Title: Active Components for Microwave Vacuum Tubes

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Many microwave systems rely on vacuum tubes (Traveling Wave Tubes, Klystrons, Magnetrons) to generate or amplify the required RF energy. This is especially true where high power bandwidths are required. Satellite uplinks and downlinks, some cellular applications, and direct broadcast applications typically use vacuum tubes for the final amplifier. Additionally, many military systems rely on vacuum tube technology to achieve the required frequency agility and extremely high power bandwidth required for these systems.

Dispenser Cathodes

In order to achieve the high efficiency and high power bandwidths demanded by many applications, a very high brightness and precisely focused electron beam is required in the tube. The electron source for these tubes must therefore be capable of sustained high current density and long life. The dispenser cathode was developed to fill this need. Emission current densities up to 8 A/cm^2 and lifetimes up to 120,000 hours are achievable with today's dispenser cathodes. Figure 1 shows typical dispenser cathode specifications.

Figure 1. Typical Dispenser Cathode Specifications

Commercial, Military, or Space Qualification	
Size Range	0.010" - 8.00" (0.25 mm - 200 mm)
Tungsten Density Range	74% - 84%
Impregnant Types	4:1:1 (S), 5:3:2 (B), 6:1:2, 3:1:1, or any other required type
Sputter Coatings	Osmium Ruthenium (M), Iridium. Other coatings possible.
Materials	Tungsten, molybdenum, molybdenum-rhenium, rhenium, tungsten-rhenium, Kovar, nickel, stainless steel, Monel and others.
Machined Tolerances	To ±.0002" (±0.005 mm)
Brazes	Ranging from molybdenum-ruthenium (mp 1980°C) to low temperature alloys such as copper-gold (mp 910°C)
Operating Temperature	From 910 °C_B to 1200°C_B
Emission Density	Continuous, as high as 20 A/cm^2, typically 2-5 A/cm^2; pulsed, as high as 120 A/cm^2, typically 30-70 A/cm^2
Life Expectancy	From 3,000 hours to 150,000 hours

A dispenser cathode consists of a porous tungsten matrix infiltrated with a barium electron emission-enhancing compound. The microstructure of the tungsten sponge is carefully controlled to produce predictable performance. An integral vibration hardened heater and mounting structure is a part of the cathode design. In many cases the entire tube including the cathode structure must be capable of withstanding the high shock and vibration encountered during satellite launch. Mechanical properties are precisely controlled which is necessary for consistent operation of the vacuum device. Strength and stiffness are balanced against thermal efficiency for various applications.

Semicon Associates, A Ceradyne Company, is a major supplier of dispenser cathodes for the microwave tube industry for over 40 years. Complete design and manufacturing capabilities allow Semicon to satisfy any requirement for virtually all of the world's microwave tube manufacturers.

Recently Semicon Associates has embarked on a program to produce higher level assemblies incorporating the cathode and the gun structure. This is a natural addition to the manufacture of dispenser cathodes since the cathode must be integrated into the gun structure in order to function. By performing some or all of this integration process, Semicon Associates assumes the risk of handling the environmentally sensitive cathode and can provide the tube manufacturer with a value added assembly ready to install in the tube. The tube manufacturer benefits from reduced total costs and improved allocation of technical resources. Figure 2 shows a variety of Semicon Associates' components for microwave vacuum tubes.

Figure 2. Semicon Associates Components for Microwave Vacuum Tubes

Lossy Ceramics

The efficient operation of many microwave vacuum tubes (TWT, Klystrons, Magnetrons) rely on the absorption of specific higher order mode (HOM) frequencies and/or on the absorption of microwaves over a wide range of frequencies at terminal ends of the tubes. Components such as absorbers, slot mode absorbers, severs, pellets and terminations are used in various parts of the tube to absorb the unwanted frequencies. These components are manufactured from ceramic materials with tailored dielectric properties based on beryllium oxide (BeO), magnesium oxide (MgO), aluminum oxide (Al_2O_3), or aluminum nitride (AlN). The choice of ceramic formulation is dependent on the tube's power requirements and the specific frequencies that are to be absorbed. Ceradyne, Inc. offers lossy components from non-berilia containing lossy material families. Examples of components manufactured by Ceradyne, Inc. are shown in Figure 4.

Figure 3. Lossy Components produced by Ceradyne, Inc.

The microwave industry is becoming aware of the potential health and environmental issues during BeO and BeO based lossy component manufacture. The inhalation of fine dust particles created during the ceramic manufacturing and the final machining process can result in chronic beryllium disease, a severe respiratory illness. This has caused Ceradyne and others to discontinue the manufacture of BeO based lossy components and has prompted Ceradyne to investigate alternatives to the BeO materials.

Ceradyne offers AlN based lossy materials that have tailored dielectric properties designed to replace existing BeO based lossy materials. Figure 5 shows the output of an S-Band tube with BeO based lossy terminations and AlN based lossy terminations is equivalent. Figure 6 shows the AlN terminations. The AlN based lossy compositions have equivalent thermal conductivities at operating temperatures. These materials are designed to retain their dielectric loss at cryogenic temperatures (a requirement for some accelerators). AlN based lossy components are vacuum compatible, thermally stable and can be bonded to metals by appropriate techniques.

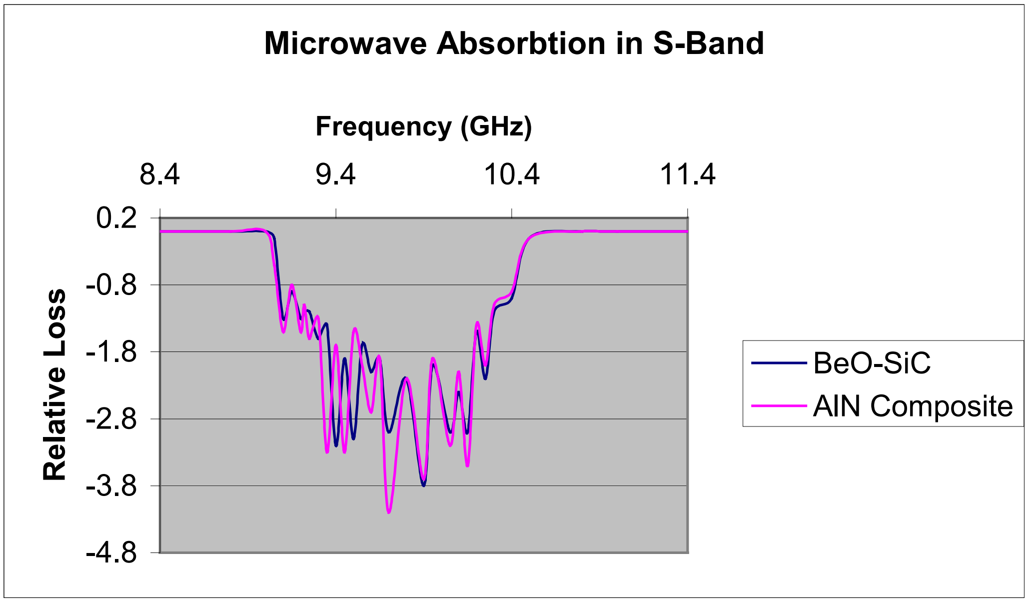

Figure 4. Microwave Absorption in S-Band

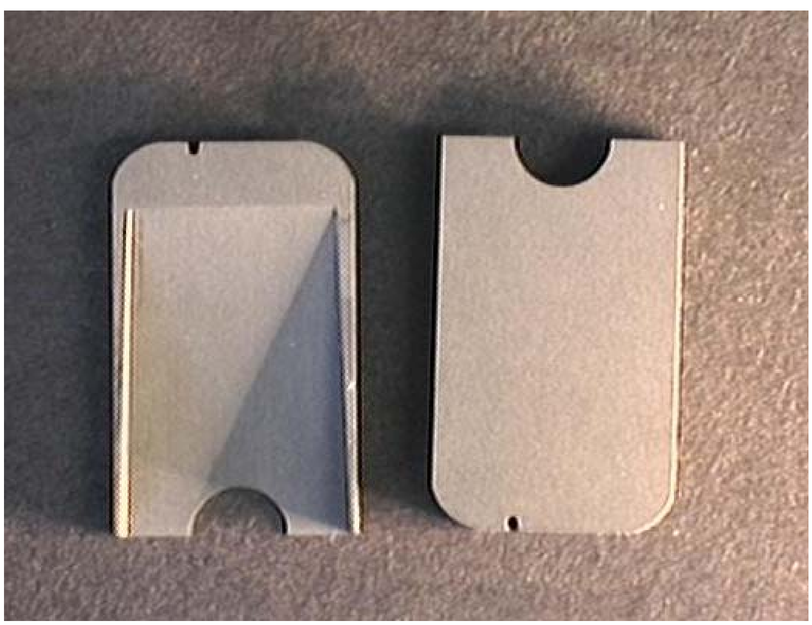

Figure 5. AlN Terminations

Structural Ceramics

Structural components such as collectors, collector rods, helix support rods and microwave windows are used in microwave tubes for structural support of selected metallic components and to facilitate thermal management. Ceramic materials such as aluminum oxide (Al_2O_3) or beryllium oxide (BeO) are selected for these components because they are electrical insulators, have very low dielectric loss in the microwave frequency range and in the case of BeO have a high thermal conductivity.

Aluminum nitride (AlN) is considered to be the best choice as a replacement for BeO for structural microwave components (Figure 7). Although AlN typically has a lower thermal conductivity than BeO at room temperatures, at operating temperatures (150-300°C) these differences become negligible (Figure 8).

Property	AlN	BeO
Density (g/cm^3)	3.26-3.32	2.86
Bend Strength (MPa)	200-350	150-200
Youngs Modulus (GPa)	310	300
TEC, RT-400°C (1/ °C)	4-5	7.2
Thermal Conductivity (WmK)	160-200	250
Permittivity, real part (1 GHz)	8-9	7
Loss Tangent (2.4 GHz)	~0.001	0.0005

Figure 6. Property Comparison, AlN and BeO

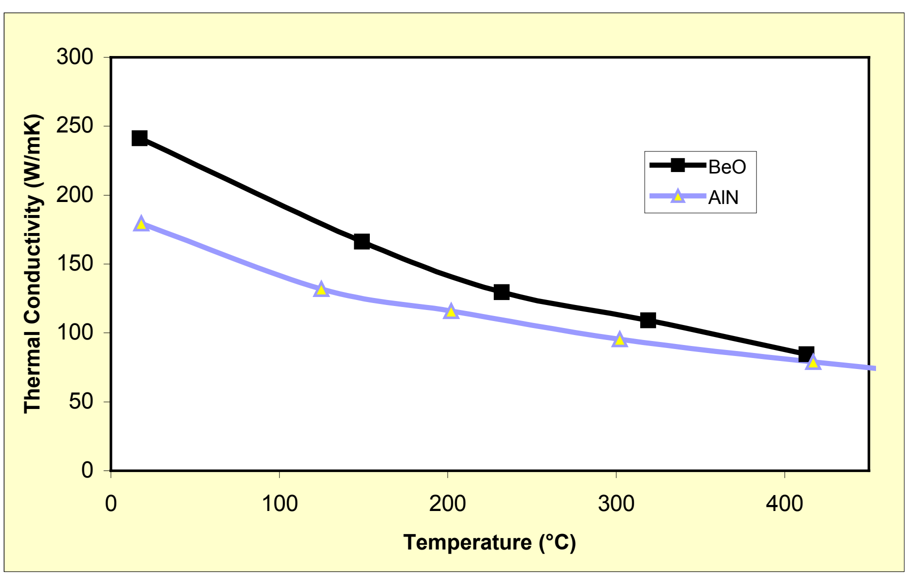

Figure 7. AlN and BeO and thermal conductivities versus temperature

Ceradyne, Inc. manufactures a high thermal conductivity grade of aluminum nitride (**Ceralloy**® 1370DP) for collectors, collector rods and helix rod support applications in microwave tubes.

AlN can be metallized using either thick film or thin film techniques and then coated with nickel for brazing to metal structures. Active metal brazing techniques can also be employed.

List of Figures

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