Low melting temperature thin coating of zinc on Si(100) for diamond film growth

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In hot filament chemical vapor deposition (HFCVD) the substrate temperature has to be maintained [1] at about ~700°C. This has resulted in the use of substrates or coatings with a melting point higher than the substrate temperature during the diamond film growth. In this communication we show using atomic force microscopy (AFM), scanning electron microscopy (SEM) and Raman spectroscopy that even low melting point zinc on a scratched Si(100) substrate could produce a good quality diamond film at a substrate temperature ~750°C. A liquid substrate can support the growth of diamond film.

Diamond thin films have numerous applications from protective coatings to electronic devices and are widely used in industry. Therefore, several efforts have been made to achieve high quality diamond coatings in terms of density, adherence, purity and desired properties on different substrate materials with a focus on the nucleation and growth rate. This has culminated in exploring different substrate surface treatments and deposition techniques including HFCVD, with substrate temperature around 700°C, as reviewed in [1–3]. Roy et al. [4] have proposed that a 'liquid substrate' can be used to achieve 'rheotaxial' growth of diamond films. At such a low melting point, the vapor pressures of participating elements are lower and growth on a 'liquid substrate' occurs. Fang and Hou [5] and Kao et al. [6] also used liquid substrates for diamond films. Interestingly, Kanda et al. [7] have shown that diamond crystals can be grown using even Cu, Sb, and Ge at temperatures much higher than their melting point. Here we show that dense, good quality diamond films can be deposited on a zinc coated Si(100) substrate using the HFCVD technique.

Boron doped Si(100) substrates (15 × 7 × 0.650 mm³) were scratched manually using diamond paste (1 μm size) and washed with acetone and de-ionized water. Zinc (99.9%, Aldrich) flakes were evaporated from a tungsten filament in a separate vacuum chamber (10⁻⁶ Torr). Zinc coated Si substrates were transferred to the HFCVD set up, as described elsewhere [2]. For growth, the filament temperature was 2150 ± 50°C and the substrate temperature was ~700 ± 50°C with a mixture of H₂ (99.999%) and CH₄ (99.9%) in 1:100 proportion (total flow rate of 100 sccm, chamber pressure of 30 Torr). Initially the substrate was negatively biased to 280 V for 30 min and deposition was continued without bias for a further 90 min.

AFM in the tapping mode, (NS-IV from di Digital Instruments) and SEM were used to examine the surface morphology of the substrate and films. Raman spectra were recorded using argon ion laser source, λ = 514.5 nm.

Fig. 1a, a planar AFM image, shows the presence of random scratches on scratched and Zn coated substrates. The RMS roughness of both samples is ~2.5 nm. The zinc film is thin and probably follows the morphology of the substrate; the particles appear to be mostly aligned along scratch directions indicating the growth of zinc particles on scratches. The surface roughness of the diamond film, estimated from AFM images, on silicon is 88 nm (Fig. 1b), slightly larger than that on zinc (71 nm). Besides, the film on zinc is denser than that on bare silicon surface.

The difference between the film density on the scratched and Zn coated substrate can be clearly seen in SEM images (Fig. 2a and b). Larger and randomly