBM specimens has been completed and a publication is in preparation. A second publication on Rietveld refinement of EBM neutron diffraction results is also underway.

Estimated Start Date: Fall 2018	**Estimated Knowledge Transfer Date**: Spring 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.**