BeO Still A Force In RF Power Transistor Packaging

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The excellent performance characteristics of beryllium oxide (BeO) continue to make it well suited for RF power transistors and other devices that operate at very high power levels. Typical applications include military and aerospace pulsed power applications, where its inherent advantages remain unchallenged. BeO's continued importance as an insulating material is a result of its superior thermal conductivity (TC) of about 325 W/mK at room temperature, which among insulating materials, exceeds all but diamond (up to 1800 W/mK). Its nearest competitor in this respect is aluminum nitride (AlN) at about 185 W/mK, with alumina (Al_2O_3) at a distant 25. As a result, when thermal management and electrical isolation are key considerations, RF power transistor packages based on BeO are the best choice (*Figure 1*).

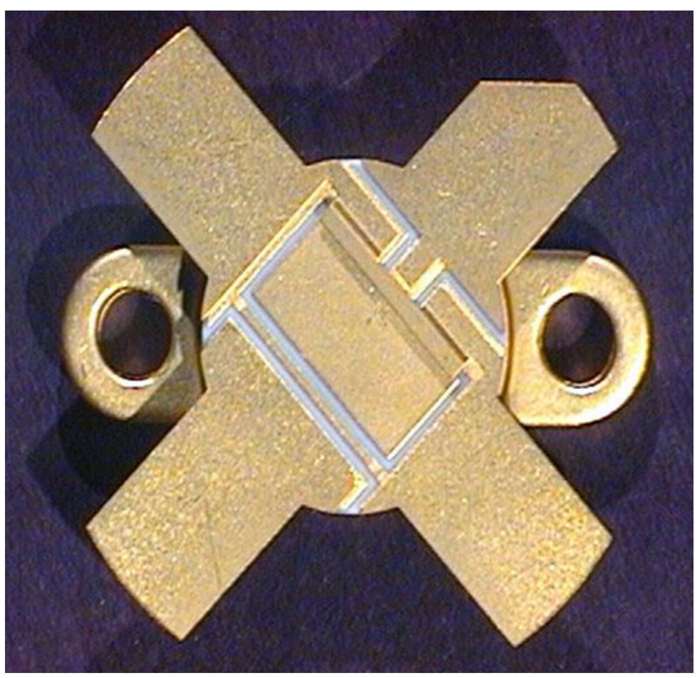

Figure 1*: A typical stripline-opposed-emitter (SOE) package used for UHF-VHF silicon power transistors. (Photo courtesy Zentrix Technologies.)*

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In addition to thermal conductivity, BeO's coefficient of thermal expansion (CTE) at 9.0 ppm/ºC is close to that of gallium arsenide (6.9) and is also well matched to other metal matrix composites (MMCs) such as Cu/W, Cu/Mo, Al/SiC, and E-materials. In other relevant areas, such as electrical resistivity and dielectric strength, BeO has better electrical characteristics than AlN and is similar to alumina. With a low dielectric constant of 6.7 and low loss index of 0.0012 at 1 MHz, BeO is well suited for use at high frequencies as well. In addition to these characteristics, BeO also is inherently stable in oxidizing environments, in contrast to nitrides such as AlN that decompose over time to their oxide equivalent.

Since beryllium is an oxide ceramic, BeO is very stable in oxygen/moisture-containing environments. Ceramic-to-metal joints and metallization coatings are generally very strong and reliable, which is important in the design of high-reliability military systems. In addition, BeO is also about 11 times more resistant to thermal shock than alumina.

Like other ceramic materials, BeO's thermal conductivity decreases with increases in temperature, in contrast to metals whose thermal conductivity deteriorates less with temperature increases. Consequently, combinations of BeO and metal films have proven very effective for RF power packaging. In the temperature range at which RF power transistors operate, BeO also offers about 30% better thermal dissipation properties than AlN. Even at lower than ambient or cryogenic conditions, beryllium remains superior to all other ceramic materials.

The ability of a device or subsystem to rid itself of heat is exceptionally important to product life, and most failures in base station electronics are related to thermal issues. Without good package heat dissipation, a device will degrade at an accelerated rate and ultimately fail, and the higher the temperature the sooner this will occur. BeO packaging is very appealing in such dense environments, where even incremental improvements in thermal management can play a major role in extending system operating life. In higher-frequency applications, greater current is required near bond interfaces, which necessitates less-resistive interface layers. BeO offers the ability to reduce the area and size of a device while dissipating the same power and reducing capacitance. In small leadless packages, for example, BeO provides an advantage over AlN, which at high frequencies cannot provide the expected electrical or thermal performance that can be achieved when using BeO.

Dielectric constant and dissipation factor are also important parameters in which the characteristics of BeO are desirable. Transmission lines and passive structures are critical components of RF and microwave modules. For many applications, lower dielectric constants are preferred because transmission line losses are lower and conductor width is increased, which makes circuits more easily produced. Dielectric losses are also reduced with decreasing dielectric constant.

The cut-off frequency of a particular substrate thickness also increases as dielectric constant is lowered for microstrip circuits. As a result, a BeO substrate of a given thickness can be used at frequencies about 20% higher than it could with an alumina substrate of the same thickness. Thick-film lithographically-etched, gold-metalized substrates manufactured on

BeO exhibit these important characteristics and can operate upwards of 44 GHz. Bonding of copper to BeO improves the performance of the ceramic, and it can be applied via the Direct Bond Copper (DBC) process. DBC on BeO further enhances the thermal performance of the BeO while allowing high power transmission. Transistor packages produced via the DBC process perform extremely well through 8 GHz with less than 1 dB of insertion loss.

BeO Enhancements

Several recent developments have further expanded the utility of BeO. The one of greatest significance for RF power transistors is a very recent increase in thermal conductivity to 325 W/mK achieved by Brush Ceramic Products, a division of Brush Wellman, Inc. This is the biggest enhancement to the material's basic properties in many years, further separates the thermal conductivity of BeO from other candidate materials, and makes it suited for future RF power devices that deliver greater RF outputs and have correspondingly greater need to dissipate waste heat.

Other enhancements include the ability to produce BeO plates up to 4.5 in x 4.5 in., which reduces cost by allowing a greater number of patterns to be created on a single plate. In addition, the new BW1000 substrates from Brush Ceramics increase material strength by up to 25% to 38,000 lb./in.^{2}, which was achieved by adding proprietary additives while maintaining a purity level of 99.5%, and by precisely controlling grain growth and grain distribution during sintering. The material can also be formed into many shapes to serve diverse applications (*Figure 2*).

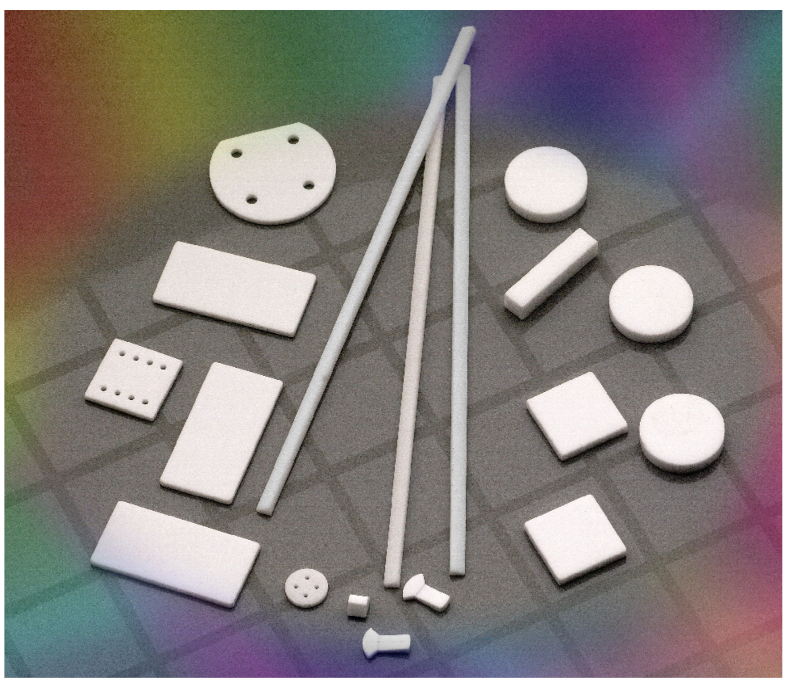

Figure 2*: BeO can be formed into a wide variety of shapes to accommodate many applications.*

Conclusion

After more than 50 years, BeO packaging technology for microwave and power RF applications remains superior at the highest power levels when the greatest amount of heat is dissipated. The stability of BeO ceramic components in reducing and oxidizing environments also makes it the prime candidate for long-life, high-reliability commercial and defense applications. As a thermal management ceramic, BeO outperforms AlN for pulsed-power RF packaging applications. Finally, BeO's properties and metallization technologies have been very consistent over time. So while the onslaught continues from other insulating materials, the use of BeO continues to grow in RF applications that demand its inherent superiority in many key parameters, and will likely continue to do so for many years.

For more information about BeO products, technology, and applications in RF and microwave products, visit https://materion.com/businesses/ceramics, call 520-746-0699, or e-mail ceramics@materion.com