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Infrared optical properties of diamond films synthesized by MWPCVD

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Diamond films (DFs) are very attractive for use in infrared (IR) windows, so the study on the IR optical properties of DFs is an important task at present. The effects of processing parameters on IR transmission of DFs have been studied. The IR transparency of the free—standing diamond film reached 97%, the IR transparency of DF with Si substrate reached 88%.

1. INTRODUCTION

Recently, infrared (IR) optics have been rapidly developed and extensively applied in many fields such as communication, infrared photography, military affairs, pyrometry, receiver, medicine surgery, etc.. The development of infrared transmissive materials has not reached the correspondent level reguired for these applications. The IR optical materials which are suitable for both drastic wind and sand, or damp outdoor environments and high temperature, erosion, high concentration dust indoor environments have not yet been found. Diamond becomes an ideal infrared optical material used in severe environment because of its excellent resistance to abrasion and erosion, extreme hardness, high mechanical strength, the highest thermal conductivity, and fine IR optical transmission. Since natural diamond and diamond synthesized under high temperature and high pressure are small in grain size, and high cost, their applications are considerably limited.

Since the early 1980' s, DFs have been prepared and have interested scientists very much. Some studies on IR optical properties of DFs have been reported[1—6]. Here, we study on IR optical properties of DFs in detail and increase in IR transmittance of DFs made by MWPCVD.

2. EXPERIMENTAL

The silicon substrate was treated by diamond grits and ultrasound, then placed into the microwave plasma of a methane—hydrogen gas mixture. Processing parameters of synthesized diamond films were: microwave power 400 — 700W, pressure 2.5—6.5KPa, CH_4 concentration 0.2—0.6%, deposition time 4—24hrs.. Free—standing diamond films were produced by etching silicon with mixture of HNO_3, HF and the acetic acid.

IR optical transmission of diamond films with and without the substrate were measured by a Fourier Transformation IR spectrometer.

3. RESULTS AND DISCUSSION

3.1. Infrared transmittance characteristic of free—standing diamond films

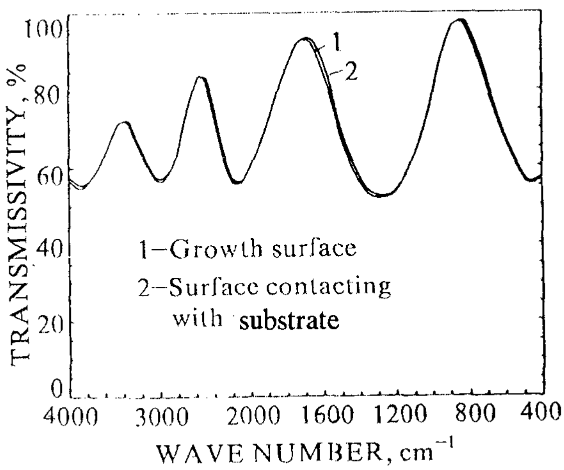

Figure 1. IR transmissivity of DFs (without Si substrate).

Figure I shows the IR transmissivities of the diamond film. Curve 1 presents for IR transmittance of the DF growth surface, and the curve 2 represents the IR transmittance of the DF surface contacting with Si substrate. Comparing the two curves, it can be shown that the IR transparency measured from the DF growth surface is lower by only 1% than that measured from the DF surface contacting with the substrate, thus, the two curves are very similar. It is shown that the prepared diamond films are rather smooth so that the scattering loss is not significant and the IR transmissivity of DF can reach a very high value of 98%.

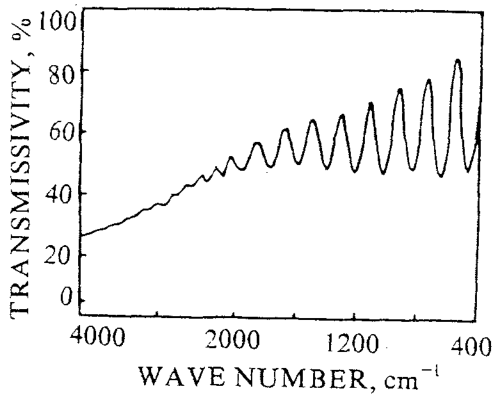

Figure 2. IR transmissivity of DF having crystallite size of 3μm (without Si substrate).

Figur 2 shows the IR transmission of DF having crystallite size of 3μm. The IR transmissivity is lower 13%—20% than that of DF having smaller crystalline size in Figure 1. It is shown that the larger the crystalline size of DF, the greater the surface roughness of DF. It leads to significant scattering loss which results in a decrease in the IR transparency.

3.2. IR transmission of DF with substrate

IR transmissivity spectrum of diamond film together with silicon substrate is shown in Figure 3. The highest value can reach 88%. The IR transmissivity of silicaon substrate is about 58%, the IR transmissivity of DF with Si substrate is higher about 50% than that of the Si substrate. It is obvious that DF possesses a function of increase in transmissivity.

3.3. IR Reflection of DF

Figure 4 shows the IR reflection measured from the DF growth surface and the DF surface contacting with substrate. The IR reflection coefficient of the DF growth surface is lower about 4% than that of the DF surface contacting with substrate. The growth surface is rougher than the surface contacting with substrate resulting in the decrease in IR reflection.

3.4. Computer simulation of IR optical characteristic for DF

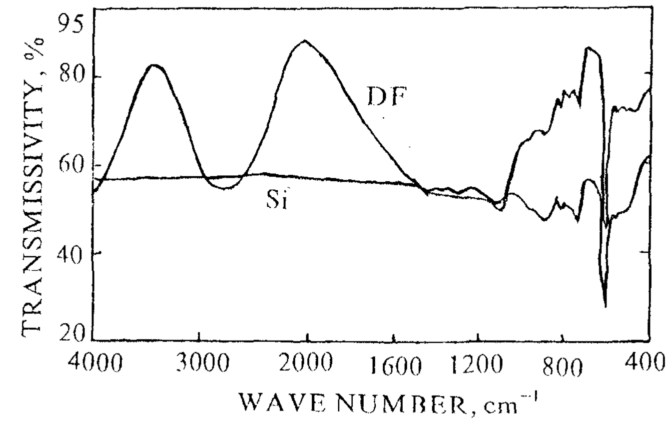

Figure 3. IR transmissivity of DF with Si substrate.

The computer simulation of IR optical properties was carried out using the following mathematical model of transmittance[4]:

$$T = \left| \frac{t'_{01}t'_{10}exp(-i\beta)}{1 + r'_{01}r'_{10}exp(-2i\beta)} \right|^2$$

The computing values are very close to

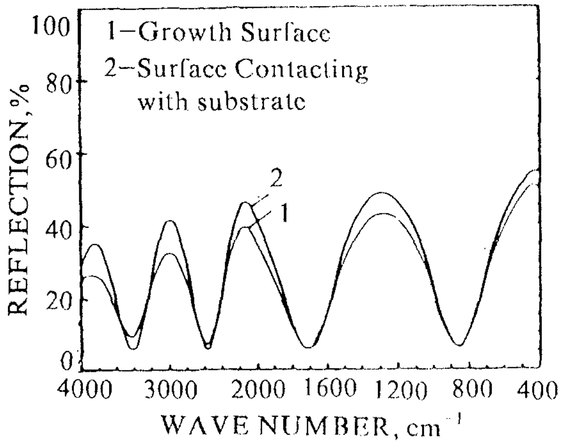

Figure 4. IR reflection of DF.

experimental values shown in Figure 5. Some optical parameters by simulating calculation have been obtained as follows: the refractive index $\eta = 2.30$, the thickness $d = 2.50\mu m$, the surface roughness $Ra = 0.122\mu m$, which is rather close to the measured value $0.100\mu m$.

4. CONCLUSION

1. Under optimum processing conditions, the surface of diamond films synthesized by MWPCVD is very smooth. The surface roughness Ra can reach 0.03 to 0.2μm so that the scattering loss is very little, the IR transparency of the free-standing DF reached 97% and the IR transparency of DF with Si substrate reached 88%, they are higher than those in Literature [1, 5, 6]. Thus making diamond films viable as coating materials for IR optical window.

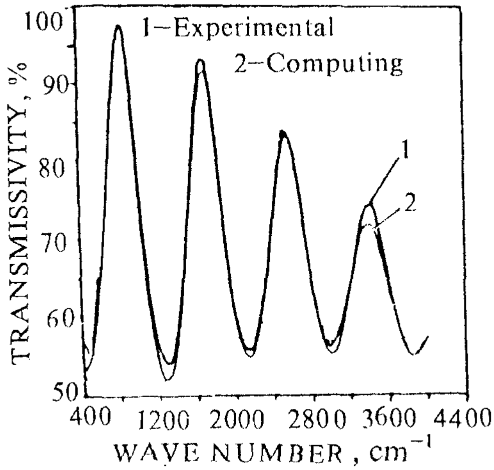

Figure 5. Computing and experimental IR transmissivity of DF.

2. Diamond film having IR transmittance—enhanced according to the application requirement can be obtained by changing processing parameters.

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