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Application News

Electron Probe Microanalyzer EPMA-8050G

Cross-Sectional Analysis of Power Semiconductor and Silver Sintering Die Attach Material

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User Benefits

- Useful in evaluation of the particle shape of silver sintering die attach materials.
- Useful in evaluation of the sintered condition, such as voids, and the diffusion of elements at the bonding interface in silver sintering.
- Useful in research on surface properties, such as the film thickness in metalizing treatment.

■ Introduction

Power semiconductors are used in a wide range of applications, from household electrical appliances and automotive devices to power transmission and distribution systems. Recently, SiC (silicon carbide) semiconductors, which allow high-temperature operation, have attracted attention as a substitute for conventional Si (silicon) semiconductors. With application of SiC, the operating temperature of power semiconductors is expected to increase to 200 ˚C or more in the future. However, in this case, the heat resistance of the die bond where semiconductor chips are bonded to a substrate becomes an issue, as high-temperature operation may cause deterioration or embrittlement of the joining material.

Silver (Ag) sintering materials can withstand high temperatures exceeding 200 ˚C and have excellent thermal conductivity, enhancing heat dissipation and realizing improved temperature management of devices. Since embrittlement can be preventing by using Ag sintering materials, thereby improving the reliability of the bonds, Ag particles have attracted interest as a die bond material with excellent heat dissipation.

This Application News article introduces an example of analysis of a power semiconductor using an EPMA™ electron probe microanalyzer (EPMA-8050G).

■ Power Semiconductors

With conventional Si semiconductor, a large amount of energy may be lost during power conversion, but energy loss can be improved significantly by introducing a SiC widegap power semiconductor. SiC has a wide bandgap and is superior in terms of pressure resistance and heat resistance due to its excellent thermal conductivity, which allows efficient management of generated heat and stable operation even under high-temperature environments [1), 2)].

In the vertical package structure of a power semiconductor device, wiring is formed on the SiC device surface, and the heat generated by the semiconductor (die) is dissipated downward.

The back of the SiC chip analyzed here was metalized by ion plating. Titanium (Ti) plating, nickel (Ni) plating, and gold (Au) plating were carried out. The AMB (Active Metal Brazing) substrate consisted of a three-layer structure of a pure copper (Cu) substrate, a ceramic substrate, and a pure Cu substrate. High bond strength and thermal conductivity were secured in the SiC chip and the AMB substrate by sintering Ag particles.

Fig. 1 shows mapping images of the specimen described above. No delamination of the interface or cracking in the bond layer can be observed. The ceramic substrate and pure Cu substrates are joined by an active metal brazing material suitable for joining dissimilar materials. A bond layer consisting of an AgCuTi alloy can be observed. Trace amounts of magnesium (Mg) and yttrium (Y) are dispersed in the silicon nitride (Si_3N_4) of the ceramic to improve mechanical strength and heat resistance.

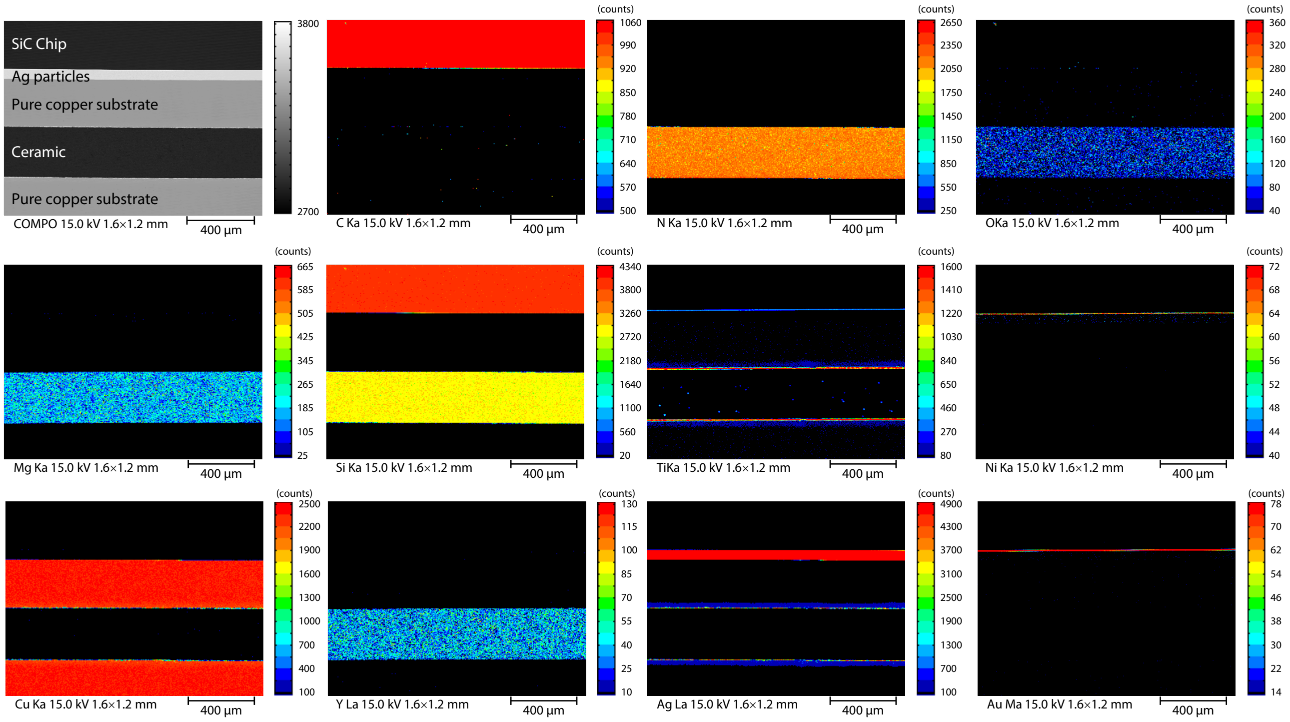

Fig. 1 Mapping of Power Semiconductor

■ Ag Sintered Bond

When Ag particles are used, a metallic bonding layer with a high melting point can be obtained by sintering at a comparatively low temperature, without melting the bonding material, by atomizing the particles to enhance their reactivity. The SE images in Fig. 2 show (a) an image of the entire Ag sintered bonding layer and high-magnification SE images of (b) the chip side, (c) the central area, and (d) the substrate side. The sintered structure seen in these high-magnification SE images is relatively uniform with no large gaps between the particles, contributing to both high bonding strength and electrical conductivity. Furthermore, because the void ratio, representing the percentage of gaps, is approximately the same, the density of the sintered layer is high, maintaining mechanical properties and electrical properties.

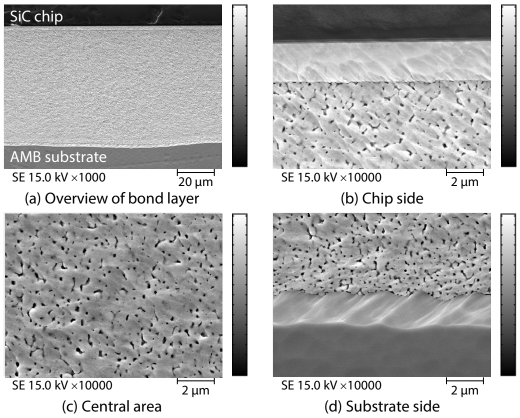

Fig. 2 Ag Sintered Bond Layer

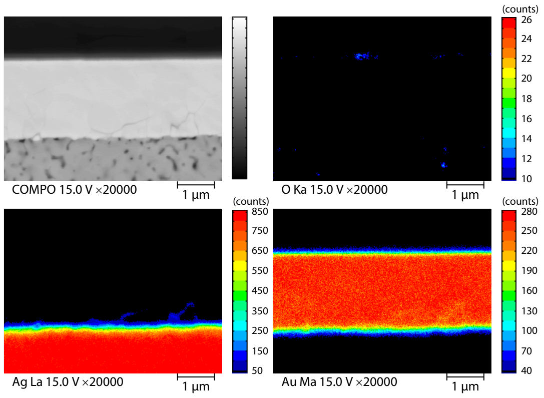

Fig. 3 Mapping of SiC Chip/Ag Sintered Bond Interface

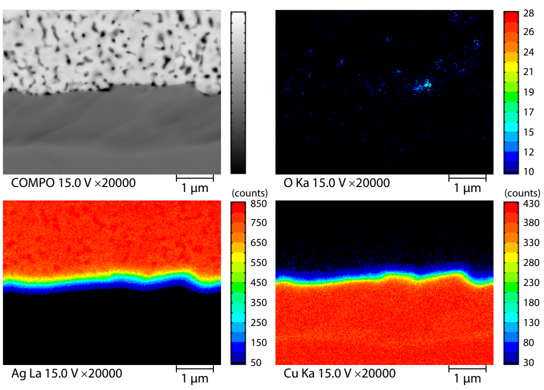

Fig. 4 Mapping of Ag Sinter/AMB Bond Interface

Although the Cu substrates were cleaned with sulfuric acid, the copper oxide that was not removed prevented contact between the Ag particles and the Cu substrate, which reduced bonding strength. Fig. 3 and Fig. 4 are mapping images of the interface between the SiC chip and the Ag sintered bond and between the Ag sinter and the AMB substrate bond, respectively. No delamination of the bonding layers can be observed in either figure. The thin oxide film that could be observed in the bulk state was not detected at the bonding interfaces. However, from the trace distribution of oxygen seen in Fig. 4, the possibility of oxidation of the Cu surface is a concern.

■ SiC Chip Back Electrode

Metalizing treatment is used to form electrodes on the back side of a SiC chip. In Ti/Ni/Au metalizing, the Ti barrier layer has high bond strength with SiC, prevents oxidation of Ni, and suppresses diffusion to Au. The Ni layer has good electrical conductivity and forms a bond with Au. The Au layer maintains excellent electrical conductivity, and also has high corrosion resistance, ensuring long-term reliability. Fig. 5 shows mapping images of the SiC chip. It can be understood that no delamination has occurred in the Ti and Ni layers, which have a thickness of approximately 0.1 µm, and the film thickness has also been formed uniformly. In SiC chips with this type of metalized structure, chip performance and reliability are improved by high bond strength and excellent electrical properties and high-temperature operating characteristics.

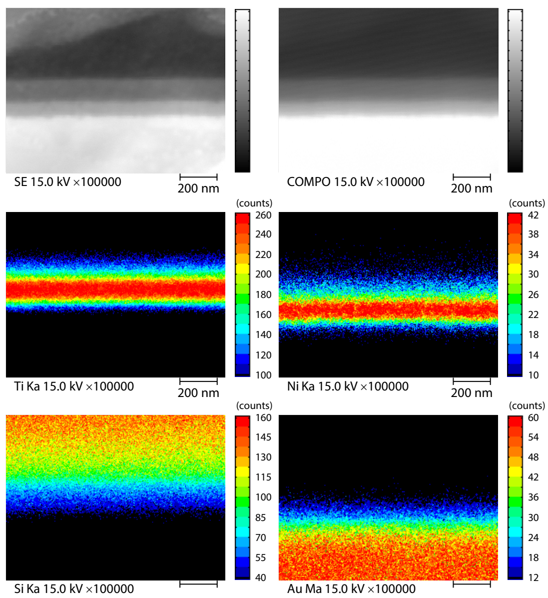

Fig. 5 Mapping of Back Electrode of SiC Chip

■ Conclusion

In response to high-temperature operation of power semiconductor devices, Ag particles have attracted considerable attention as a die bond material. Their high-temperature resistance and superior heat dissipation properties are expected to improve device reliability and are being utilized in research and development, such as evaluation of the bond interface.

<References>

1) Katsuaki Suganuma: Osaka University Engineering Society, Manufacturing and Technology, Vol. 69, No. 2, 105 (2017)
2) Chuantong Chen and Katsuaki Suganuma: Engineering Materials, Nikkan Kogyo Shimbun, Ltd. Winter 2022, Vol. 70, No. 1 (2022)

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