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Abstract: The sine quo non of terahertz (THz) vacuum electron beam devices is a high current density thermionic cathode, the development of which has been a major focus of our efforts. As a specific application, we have fabricated a high current density, long life scandate dispenser cathode to develop a 220 GHz sheet beam electron gun for a high power traveling wave tube (TWT) amplifier for the DARPA High Frequency Integrated Vacuum Electronics (HiFIVE) program. Using the solution-gelation (sol-gel) method, Sc₂O₃-added tungsten powders were made for use in high current density thermionic cathodes. The particle size of the powders was uniform, spanning the range from nanometers to micrometers, and was controllable by adjusting the sol-gel processing parameters. The densified cathode matrix fabricated from the powders has high porosity, uniform grain size and scandia dispersion, and open pore distribution.

By using the Mori Seiki NN1000 nano-CNC (developed by DTL, Davis CA), high current density nano- and micro-composite scandate dispenser cathodes were machined with high precision resulting in good surface smoothness, tight tolerance, and sharp edges. Sc₂O₃-added tungsten dispenser cathodes were tested in both UHV cubes employing a closely-spaced diode (CSD) configuration under pulse mode and in Cathode Life Test Vehicles (CLTV) with a Pierce gun configuration under CW mode. Space charge limited current densities of 38 A/cm² at 9150C_{br}, and 80 A/cm² at 1050^oC_{br} were obtained by using Sc₂O₃-added (3.56 wt.%) tungsten powders. The cathode was sintered at 1700^oC by using a batch of Sc₂O₃-W powder with an initial particle size of 700 nm yielding cathode pellets strong enough for machining. In CLTV #1, owing to a perveance issue (there is a 100 micron gap between the focus electrode and cathode emission surface), 10 A/cm² dc current density can be achieved at practical temperature of 1120^oC_{br} for more than 2000 hours. In CLTV #2 with a reduced focus electrode gap (30 μm), 45 A/cm² dc current density has been obtained. The collector pulse current density with 56 A/cm² at 960^oC_{br} at 4 kV, and up to 104 A/cm² at 1040^oC_{br} was obtained in the CLTV #3 gun with a cathode out of 70 microns beyond electron focus. This CLTV will be under CW life testing with 40 A/cm² current density which is the design value for the 220 GHz sheet beam TWT.

Keywords: Scandate cathodes, High current density, CLTV (Cathode Life Test Vehicle), Nano CNC machining.