Aluminum Silicon Carbide (AlSiC) for Advanced Microelectronic Packages

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Abstract

Aluminum Silicon Carbide (AlSiC) metal matrix composite (MMC) materials have a unique set of material properties that are ideally suited for all electronic packaging applications requiring thermal management. The AlSiC coefficient of thermal expansion (CTE) value is compatible with direct IC device attachment for the maximum thermal dissipation through the 170 – 200 W/mK thermal conductivity value material. Additionally, the low material density of AlSiC makes it ideal for weight sensitive applications such as portable devices.

The AlSiC material and functional electronic packaging geometries are produced using the Ceramics Process Systems Corporation's QuickSet™/QuickCast™ net-shape (without machining) fabrication process. Additionally, functional packaging features such as feedthrus, sealrings and substrates are incorporated in AlSiC during fabrication using the CPS Concurrent Integration™ technique eliminating the need for the traditional assembly and brazing (or soldering) operations.

The ideal AlSiC material properties and the AlSiC net-shape fabrication process provides low-cost high performance functional thermal management packaging solutions. This paper will review the material properties of AlSiC contrasted to traditional heat-sinking materials. AlSiC fabrication processing flow will also be reviewed and discussed. Functional packaging designs and application solutions will be illustrated through CPS AlSiC product examples.

Introduction

Maximum heat dissipation is a requirement for today's microelectronic systems. The maximum heat dissipation is achieved by mounting active devices directly to high thermal conductivity heat-sinking substrates or packages. Direct attachment requires a compatible coefficient of thermal expansion (CTE) value of the heat sink material to avoid stress failure of the IC device.

Traditional thermal dissipation materials like copper and aluminum have CTE values that are much greater than IC devices. To compensate, the IC device is mounted on a stress reducing interface material with a marginally compatible CTE to the heat-sinking device. Interface materials, such as highly thermally resistive alumina substrates, result in a thermal dissipation penalty.

The Fe-Ni alloy packaging materials like Kovar have compatible CTE values but offer no thermal dissipation advantage due to low thermal conductivity values. Although CuMo and CuW packaging materials have high thermal conductivity and compatible CTE values, these materials have high densities that make them inappropriate for weight sensitive applications such as portable devices[1,2].

The Aluminum Silicon Carbide (AlSiC) material system offers the packaging designer a unique set of material properties that are suited to high performance advanced thermal management packaging designs. AlSiC has a high thermal conductivity and compatible CTE permitting direct IC device attachment. AlSiC is also lightweight, making it appropriate for portable designs and other weight sensitive application.

Additionally, the AlSiC material and process system have two significant advantages over traditional packaging materials. The first advantage is that packages are fabricated to net-shape during material processing using the Ceramics Process Systems Corp. (CPS) QuickSet™/QuickCast™. Net-shape fabrication offers the designer flexibility to develop complex tight tolerance package geometries without the need to machine these features. The second advantage is that functional components such as feedthrus, sealrings, and substrates can be hermetically integrated in packages during AlSiC processing[3,4]. This single step process, termed Concurrent Integration™, eliminates the need for subsequent integration operations such as brazing and soldering which can be yield limiting. Net-shape fabrication and Concurrent Integration™, coupled with thermal conductivity, compatible CTE, and low material density are technology enabling attributes of AlSiC that offer low-cost design opportunities for the packaging engineer[5].

AlSiC Composite Material System

The AlSiC material is fabricated by pressure infiltration of molten aluminum metal into a SiC particulate preform. The SiC preform, fabricated by CPS QuickSet™ injection-molding process, is inserted into an infiltration mold for pressure assisted molten Al-metal infiltration, the CPS QuickCast™ process. The SiC preform and the infiltration tooling incorporate all the features of the final product allowing for the net-shape package fabrication[5,6,7]. Figure 1 displays a SiC lid preform with the corresponding AlSiC lid. Cavity and seal ring features on the lid are held to +/- 0.002 inch on both the SiC preform and infiltrated AlSiC product.

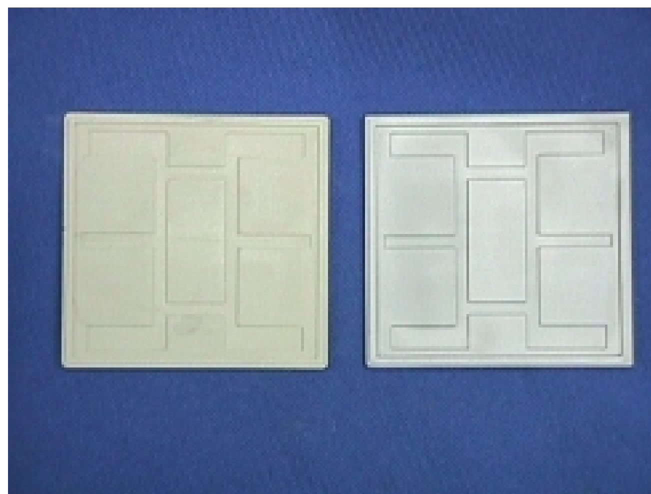

Figure 1. SiC Preform (l) and AlSiC Lid (r).

The AlSiC microstructure is composed of a continuous Al-metal phase with discrete SiC particulate phase, as shown in Figure 2. The AlSiC composite microstructure is fully dense with no void space creating a hermetic material; He leak rates are better than 10-9 atm cc/s measured on 0.010-inch material cross sections. This hermeticity level allows fabricated AlSiC packages to provide environmental protection of functional components.

The unique AlSiC material properties result from a combination of the constituent material properties; AlSiC properties are tailored by varying the ratio of these constituents. The IC CTE compatible AlSiC compositions have a SiC particulate content between 50-68 vol%. Table 1 compares the material properties of AlSiC to Si, GaAs and traditional packaging materials.

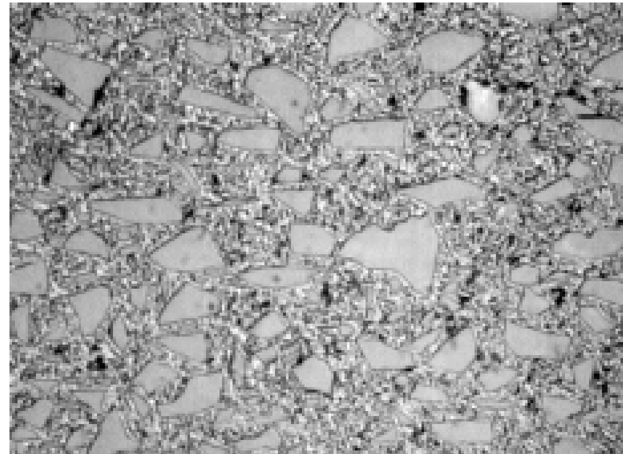

Figure 2. AlSiC Microstructure (SiC in dark contrast).

AlSiC composite materials have thermal conductivity values that are similar to aluminum metal, and CTE values that are similar to alumina. These attributes make AlSiC packages ideal for direct active device attachment to maximize thermal dissipation and improve product reliability.

AlSiC strength and stiffness compare favorably to traditional packaging materials. The ultimate bending strength of AlSiC is two to three times greater than Al-metal. The AlSiC Young's modulus - a measure of a material's stiffness - is three times greater than Al-metal, and two times

TABLE 1: AlSiC Material Properties Compared with Common Packaging, Substrate and IC Materials. (Typical Values)

Material	Density (g/cm^3)	CTE ppm/° (25-150°C)	Thermal Conductivity (W/mK)	Bend Strength (MPa)	Young's Modulus (GPa)
Si	2.3	4.2	151		112
GaAs	5.23	6.5	54		
AlSiC (63v% SiC)	**3.0**	**7.5**	**170 - 200**	**450**	**175**
Kovar (Ni-Fe)	8.1	5.2	11 - 17		131
CuW (10-20% Cu)	15.7 - 17.0	6.5 - 8.3	180 - 200	1172	367
CuMo (15-20%Mo)	10	7 - 8	160 - 170		313
Cu	8.96	17.8	398	330	131
Al	2.7	23.6	238	137-200	68
SiC	3.2	2.7	200 - 270	450	415
AlN	3.3	4.5	170 - 200	300	310
Alumina	3.98	6.5	20 - 30	300	350
Beryllia	3.9	7.6	250	250	345

greater than Cu-metal. The high stiffness to low density ratio is structurally desirable for larger parts with thin cross sections. This attribute permits designs to incorporate feature like fins to maximize cooling surface area. Figure 3 shows an AlSiC heat sink and BGA lids with integral cooling fins and pin fins.

AlSiC Plating and Integration

AlSiC packages and substrates can be plated using similar plating processes as traditional packaging materials that include Ni, Ni-Au, anodization and plasma flame spray coating. AlSiC packages can also be assembled with sealrings, feedthrus, and substrates using traditional low temperature eutectic brazing and soldering techniques. Figure 4 shows an Alloy-48 sealring and planar ceramic feedthrus that were brazed to an AlSiC substrate.

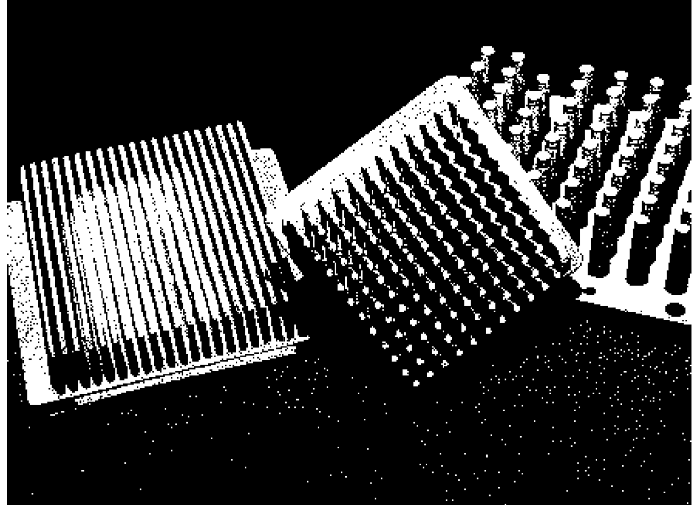

Figure 3. AlSiC BGA Lid with Integral Heat Sink Fins.

AlSiC Concurrent Integration™

Sealrings, feedthrus, and substrates can be integrated in AlSiC packages during the fabrication process[3,4]. Concurrent Integration™ has the advantage of forming a hermetic seal between the functional component and AlSiC material in a single process step[6].

Figure 5 shows an AlSiC microwave housing with coaxial feedthrus that is Concurrently Integrated™; ceramic ferrules and preform are also shown. This produce is assembled by infiltrating the net-shape SiC preform and ceramic ferrules together in the infiltration mold. The ceramic ferrules are filled with and are sealed to the housing during the infiltration process by the Al-metal.

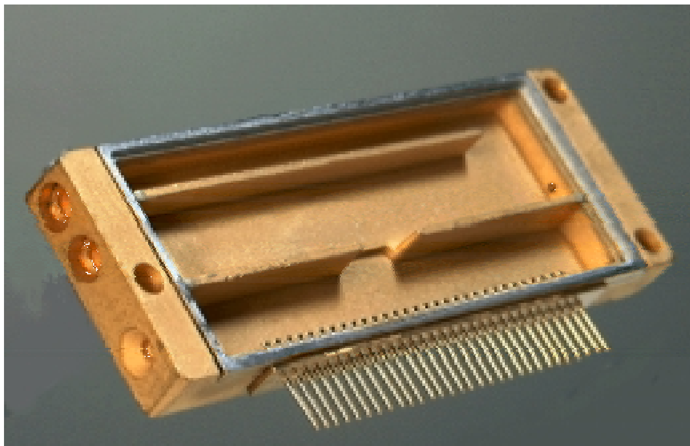

Figure 4. AlSiC Substrate with Brazed Seal Ring and Planar Feedthrus**.**

Another example of Concurrent Integrated™ AlSiC housing is shown in Figure 6. In this housing a high thermal conductivity aluminum nitride substrate is captured in an AlSiC frame. In addition, electrical traces of aluminum metal were also incorporated on the AlN substrate surface

during the infiltration process. The housing is Ni-plated to facilitate solder and wire bonding. Other substrates such as alumina, zirconia toughened alumina, silicon carbide, diamond-coated silicon carbide, and diamond have also been integrated into AlSiC housings.

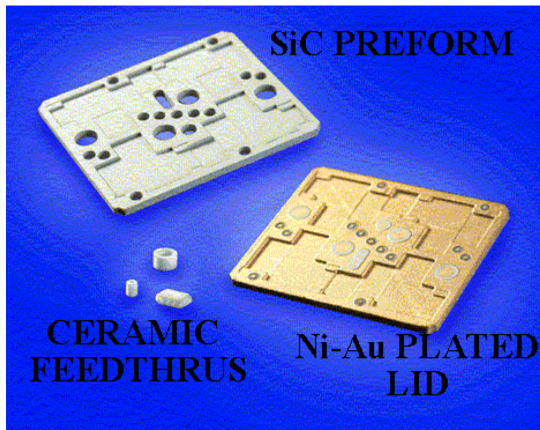

Figure 5. Concurrently Integrated™ AlSiC Housing with coaxial feedthrus.

Figure 6. Concurrently Integrated™ AlSiC Housing with AlN substrate.

Conclusions

AlSiC is an ideal packaging material for today's microelectronic components and devices that require thermal management. The low density of AlSiC makes it an appropriate choice for weight sensitive applications such as portable devices. Furthermore, net-shape fabrications, as well as Concurrent Integration™ processing offers significant low-cost design advantages over the traditional packaging materials. These attributes enable improvements in packaging and thermal management designs that ultimately improve component reliability and reduce cost.

The significant process and material advancements of AlSiC in past years has gained the acceptance of AlSiC heat sinks, packages and substrates in both military and commercial applications. Product designs in AlSiC are cost competitive and offer significant performance value.

References

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