RX15-13

1. **Research Title:** Characterization of Directionally Solidified Eutectic Materials
2. **Individual Sponsor:** List the AFRL research topic sponsor's contact information


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3. **Academic Area/Field and Education Level**

   Field and Education Level: Graduate student in materials science/materials engineering/physics-optics

   (MS or PhD level)

4. **Objectives:** To determine the mechanisms for enhanced thermionic emission from Directionally Solidified Eutectic (DSE) materials. The DSE materials consist of a $LaB_6$ ceramic matrix with embedded $MeB_2$ fibers where Me can be Zr, V,Ti, Ta, or Hf. DSE materials with a $LaB_6$ matrix have demonstrated enhanced thermionic emission properties over $LaB_6$ alone, however the emission mechanism is not well understood. A thorough investigation of the emission physics with correlation to the DSE material microstructure is needed to determine the reason for the enhanced thermionic emission.
5. **Description:** Lanthanum hexaboride ($LaB_6$) single-crystal ceramics are used as hollow cathode materials in electric propulsion systems due to good emissive properties, high thermo-ionic current densities, and thermo-mechanical stability under ion bombardment at elevated temperature. However, $LaB_6$ single crystals have a brittle behavior and a low thermal shock resistance which represents a strong drawback when manufacturing $LaB_6$ items of complex shapes and for their long term use. To address this challenge, $LaB_6$–$MeB_2$ *in-situ* composites were developed by directional solidification of the corresponding eutectics, where Me represents a transition metal such as Zr, V,Ti, Ta, and Hf [1]. A cooperative growth, from a melt at the eutectic invariant point, results in a $LaB_6$ ceramic matrix embedding $MeB_2$ fibers. The eutectic composite displays a highly organized microstructure with a uniform distribution of fibers aligned along the axial direction of the extruded rod. The mechanical properties of DSE composites are significantly improved with regard to the $LaB_6$ single crystal.

   Moreover, the emissive properties of DSE composites are also improved, however the mechanism is not understood. It has been hypothesized that the emission is enhanced at the interfacial matrix-fiber region due to increased electron mobility and work function lowering. Therefore a thorough study needs to be undertaken which examines the correlation between the surface microstructure and electron emission. Emission physics can be investigated with techniques such as low-energy electron microscopy (LEEM) and photoelectron emission microscopy (PEEM). PEEM provides the ability to map the emission sites in both thermionic (ThEEM) and field (FEEM) emission modes and is therefore ideal for studying the multi-phase surfaces of DSE materials. This data can then be correlated to the material microstructure as determined by atomic force microscopy (AFM), scanning electron microscopy (SEM), and transmission electron microscopy (TEM).

[1] A. Taran, D. Voronovich, D. Oranskaya, V. Filipov, O. Podshyvalova, *Functional Materials* 20, No. 4 (2013)

6. **Research Classification/Restrictions:** Unclassified
7. **Eligible Research Institutions:** Indicate to what organizations this topic should be provided

■ **DAGSI** (Wright State University, AFIT, Ohio State University, University of Dayton, Miami University, Ohio University, University of Cincinnati) NOTE: Topics submitted to DAGSI must be approved for public release. **Need PA Approval #**

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