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Research Paper

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CVD Diamond Incubation on SnO_2 Coated Silicon Substrate

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Abstract- Substrate treatment affects the nucleation and growth of the diamond films. In the case of silicon substrate the scratching of the sample with diamond paste is popular process. In the present study efforts were taken to study incubation period of diamond deposition before actual starting of diamond crystallites. The SnO_2 is used as overlayer on the pre-scratched Si substrate. The deposited samples were characterised by Scanning electron Micrograph and Raman Spectra.

Keywords- HFCVD, Incubation Period, SnO_2, Diamond, Pre-scratching

I. INTRODUCTION

The crystalline CVD diamond has been achieved popularity for the industrial application because it possesses a number of excellent properties, such as high energy band gap, high thermal conductivity, high hardness, negative electron affinity and it gives some non-precedential properties (n or p type doping opens the use of diamond as semiconducting material). Among a number of diamond deposition methods, the Hot Filament Chemical Vapour Deposition (HFCVD) method has many advantages such as, Low cost, moderate deposition rate, simple principle and easy to handle[1-2].

Deposition of diamond thin films is through continuous nucleation and growth, nucleation facilitates the growth and growth starts nucleation both are supportive to each other in case of diamond deposition. When gas is passed over the filament first filament have been carburized and tungsten carbide (WC) is formed on the tungsten filament then there is diffusion of carbon species of CH_4 and atomic hydrogen towards the surface of the pre-scratched silicon sample. At the silicon substrate there is adsorption or chemical reaction with silicon to form silicon carbide. Hence, there is some what delay in actual growth of diamond crystallites. In the present study the efforts were taken to find out what is the incubation period before actual diamond crystallites starts growing.

II. RELATED WORK

From last few decades diamonds have achieved great attention of scientists worldwide to exploit its unique properties for variety of applications such as hard coating for drill bits to high temperature electronics. It is very difficult to exploit the properties of the diamond because of its cost scarcity and the fact that it is available only in stones. As diamond is the crystalline form of only carbon hence most attempts were taken to convert graphite, another carbon allotropes available in abundant as starting material. It was extremely difficult because at room temperature and pressure, graphite is the thermodynamically stable[3-4]. Due to large thermodynamic activation energy barrier between graphite and diamond prevents the inter conversion of these phases so diamond is metastable.

General electric were developed high pressure and high temperature (HPHT) growth technique, and marketed industrial diamond for several decades[5]. Main difficulty in this diamond growth is that doping with impurities to produce semiconducting diamond for electronic devices not possible. Its metastable property was exploited by using chemical vapour deposition CVD technique and now it is possible to develop semiconducting devices of CVD diamond. Now a days CVD diamond is more popular in single crystal industries as well as in semiconducting applications.

III. EXPERIMENTAL PROCEDURE

In this experiment tungsten filament was preheated at 2100^0C and due to radiation from the filament the substrate was heated to (900^0C) and vacuum of the chamber was maintained at 50 torr. The ratio of methane CH_4 to hydrogen H_2 is 1:100 . Si sample were used for the deposition of thin film diamond. The sample was prepared by scratching it with diamond past and then depositing SnO_2 over layer on it [6-7].

First chamber was evacuated to 50 torr vacuum level then filament was heated to desired temperature by using external power supply. After achieving the desired temperature at substrate which was placed below the filament the gas mixture was introduced over the filament by gas controllers and pipeline. The deposition was carries out for different time durations(15,30,60,120 minutes).

IV. RESULT AND DISCUSSIONS

The deposition of diamond thin films was carried out for different time duration keeping all other conditions same. The sample deposited for 15 minutes (fig a) shows the ice-ball like particles of different sizes which are randomly distributed on the sample surface. The total background signal is fairly high which indicates to the fluorescence in the substrate and broad hump like appearance near 1600 cm^{-1} corresponds to non-diamond carbon is fairly well resolved. This nondiamond carbon is promoting factor for diamond nucleation.

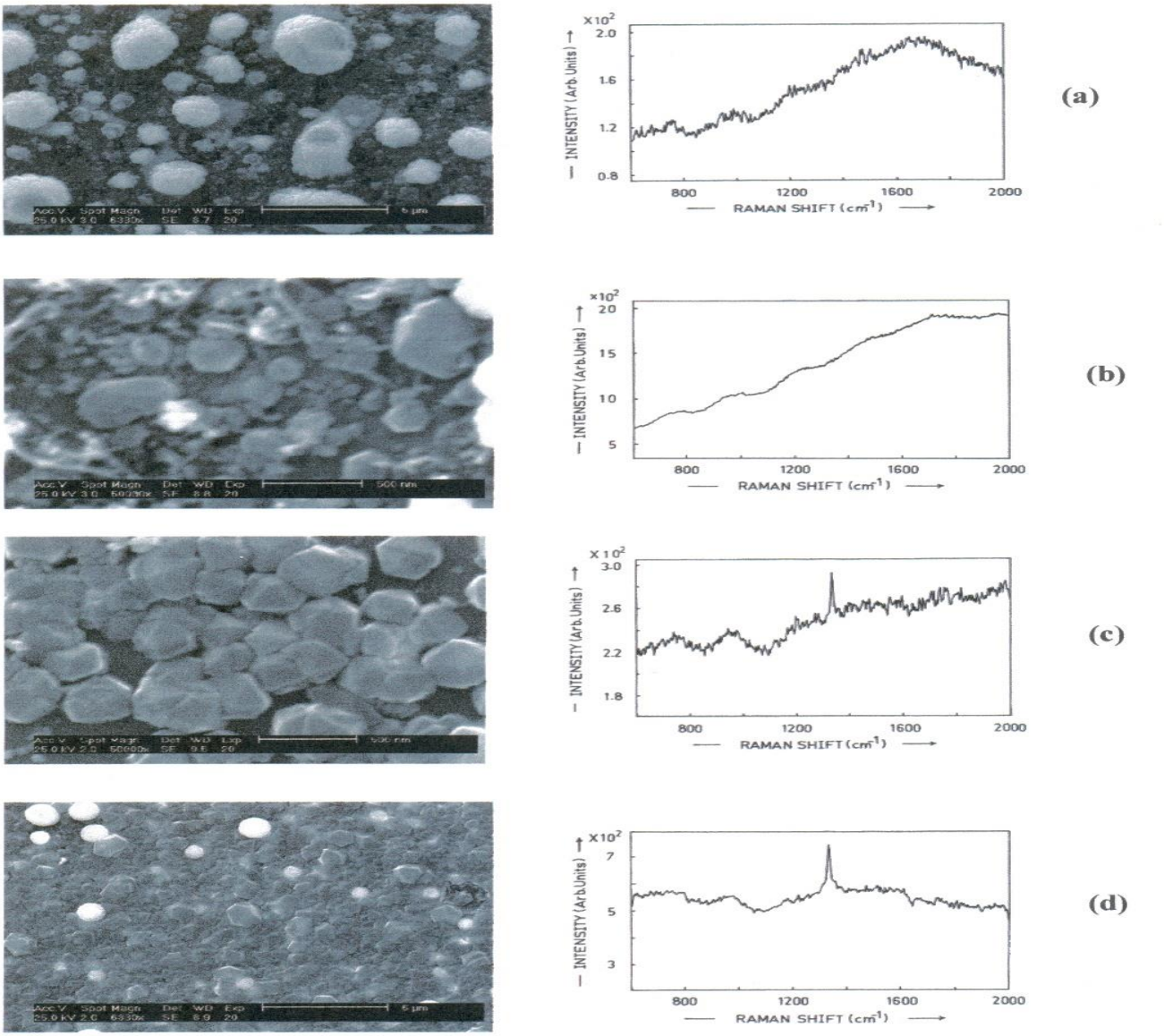

Fig: 1. SEM of diamond thin films deposited on pre-scratched Si substrate with SnO_2 overlayer for the duration of (a) 15 min (b) 30 min (c) 60 min (d) 120 min. Corresponding Raman spectra are shown on the right of the micrograph

When the deposition was carried out for the duration of 30 minutes (fig b), the surface morphology of the diamond film is relatively non-uniform. The development of crystallite facets on some of the deposited particles is also clearly observed. The Rama spectra of this films has overall features are same in previous case but there is negligibly small contribution near 1332 cm^{-1} corresponding to crystalline diamond. This shows that there was formation of faceted diamond particles begins during the first 30 minutes of the deposition process.

The surface morphology of the diamond thin film was improved after deposition of 1hour. For 1 h deposition (fig c) there is well faceted diamond crystallites with an average size of 0.29 µm is observed. It can be seen that (111) facets are dominant with well defined gain boundaries. The nucleation density was found to be $\sim 8.7 \times 10^8\, cm^{-1}$. The diamond spectrum of the corresponding diamond film shows the characteristic peak at $\sim 1334\, cm^{-1}$ weak peak and broad hump at about $\sim 1550 cm^{-1}$ which indicate the coexistence of a small amount of non-diamond carbon with the diamond in the

film. The Raman spectrum reveals that there is increase in the sp^3/sp^2 ratio and lower luminescence background. Hence the quality of the diamond film improves as the duration of the deposition increased.

The SEM of diamond thin film deposited for 2h (fig d) shows continuous growth of the film with (111) and (100) facets. Voids are not observed in the film. $\sim 0.47\ \mu m$ is the average size of the diamond crystallites and nucleation density is $\sim 2.9 \times 10^8\ cm^{-2}$ from SEM. The Raman spectrum shows the diamond peak at $\sim 1332\ cm^{-1}$ [8] and broad hump at about $\sim 1550 cm^{-1}$[9].

V. CONCLUSION AND FUTURE SCOPE

The investigation clearly shows that the improvement in the surface morphology and Raman quality of diamond film takes place as the duration of the deposition is increased. Also, the size of the diamond crystallites is increased with the duration of the deposition. From these results it was concluded that the incubation period for the diamond crystallite deposition is between (30minutes to 60 minutes).

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AUTHOR CONTRIBUTION

Author fabricated and commissioned hot filament chemical vapour deposition system during his Ph.D. tenure.

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AUTHOR'S PROFILE

J R Mahajan pursed his Ph.D in Physics, from Kavayitri Bahinabai Chaudhari North Maharashtra University Jalgaon, in Physics. He received Senior Research Fellowship From CSIR New Delhi to complete doctoral degree. He also visited to several countries to present papers and to serve as resource person, chairman of the session. He received travel grant from UGC, DST to travel abroad to attend the conferences. Till he has published nearly 20 research papers in national and international journals with Scopus, Thomson Reuters (SCI & Web of Science) and UGC recognised. Recently he is working in Department of Physics, Deccan Education Society's, Kirti M. Doongursee ASC College, Dadar(W), Mumbai. His main research work focuses on CVD diamond (single crystalline and polycrystalline), Nano oxides, Conducting Polymers and their Composite materials for Sensing Purpose. He has organised conferences in the host institute and also an editor of the inhouse publication of the college. He has more than 15 years of research experience.

