Advanced Cathode Research

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***Abstract*— Long life, high current density cathodes are required of several THz RF sources. Conventional porous tungsten cathodes are limited to current densities less than 10 A/cm^2 for reasonable lifetimes. This presentation describes research to develop long life cathodes with emission current densities approaching or exceeding 100 A/cm^2.**

I. Program Description

CALABAZAS Creek Research, Inc. (CCR) is developing high current density cathodes for high frequency RF applications. The feature size of RF source components scales inversely with the frequency, so conventional techniques become difficult to implement above 100 GHz. To achieve high power, it is still necessary to transmit high current density beams through the RF circuit; however, typical compression ratios become impractical with submillimeter tolerances. Consequently, advanced cathodes are needed to provide the required current density without significant beam compression.

Previously, CCR reported development of sintered tungsten wire cathodes that provide controlled porosity and high levels of barium diffusion [1]. In that development, tungsten wires are bundled and sintered to form a uniform distribution of pores for barium diffusion. The Air Force Office of Scientific Research (AFOSR) funded a program to enhance cathode performance using scandium. Research confirmed that scandium reduces the surface work function, allowing high current density emission at reduced temperatures [2]. Emission current densities of approximately 100 A/cm^2 were demonstrated [3]; however, life time of the scandium is a serious issue. Erosion of the surface scandium by back ion bombardment and other processes results in unrecoverable deterioration in performance. CCR's research focused on providing the initial scandium on the surface and mechanisms for replenishing scandium removed by various processes. This presentation will describe results of that research effort.

II. Design Approaches

The technique used to produce sintered tungsten wire cathodes was described in reference 1. Basically, tungsten wires are sintered into a controlled porosity structure and sliced to form the cap for reservoir cathodes. Figure 1 shows a photograph of the material resulting from this process.

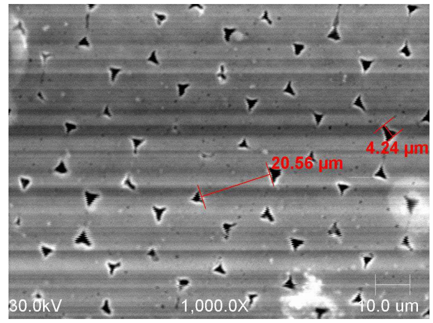

Figure 1. Cathode surface created from sintered tungsten wires.

The porosity can be controlled to allow high current density emission while the reservoir provides sufficient barium for long life operation. This allows the designer to customize the cathode for the required emission current density and lifetime. A cathode using this approach is currently being installed in a test vehicle for high power testing. A photograph of the cathode is shown in Figure 2.

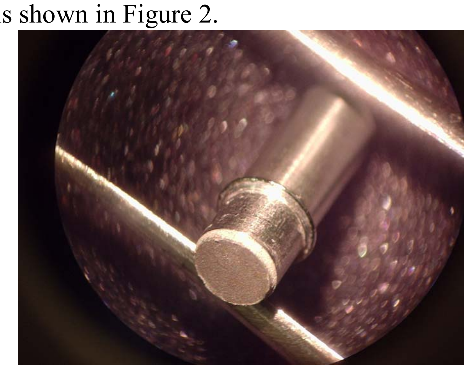

Figure 2. Reservoir cathode fabricated from sintered tungsten wires

The addition of scandium to the reservoir mixture should lower the work function, allowing increased current emission without an increase in barium consumption. Three techniques were investigated to provide the initial scandium as well as a continuing source for the life of the cathode.

The first technique involves adding scandium powder to the reservoir mixture. Scandium would be carried through the thin cap to the surface with the barium. The second technique uses scandium as a braze alloy to bind the tungsten wires instead of sintering. Figure 3 shows a photograph of a potential emission surface using this technique. SEM photographs confirm that the pores remain open while significant scandium is on the surface and within the tungsten structure.

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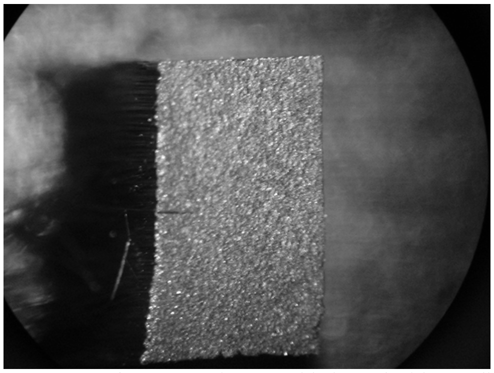

Figure 3. Face of tungsten wire assembly brazed with scandium

The third technique uses advanced chemical vapor deposition processes that deposit both surface and subsurface concentrations of scandium. This technique is applicable to porous tungsten cathodes as well as sintered wire cathodes. The research on this technique used porous tungsten material.

Figure 4 shows deposition of scandium on the surface of the material. In addition to the white surface feature, which is scandium, there is approximately 2% scandium deposition on the other surfaces. It is likely that this will be removed by normal surface erosion processes; however, the larger scandium feature should survive for the life of the cathode.

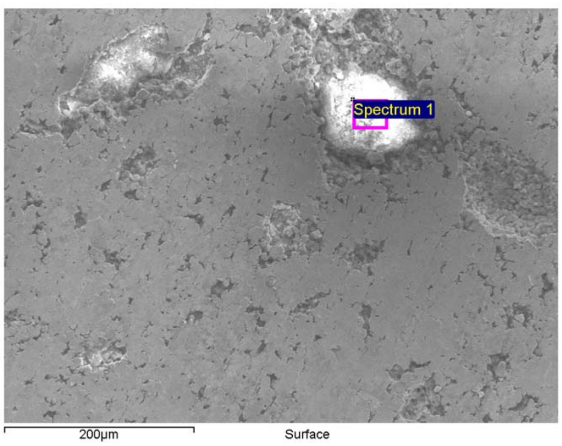

Figure 4. Deposition of scandium on a porous tungsten surface

This process also provides subsurface deposition of scandium. Figure 5 shows a scandium deposit approximately 20 microns below the porous tungsten surface. Such deposits could provide a reservoir of scandium during the lifetime of the cathode.

This deposition process provides a mechanism for improving the performance of existing cathode configuration. CCR is pursuing application of this technique to cathodes for high frequency backward wave oscillators and sheet beam guns.

III. Future Research

Calabazas Creek Research, Inc. is fabricating cathodes for high frequency RF sources at 100 GHz, 220 GHz, and 650 GHz. Each of these sources requires different cathode geometries and capabilities. The 100 GHz source will use a conventional Pierce cathode. The 220 GHz source requires a sheet beam cathode or an array of multiple beam cathodes operating at current densities exceeding 100 A/cm^2. The 650 GHz source will use a sheet beam requiring approximately 50 A/cm^2 current emission. Test results from these cathodes, which will be fabricated with different techniques, will provide much information on relative performance and fabrication issues.

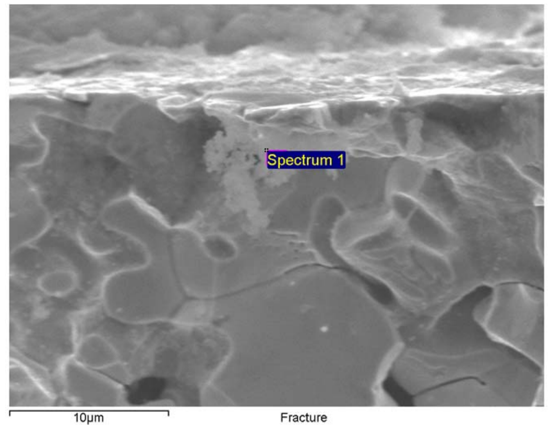

Figure 5. Deposition of scandium approximately 20 microns below porous tungsten surface

IV. Summary

Research is continuing to develop high performance cathodes for high frequency applications. The challenging performance requirements, coupled with difficulties in fabrication with the required feature sizes and tolerances, necessitate new and innovative technologies. Successful development could facilitate a new generation of RF sources in the THz frequency range for new and exciting applications.

V. References

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