ENHANCED NUCLEATION OF ULTRANANOCRYSTALLINE DIAMOND (UNCD) USING TUNGSTEN (W) FILMS

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Abstract

The initial nucleation density is critical in determining both the microstructure and the properties of Ultrananocrystalline Diamond (UNCD) films. Unlike hydrogen grown diamond thin films, the UNCD growth process results in a high re-nucleation rate, and thus the overall grain size is not limited by the initial nucleation density. Thus, controlling the nucleation density is critical in determining the quality of UNCD thin films, especially for facilitating the growth of low-temperature UNCD thin films and maximizing the mechanical and tribological properties of UNCD for potential MEMS applications.

Many techniques have been used to enhance the nucleation of diamond thin films. Unfortunately, most nucleation enhancement techniques have drawbacks. For instance, the "Rotter nucleation technique"[1] requires high temperatures while the bias[2] and chemical methods [3] have not been widely standardized into a common nucleation enhancement techniques.

UNCD is commonly grown on refractory metal substrates in order to integrate the growth of UNCD with a standardized process for generating a high initial nucleation density, while being compatible with low temperature growth of UNCD. In this study, we apply thin tungsten (W) films onto silicon surfaces prior to ultrasonic seeding. The thickness of the W layers varies from 36 Å to 100 Å. The influence of W on the subsequent UNCD nucleation and growth is examined. We have found that the initial UNCD nucleation density is enhanced considerably using W films from 10^{11} to $\geq 10^{12}$ sites/cm^2. Furthermore, by using W films, the initial UNCD growth rate is increased (less time is needed to grow a uniform UNCD film), while the surface roughness and interfacial void density are decreased.

In addition to using conventional RF sputtering techniques to deposit the W films, we also employ atomic layer deposition (ALD). ALD offers the flexibility for depositing W films on complex, nonplanar surfaces while maintaining monolayer thickness control. Scanning Electron Microscopy (SEM) results show considerable enhancement in nucleation density using both RF sputtered and ALD W on planar substrates as shown in Figure 1. The surface roughness of UNCD films grown on W films using the above two techniques will be compared using Atomic Force Microscopy (AFM).

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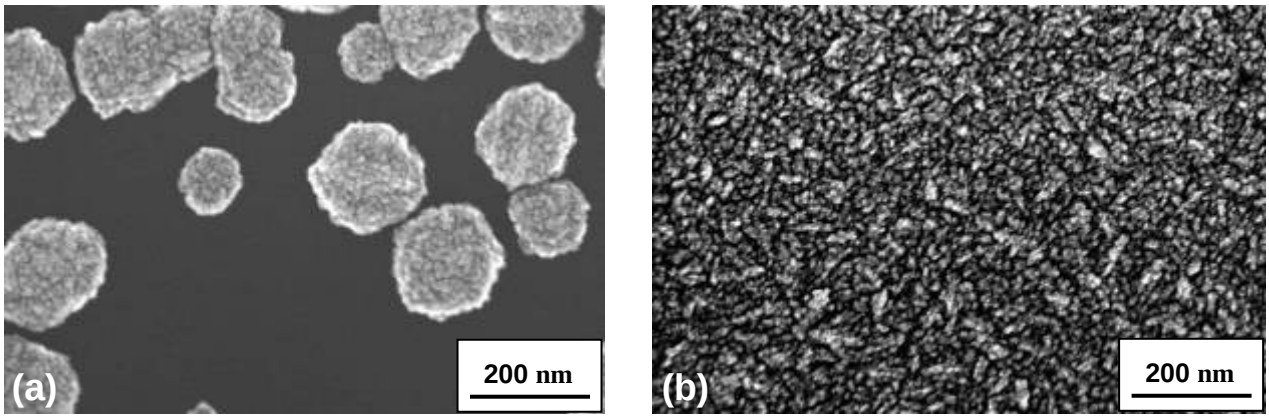

Figure 1: SEM images of UNCD films (grown at the same time under identical seeding conditions); (a) without W film added and (b) with W film (100Å thickness). The nucleation density has been dramatically increased by using the W film.

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2. See, for example, S. Saada, S. Barrat, E. Bauer-Grosse, *Diamond & Rel. Mater.*, **10**, 300 – 305 (2001).

3. Anne Giraud, et.al , *J. Am. Chem. Soc.*, **123**, 2271 – 2274 (2001).