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Growth studies of laser-induced CVD diamond films

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Abstract: The growth of laser-induced chemical vapour deposition diamond thin films are studied. The X-ray diffraction (XRD) and electron diffraction analysis showed the structure of these film layers change from an amorphous to polycrystalline is obtained on scratched silicon substrate and at different growth conditions. The process of growth and structure of these films have been discussed.

I - INTRODUCTION

Diamond has superior properties for example great hardness, high thermal conductivity, chemical inertness, high stiffness, high carrier mobilities etc. Diamond coatings and films have been prepared from the vapor phase at low pressure. These preparation techniques have been developed include chemical vapor deposition (CVD) [1], ion beam techniques [2], plasma induced deposition [3], microwave plasma deposition [4] and variations or hybrids of these. Laser induced CVD seems to proceed through a mechanism quite different from that of other methods [5]. In the paper, we report the growth condition and structure of laser induced-CVD of diamond films. It is shown that the polycrystalline diamond films with good crystallinity are obtained on roughened <111> silicon substrate. The experiment indicates these films are more uniform and the growth temperature is lower than using conventional methods [6].

II - EXPERIMENTS

The diagram of experimental set-up for laser-induced CVD diamond film is shown in Fig. 1. The reaction is carried out by use of methane diluted with H_2 (CH_4 concentration 1%) as a source gas ($H_2 + CH_4$) at low pressure. The smooth substrate surface of (111) silicon is scratched and roughened to facilitate nucleation before growth beginning. The substrate is kept at a temperature of 50-700°C. In experiment the irradiation of focused two laser beams ($\lambda = 266nm$) are separately against and parallel from the substrate (Fig. 1), the power density on the substrate is 50mJ/cm² pulse.

The samples of diamond films are detected by the X-ray diffraction (XRD), high energy electron diffraction (RHEED) and scanning electron microscopy (SEM). These results are given in Fig. 2-3-4.

Fig.1 Diagram of experimental set-up

1. reactor 2. substrate 3. window 4. source gas 5. pumping 6. laser beam

Fig.2 XRD for diamond film (substrate temperature 420°C)

(a) at 420°C growth (b) at 520°C growth (c) at 620°C growth
Fig.3 RHEED patterns of diamond films

(a) on scratched silicon substrate

(b) on rough silicon substrate

Fig.4 SEM patterns of diamond films (X5.00K)

III -RESULTS

It is shown that the laser induced-CVD would appear to be effective in lowering the reaction temperature (420°C). The XRD shows in good agreement with the values reported for cubic diamond (Fig.2). A typical RHEED photograph of diamond film, which is prepared at 420°C, shows that all diffraction lines belong to diamond (Fig. 3(a)). Irrespective of deposition temperature, a few RED photographs show that the coexistence of graphite and SiC (Fig. 3 (b), (c)). The XRD, RHEED and SEM analysis show that the structure of the film layers changes from amorphous to polycrystalline on (111) silicon substrate, in different growth conditions (Fig.3 and Fig.4). A SEM photograph of the same sample is shown in Fig.4. Particles which do not show clear shape with diameters $\sim 0.5 \mu\text{m}$ grow along the edge of the scratch lines, as is observed in experiment (Fig.4(a)). The diamond films, which obtained by laser induced-CVD technique on the rough silicon substrates, possess uniform structure feature (Fig.4(b)).

IV -DISCUSSION

The decomposition of CH_4 and H_2 by laser induced mainly occurs at the substrate surface, because the scanning double laser beams react to substrate surface and source gas respectively for produced hydrogen atoms and activated intermediates. The hydrogen atoms play an important role in the growth mechanism of diamond. Methyl radicals and other activated radicals are also important. If these radicals could be produced at high density and supplied to the substrate, diamonds would be formed with high growth rates. Diamond is formed when the power density of the focused laser beam appears to be enough to yield activated radicals by way of multiple photon process. A few RED photographs show the coexistence of graphite and SiC (Fig. 3(b) (c)), because on a silicon substrate the growth condition of SiC by thermal diffusion of carbon into Si is same as that of diamond.

V -CONCLUSION

In the paper, the experiment indicates diamond can be formed by double focusing beams ($\lambda=266\text{nm}$) laser-induced CVD technique. The experiment has also indicated that the optimal deposition conditions of diamond films growth. The polycrystalline diamond films are obtained at 420°C . The suitable irradiation power density and irradiation geometry are important, because the growth process of diamond is a multiple photon process.

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