RX19-6

DAGSI Research Topic

1. **Research Title:** Cathode and Development and Design for High Power Microwave Applications and Vacuum Electronic Devices
2. **Individual Sponsor:**

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

   Field and Education Level: Graduate student in electrical engineering/materials engineering/physics (PhD level)

4. **Objectives:** High Power Electro-Magnetic (HPEM) devices will play a key role in next generation Air Force communication and weapon systems. Pulsed power vacuum electronic require improved cathode and anode materials. Outgassing and plasma formation in the vacuum gap are detrimental to the performance of the vacuum electronic devices, therefore AFRL/RX is analyzing improved materials and surface treatments to mitigate these effects. HPEM anode materials outgass of hydrogen while in operation and high secondary electron yields which can lead to multipactor and ultimate device failure. Nanostructured carbon materials have shown great promise for replacing traditional carbon cathodes and graphite cathodes. A major challenge will be to determine the best way to adhere the nanostructured carbon cathode to a metal electrode and many possibilities must be explored to find the optimal configuration. The anode for HPEM and vacuum electronics also poses its own challenges with limiting hydrogen outgassing and minimizing secondary electron emission. New materials engineering investigations are needed to investigate this effect. Achieving approximations to single crystal structure to maximize grain size and minimize grain boundaries in order to reduce hydrogen storage within the material is one possibility. Employing laser surface treatments to re-engineer the surface has shown potential and needs to be further explored. Finally, developing and implementing a surface design and morphology to minimize secondary electron emission is needed for optimizing the anode for HPEM applications. Overcoming all of these challenges will provide the USAF with the ultimate, next generation HPEM vacuum electronic devices.

5. **Description:** This topic will investigate new cathode technology for HPEM devices using nanostructured carbon materials. Investigations will include operational temperature, plasma formation and outgassing properties, as well as study the optimal adhesion techniques for bonding the CNT material onto a HPM cathode structure. Small experimental nanostructured carbon prototype cathodes will be tested at RX to determine the optimal configuration for high voltage operation. The goal is to develop a cathode with lower turn-on voltage, lower field strength operation, lower outgassing, reduced plasma formation, and longer lifetime.

6.

Hydrogen outgassing is a significant problem with HPEM anode materials as well as structural materials which are typically made of bulk metals. There are two approaches to investigate for mitigating hydrogen outgassing from metallic materials, which are: (a) minimizing the concentration of hydrogen originally present in the metal, and (b) providing fewer pathways along which atomic H can diffuse in the bulk. The feasibility of using Laser Surface Melting (LSM) to minimize hydrogen outgassing from metallic anodes needs to be investigated. The LSM processing technique entails irradiating a sample with the output of a high energy, continuous laser beam, thereby causing melting, flow and re-solidification of the material as the laser beam is scanned across the anode surface. This process reduces outgassing significantly by reducing the amount of hydrogen present in the laser-treated, recrystallized near-surface region, and also by forming a more crystalline layer (with fewer grain boundaries), thereby reducing the number of pathways through which hydrogen can diffuse from below. Preliminary results have shown this technique can produce a reduction in outgassing from a stainless steel surfaceof 50x, as compared to just 20X achieved by recent advanced bake out techniques. This type of improvement can significantly reduce dependency on ancillary pumps to maintain the vacuum required for stable HPEM operation. Additionally, secondary electron emission can lead to multipactor which ultimately leads to device failure. Surface patterning such as micro-hole arrays have showed promising preliminary results and need to be investigated further for mitigation of secondary electron emission.

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

[X] **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 #

[ ] **AFIT** (only)

[ ] **USAFA** (only)

If you are submitting a topic for the USAFA, indicate if you are also interested in sponsoring a USAF Cadet in summer 2015 (Average cost for USAF Cadet for 33 days is $5000)

[ ] Yes [ ] No