RX15-10

1. **Research Title:** Hybrid Materials for Advanced Pulsed Power Devices
2. **Individual Sponsor:** List the AFRL research topic sponsor's contact information

Dr. Steven Fairchild, AFRL/RXAP
AFRL/RXA Bldg 652
3005 Hobson Way
WPAFB, OH 45433
steven.fairchild@us.af.mil

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

Field and Education Level: Graduate student in materials science/materials engineering (MS or PhD level)

4. **Objectives:** The objective of this effort is to develop hybrid material solutions to address problems that occur in vacuum electronic devices such as desorption of neutral species and secondary electron emission from material surfaces. These problems result in vacuum breakdown which degrades device performance and longevity.
5. **Description:** High Power Electro-Magnetic (HPEM) systems such as radar and transmitter systems, ion propulsion systems, and directed energy systems rely on high power vacuum electronics. Advanced material solutions are needed for next generation devices to improve efficiency and operational lifetime. A common problem in these devises is vacuum breakdown, which is caused by neutral outgassing (mainly hydrogen) and secondary electron emission (SEE) from the anode that collects high current density electron beams. In particular, this is a potentially limiting factor in device miniaturization since smaller sizes result in higher electric fields and thus higher power densities.

This effort proposes to develop novel new material solutions to mitigate vacuum breakdown in pulsed power vacuum electronic devices. We will investigate the use of hybrid materials and coatings that are designed to mitigate degradation and improve efficiency of such vacuum electronic components. Phenomena such as outgassing, ion bombardment, and secondary electron emission occur simultaneously during device operation. Hybrid material structures offer the potential to create devices with truly novel, combinatorial material properties. One approach is to fabricate templated structures with ultrafast laser processing that can be used as substrates for thin film deposition. For example, a hybrid material solution is needed for electron beam collection (anodes) that has both high conductivity and low SEE. TiN is a proposed candidate to replace Cu because of its low SEE [1]; however its conductivity is too low to be an efficient collector. A hybrid collector material could be made by patterning a uniform array of vertically aligned micron scale pillars into a metallic Cu substrate. Then film deposition could then be used to create a matrix surrounding the pillars from a material with a low SEE material such as TiN. With this combination, the high conductivity surface is maintained by the Cu pillars and the SEE is reduced by the TiN matrix, allowing for a potential hybrid material solution to this common problem.

Additionally, dual laser beam, dual target pulsed laser deposition allows for materials blending and doping for additional functionality. This is accomplished by the blending of two plasma plumes that are simultaneously being evaporated rom two different targets. This allows for precise control of the blended materials [2]. For example, small concentrations of Ti added to Cu could be an efficient way to getter the hydrogen that diffuses in Cu when used as an electron beam collector [3]. Blended deposition offers an easy way to explore a wide range of optimal compositions. Blended materials combined with templated substrates allows for the possibility of a truly combinatorial approach to material solutions.

Additionally, RXAP has developed a unique characterization system for simulating materials performance in a an extreme environment for better understanding neutral outgassing and SEE. Extreme environments are simulated by bombarding materials with a high energy electron beam and characterizing desorption focusing primarily on desorbed H_2. The experiment measures relative species yield, speed, and angular distributions determined by a combination of RGA and time of flight measurements. The purpose of this effort is to understand and address the deleterious effects of "neutral outgassing" and secondary electron emission (SEE) which limit the performance of vacuum electronic and particle beam devices. These undesirable phenomena cause "multipactor" and vacuum breakdown in HPEM devices that limit their output power and lifetime. This combination of thin film deposition capability and characterization allows for a thorough investigation of hybrid materials development and simulated performance in the extreme environments.

[1] Y. Suetsugu, et al. *Proceedings of PAC07*, Albuquerque, New Mexico, USA, (2007)
[2] R.W. Eason, et al. *Applied Surface Science* 255 (2009) 5199–5205
[3] S. Suzuki, et al. *Materials Transactions*, Vol. 43, No. 9, (2002)

6. **Research Classification/Restrictions:** None
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 #

88ABW-2014-~~3766~~ 3174