Development of ultrafast radiation hard diamond detectors for particle physics applications

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Introduction

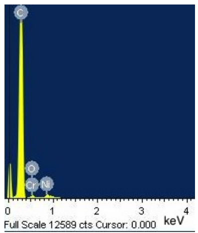
Diamond grown by chemical vapor deposition (cvd) has attracted considerable interest as an alternate detector material because of its ultra-fast (nanosecond) response time and ability to withstand large radiation dose. In this paper, we present results of our development of an indigenously produced ac-coupled cvd diamond detector with pixel size 3.5mm x 3.5mm. We have developed a readout system employing multi-stage GHz bandwidth amplifiers to test the detector's response to stopping alpha and beta particles. We also present the simulation using the SentaurusTM TCAD tool suite to study free charge carrier transport properties in cvd diamond sensors measured using transient current technique.

1. Diamond Detector

With a high band gap of $E_g = 5.5\ eV$, diamond gives negligible intrinsic carrier densities even at room temperature, allowing to operate diamond as a detector. The dark current of the diamond samples is less than 1 $nAcm^{-2}$ at an electric field of 1 $V\mu m^{-1}$[1]. Detector is prepared from 300 μm thick single crystal CVD diamond samples with an area of 3.5 mm $\times$ 3.5 mm.
Before contacts were deposited, the diamond surface was cleaned to remove surface contaminations[2]. After cleaning sample was tested for contaminations. Few test have been done like fourier transformed infrared spectroscopy (FTIR), scanning electron microscope(SEM), energy dispersive X-ray spectroscopy (EDX) and X-ray diffraction (XRD). Fig. 1 shows EDX results for diamond sample.

Element	Weight%	Atomic%
C K	93.82	95.49
O K	5.76	4.40
Al K	0.00	0.00
P K	0.14	0.06
Cr K	0.00	0.00
Ni K	0.28	0.06
Sn L	0.00	0.00
Au M	0.00	0.00
Pb M	0.00	0.00

(a)Element composition table



(b)Element composition plot

FIG. 1: EDX results for re-used diamond sample

Fig. 2 shows XRD results for diamond sample and it confirms peaks related to 200, 220, 311 crystal orientation in sample [3] [4].

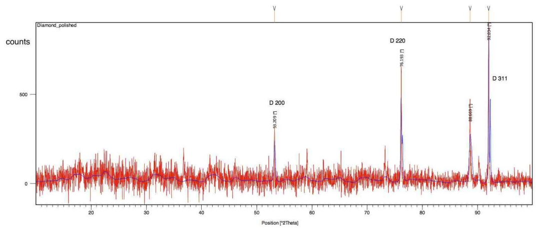


FIG. 2: XRD spectra of diamond sample.

A metallic thermal evaporation technique was used to coat both sides of the diamond with successive metals: Cr (500 Å) and Au (2500 Å) [5]. Then sample was annealed at 700°C in an N_2 environment to allow the chromium to form a carbide with the diamond.

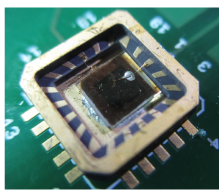


FIG. 3: Diamond Sensor with Cr-Au coating.

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For electronic connection, diamond is mounted on leadless ceramic chip carrier. Fig.3 shows Sensor with Cr/Au contacts mounted on lcc-20.

2. Characterization

It uses Keithley 2410 source meter for IV measurement and keithley 4200 SMU for capacitance measurement. The Fig.4 shows current Vs Voltage in range of $\pm$ 1000 V which is $\approx$ 3 V/μm of electric field indicating high resistivity and low leakage current. In these range we got linear behaviour with few pA of dark current. And capacitance of 2.2 pf at bias voltage of 0 V.

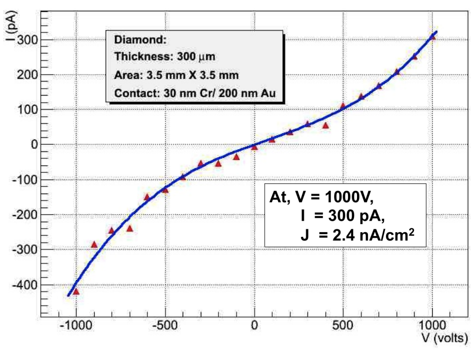

FIG. 4: I-V characteristic: 3.5 mm x 3.5 mm = 12.25 mm^2, 300μm

3. Readout Electronics

We are designing a preamplifier without feedback in order to amplify the detector current pulse. This design allows a higher bandwidth compared to a charge sensitive amplifier which make electronics noise independent of detector capacitance. Fig.5 shows 3 stage readout using RF amplifier Gali 52 with bandwidth of 2 GHz. To get sufficient amplification of observable signal, preamplifier comprised of 3 stage each with 20 dB gain. We are going to test the setup for alpha and beta source.

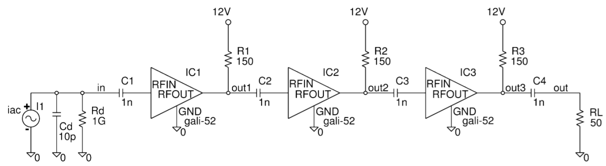

FIG. 5: Three Stage Readout Circuit.

4. Summary and Conclusions

1. We characterised the diamond sample for IV and CV which indicating high resistivity and low leakage current.

2. Contamination checks have been done before characterising diamond sample.

3. We are working on a readout system employing multi-stage GHz bandwidth amplifiers.

4. The near future plan is to set up readout and data acquisition with new Diamond sample and test it with alpha and beta source.

5. Acknowledgments

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