High strength and highly (111)-oriented nanotwinned Ag thin films on SiC substrate

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Abstract

In the fields of Artificial Intelligence (AI), compound semiconductors, high-power devices, and autonomous vehicles (AV), advanced packaging techniques are required to meet the demands of heterogeneous integration and the associated quality and reliability requirements, as well as thermal management strategies. Unfortunately, solder joint technology can no longer be used in advanced packaging technology with the shrinkage of bump pitches. Furthermore, the interconnecting technology or the die-attachment method for the power electronics chip needs to regulate a high-working temperature (>200 °C), high current, and high voltage, which often cause serious reliability issues. Thus, a high-working temperature bonding joint with a lower process temperature is desired.

Metal-to-metal direct bonding or wafer-to-wafer bonding has been regarded as a promising technique for next-generation advanced packaging. Cu-Cu direct bonding has recently attracted considerable interest and attention due to its desirable properties of e better electromigration resistance and physical properties. However, the traditional Cu-Cu direct bonding technique normally requires high bonding temperature (> 350 ℃) in a high vacuum environment. Ag is viewed as a potential candidate for achieving metal direct bonding without vacuum environments because Ag has been reported to possess superior electrical and thermal conductivity and excellent oxidation resistance.

In this study, we propose to use highly-(111) nanocrystalline Ag as interconnecting or die-attached materials in high-power devices or compound semiconductors. The highly-(111) orientation of Ag possesses the fastest diffusion rate among different crystalline planes, thus not only effectively reducing the bonding temperature but also shortening bonding time. We have successfully used magnetron sputtering techniques to fabricate the highly-(111) Ag thin films on SiC substrate. The texture coefficient of (111) on Ag thin films can reach 99%. In addition, the high density of nanotwinned structure with twin spacing of 9 nm on Ag thin films was observed. Thus, the hardness of nanotwinned Ag thin films developed in this study can reach 2.2 GPa. Furthermore, the resistivity of nanotwinned Ag thin films is 2.02 μΩ·cm. Both high strength and low resistivity of highly (111)-oriented and nanotwinned Ag thin films are beneficial for low-temperature bonding processes for power devices.

Keywords - Nanotwin, Silver, SiC, Advanced packaging