Nanocrystalline Diamond Thin Films for Tools and Other Applications

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Due to its unique chemical, physical, and mechanical properties, nanocrystalline diamond (NCD) is considered for a wide variety of structural, biomedical, and microelectronic applications [1,2]. So the fabrication of NCD films by chemical vapor deposition (CVD) method is of great interest because of their potential experimental and theoretical applications. In general surface scratching or substrate biasing is applied for nucleation of diamond on non-diamond substrates. First method produce normally randomly oriented diamond films with high surface roughness. Second method though could produce oriented smooth diamond films, but both the cases films are comprised of micron-sized crystallites and sizes are increases with the increase of the thickness of the coatings. A thick diamond films therefore has a low density of grain boundary and a rough surface. This is because of the columnar nature of growth by CVD method. If it is possible to interrupt the grain growth by a continuous secondary nucleation process, diamond films with decreased grain size should be formed. It is well known that the grain size of a film strongly affects its properties; this can be attributed to the grain boundary density. NCD films with high grain boundary density have been attracted enormous interest due to its fascinating mechanical, electrical, and optical properties [3].

NCD films were deposited on the silicon (100) substrates from a gaseous mixture of argon, methane and hydrogen by using microwave plasma enhanced chemical vapor deposition method (MPCVD) (Fig. 1). We have also tried nitrogen in the gas mixture. The NCD films were successfully grown at substrate temperature between 800ºC and 900 ºC using a high Ar concentration (95%). The pressure inside the chamber was also found an important parameter to form the nanodiamond. Ultrasonic polishing and surface scratching with fine diamond powder (0~0.5 µm) were employed to enhance the nucleation density and growth rate. The surface and structure characterizations of the films are carried out by using scanning electron microscopy (SEM), Raman Spectroscopy and Fourier transform infrared spectroscopy (FTIR). The roughness of the films was determined by atomic force microscopy (AFM) and grain size was measured by X-ray diffraction (XRD).

NCD coatings will be ideal for achieving smooth and adhering diamond coatings on tool materials. Surface roughness NCD film decreases drastically compared to MCD films (Fig. 2). Due to the smaller crystallites for NCD coating toughness of the films will improve a great deal. Lower intrinsic stress level of NCD will further enhance the adhesion of the coatings with the buffer layer resulting a hard, tough and well adhering coating. As a material, diamond has outstanding thermal, chemical and tribological properties, which should make it an ideal material for fabrication of micro-electro-mechanical systems (MEMS) [4]. Due to its exceptional physical and electrical characteristics, diamond is an excellent material for a number of MEMS and mesoscale applications including temperature sensors, radiation detectors, chemical sensors, magnetic field sensors, mass flow sensors and in electrical switches.

References:

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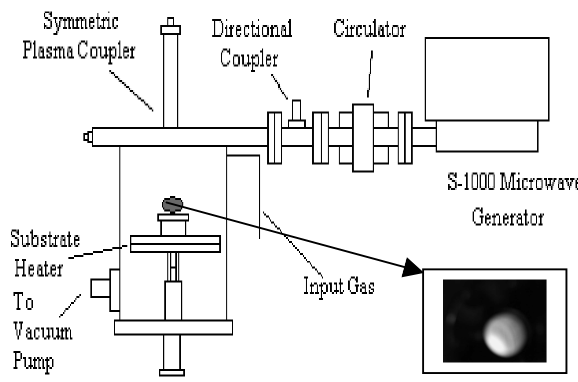
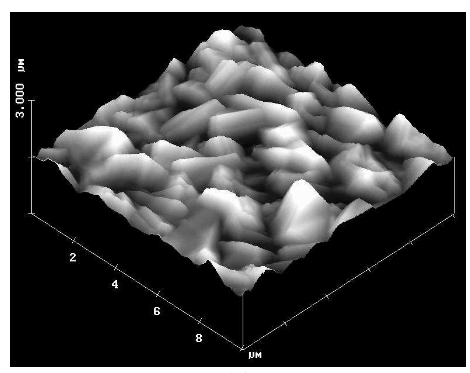
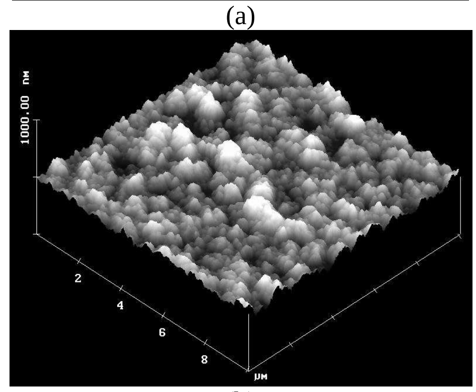


Fig. 1. Schematic of microwave plasma CVD system at NNRC system. CH_4/H_2 plasma can be seen is also shown.



(a)



(b)

Fig. 2. AFM surface view of two diamond films: (a) MCD coating and (b) NCD coatings. Roughness, R_a = 87nm (a) and R_a = 23nm (b).