Radiation Hard Detectors for Future Colliders

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Introduction

In industrial point of view diamond is a unique material and has unique properties from other materials and makes it more attractive for the application radiation detection. It can be operated at extreme temperatures with high band gap ~5.5eV, low noise, very less leakage current and its fast current signal as a result of high charge-carrier mobility and limited charge lifetime. It has a very high resistivity (>$10^{12}\Omega$cm), electric breakdown field (10^7V/cm^{-1}) [1]. On the other hand, also due to the larger band gap, the average energy required to liberate an e-h pair in diamond is 13.1 eV which is 3.6 times larger than silicon (3.6eV) due to which it results a small signal. The diamond detectors are used to detect fast neutron. The mixing parameters such as radiation hardness, temperature tolerance and ability to detect mixed types of radiations. Such excellent properties makes diamond attractive as a detector material for harsh environments such as fission and fusion [1-2]. In this paper, we present preliminary tests of diamond film which could be used for fabricating diamond detectors and finds the application for detecting the neutron particles and γ-rays.

Experimental Procedure

The sample have been grown by Microwave Plasma Chemical Vapour Deposition (MPCVD) system. Before uploaded the sample in chamber, the substrate was cleaned with an ultrasonic cleaner in order to remove dirt from the diamond substrate. The diamond film results uniform deposition as well as uniform surface morphology. The thickness of the film achieved about ~500µm. The IV measurement was measured by Cryogenic Equipment by JANIS Model No. RT-UHT-1. The Raman Spectra was measure by Horiba Jobin Yvon HR800. Deposition Conditions of the diamond film are as under**:-**

Film Name	Temp. (^{o}C)	Press. (Torr)	H_2 (sccm)	CH_4 (sccm)
Diamond	950	75	100	2

Results and Discussions

The electron hole pairs are generated due to ionization processes when the particle go through the diamond. If a bias voltage is applied to electrodes, the electrons and holes start to move which produces an electric current. Charge collection efficiency (CCE) is defined as the ratio between the total generated charge and the charge collected by the electrodes

$$CCE = \frac{Q_{coll}}{Q_{gen}} \qquad (1)$$

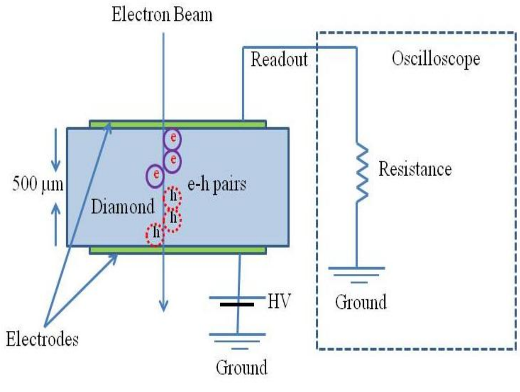
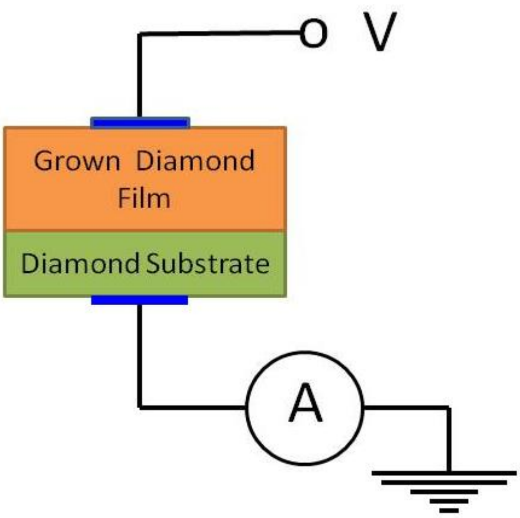


Fig. 1 Charge generation and collection scheme

I-V Characteristics measurement is an important measurement to build detector and should be done each individual diamond film which shows the characteristic quality of fabrication. The I-V characteristics of diamond film is shown in Fig.2. The dark current measurement of the sample in the graph given by Keithley 237 source measure unit. In Fig. 2 the data points in the plot were taken in order of 0 to 200V and 0 to 200V. Both the measurements have an average at 0V as shown in the data points in Fig. 2. There is increase of dark current with in the low voltages ±100V. The sample measures 4.5×4.5 mm^2 and a 500 µm thick. Circular contacts are put on the top and bottom of the surfaces of the substrate. Cr-Au contacts are used which allow wire bound connection to Amplifier.



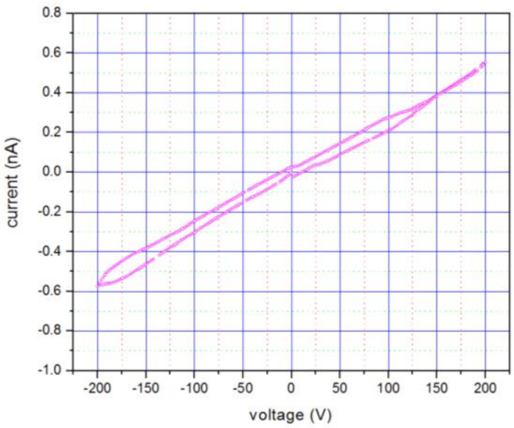


Fig. 2 I-V characteristic measurement in dark and under optical excitation obtained at room temperature.

Raman Spectroscopy has been used for the characterisation of diamond sample which shows a typical diamond peak at 1332cm-1. The characteristic peaks occurring at 1332 cm^{-1} corresponding to the cubic-diamond. The peak at 2493 cm^{-1} is a non-diamond peak which arises due to impurity. The low intensity of G peak at 2493 as shown in Fig. 3 shows lower amorphous carbon in the diamond films.

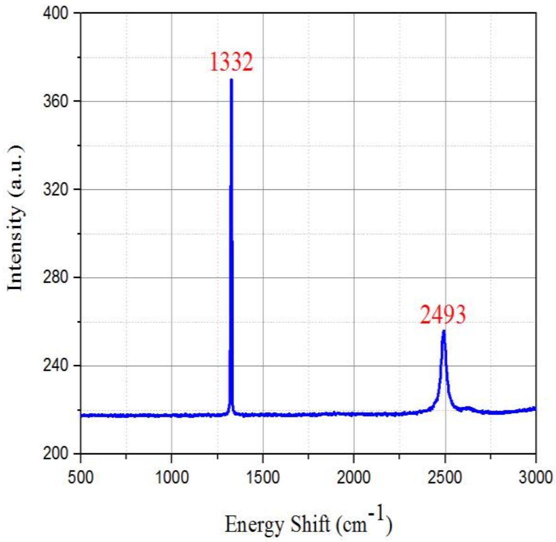


Fig. 3 Raman spectra confirms diamond at 1332 cm^{-1}.

Conclusions

We perform IV test to measure the current interms of nanoampers as the film grown by MPCVD method. Good Hysteresis behavior has been investigated clearly by IV plot. The highest dark current is measured at 200 nA level which is quite low comparing with the expected signal level (µA). Raman spectra shows a peak at 1332 cm^{-1} which is confirmed good quality diamond.

References

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