Field Emission Vacuum (*FEV*) Electronic Devices for Operation above 500 degrees Celsius.

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Abstract: The SSED (Solid State Electronics Development) group in Boeing Research & Technology is teamed with the Nanofabrication Group at California Institute of Technology to develop robust electronics for the Venus applications. Our Boeing-Caltech team has recently begun work under NASA R&A Award in the ROSES C24, Hot Operating Temperature Technology (HOTTech) Program. The main focus of our effort is to: (1) demonstrate Field Emission Vacuum (FEV) Electronics devices capable of operation at 500ºC; (2) apply FEV devices to design and prototype an oscillator for frequencies corresponding to S-band (2-4 GHz). This small integrated circuit will allow us to demonstrate the utility and the performance of FEV technology, and its relevance to avionics functions for Venus surface missions. In addition, our team will develop infrastructure required for future, larger-scale design of FEV circuits for mission applications, namely: design flow; simulation software and PDK (process design kit); test procedures for long-duration tests; test and data acquisition software.

We aim to establish the FEV devices as a robust yet low-cost technology for analog and digital circuits for operation at 500ºC. The classic well-established technology of microwave vacuum tubes is dominant for 500ºC, yet its large dimensions limit severely the complexity of circuits. Multiple development efforts in the past sought a technology which brings the simplicity of vacuum tubes at micrometer scale. During 2015-2016, the Nanofabrication Group at Caltech, under Boeing funding and collaboration, has pioneered a fabrication approach that obtains Fowler-Nordheim emission at low voltages, well below the ablation/damage threshold. This concept, which was prototyped and evaluated in detail, is the basis for the FEV devices for our C.24 HOTTech work for NASA ROSES. These robust devices are fabricated using a simple lithography process that yields stable, reproducible sub-50nm gaps between emitter, collector and gate. Heating the device to 500ºC in vacuum is compatible with the device operation, since they are not susceptible to traditional semiconductor limitations of carrier leakage, temperature dependence, and crystal imperfections.

Our paper will outline the construction and properties of the FEV devices, as contrasted with prior microvacuum-tube technologies. We will outline the applicability of FEV circuits to NASA's Planetary Science Research Program, along the guidelines of the Venus Technology Plan (May 2014) published by NASA Venus Exploration Analysis Group (VEXAG): "Development of high-temperature electronics, sensors and the thermo-electric power sources designed for operating in the Venus ambient would be enabling for future missions."