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Morphology and Properties of Diamond Deposited on Grooved 4H-SiC Substrate

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Abstract

Silicon carbide (SiC) is a reliable alternative semiconductor to replace silicon (Si) in high-temperature electronics applications. To further improve the thermal performance of SiC for certain niche applications, diamond is deposited as a heat dissipation layer due to its ultra-high thermal conductivity. In this paper, morphology, crystallinity, coverage, and thermal performance of microwave plasma chemical vapor deposited diamond on grooved 4H-SiC substrate as a function of growth time was evaluated.

1. Introduction

Silicon carbide (SiC) is one of the third generation of semiconductor materials, which is slowly but steadily becoming a reliable alternative to silicon (Si) in high-temperature electronics applications, especially in electric vehicle [1-4]. Devices manufactured on SiC substrates have improved high power reliability and performance compared to Si- and sapphire-based devices. However, SiC based devices are still limited by their thermal management. As a result, diamond with an extremely high thermal conductivity (> 2000 W m^{-1} K^{-1}) has been listed by researchers as the best choice to address this bottleneck. In order to improve the thermal performance of SiC based devices, a new process of diamond film deposition on grooved 4H-SiC substrate by microwave plasma chemical vapor deposition (MPCVD) is proposed.

2. Experimental and results

Using the current mature SiC grooving process, 4H-SiC substrate with groove width of 100 μm and groove separation apart of 1 mm (Fig. 1). The cleaned 4H-SiC substrate is placed on a molybdenum sample holder located at the middle of the MPCVD chamber. Diamond was grown on carbon-terminated surface of 4H-SiC substrate in CH_4-H_2-O_2 gas mixture by MPCVD system. In the process of diamond films deposition, the chamber is operated at a constant working pressure of 150 Torr, microwave power of 4 kW, substrate temperature of 900℃ as measured with a two-color infrared thermometer, methane concentration of 6%, oxygen concentration of 0.2%. The growth time is 10 h, 20 h, and 30 h. The deposited diamond was characterized by a field emission scanning electron microscope (SEM).

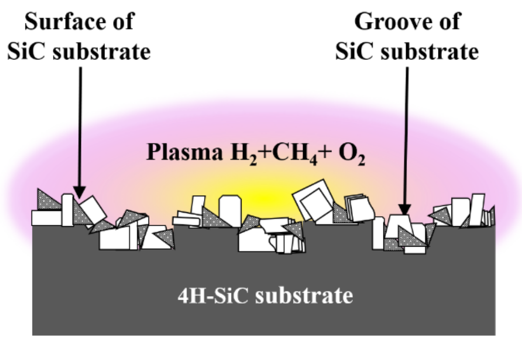

Fig. 1 Schematics for diamond growth on surface and groove of 4H-SiC substrate.

SEM micrographs of diamond growing on the grooved 4H-SiC substrate for 10 h, 20 h and 30 h are presented in Fig. 2. These images were obtained in a secondary electron mode. The grooved regions are indicated as dotted color lines in the figure. With the shortest growth duration (10 h), diamond film covers fully of the surface of SiC but not the grooved region (Fig. 2a). An obvious gap at the grooved region (Fig. 2b) can be revealed when it was observed under higher magnification. As the growth time extended to 20 h, the gap getting narrower (Fig 2d) with dedicated faceted polycrystalline grains of diamond (determined by Raman spectroscopy) almost fully covered the grooved region and surface of SiC as a continuous thin film. When the growth duration is further prolonged to 30 h, the grooved region is almost invisible (Fig. 2f). This indicates that the diamond film is continuously grown on the surface of SiC and fully filled the groove. Based on the visual inspection from surface morphology, the roughness increases as the duration of growth extended. The thermal performance of test structure will be reported in the full manuscript.

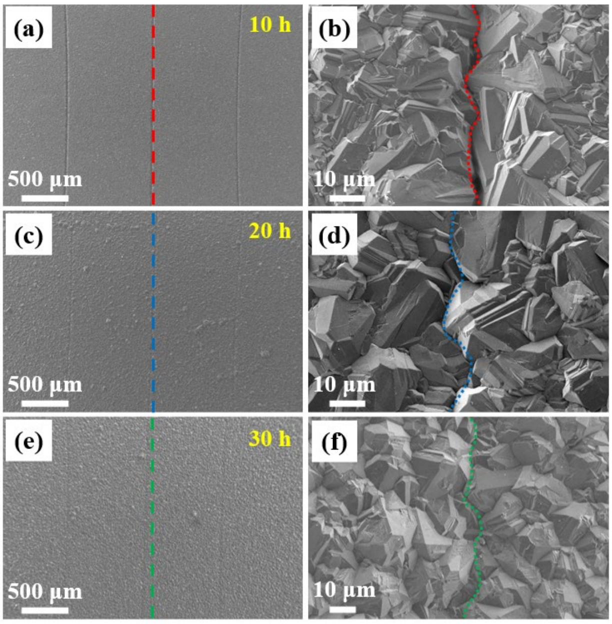

Fig. 2 SEM micrographs of diamond grown at (a) 10 h, (c) 20 h and (e) 30 h on grooved 4H-SiC substrate. (b), (d) and (f) are partial enlargements of (a), (c) and (e). The color dotted lines indicate the grooved regions.

3. Conclusions

Diamond films were deposited on grooved 4H-SiC substrates by changing the growth time. The results showed that, after 10 h deposition, the diamond films have obvious height difference and obvious gap between the 4H-SiC substrate surface and the groove. The gap gradually narrowed after 20 h growth and almost fully invisible after 30 h. Correlation between growth time, coverage of diamond film, crystallinity and thermal performance will be presented in the full manuscript.

Acknowledgements

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