Diamond detector with laser made graphitic electrodes.

E. Alemanno [1, 2] ,A. Caricato [1, 2] ,M. Catalano [3] G. Chiodini [1], G. Fiore [1], M. Martino [1, 2], R. Perrino [1], C. Pinto [1, 2], and S. Spagnolo [1, 2].

[1]Istituto Nazionale di Fisica Nucleare, Sezione di Lecce, Italy.

[2]Dipartimento di Fisica, Università del Salento, Italy.

[3]Istituto per la Microelettronica e i Microsistemi, Sezione di Lecce, Italy.

The electrical contact on intrinsic semiconductor material (such as Diamond, CZT, and CdTe) is a critical technological step. Due to the large band-gap of these materials with respect to any metal, the contacts prevent fast removal of the free charge created by the nuclear radiation.

In literature several techniques to produce a graphitic layer on the diamond surface were suggested and realized, for example by sputtering or ion implantation ([2]). The graphitic layer was demonstrated to be a good ohmic contact.

We faced this challenge with a novel idea: graphitization of the diamond surface with a gas excimer laser and creation of nano-graphite layer of about hundred nanometers. The diamond surface graphitization process is possible if the laser is absorbed by the diamond surface and the intensity is tuned to make the transition diamond-graphite thermodynamically favorite without ablating the material ([3]).

We realized in the L^3 laboratory at the Università del Salento a CVD detector-grade diamond material with graphitic electric contacts using a focused ultra-UV laser light. The nano-graphitic layer was mechanically stable and electrically conductive in both sides. The surface resistivity was measured with a multimeter and was about 40 Ohms, in agreement with the literature values.

The response to a gamma- ray source of the detector were measured for the first time. These preliminary measurements show that the pad detector with graphitized contact is capable to detect ionizing radiation in counting mode. A comparison was made between this detector and a reference detector made of same quality diamond but metallic electric contacts and no significant differences were seen.

The device was prepared by front and back irradiation of the diamond surfaces with a 193 nm UV ArF excimer laser (Lambda Physik LPX305i). In fact, chemically pure diamond strongly absorbs light having this wavelength.

The laser emitted 20 nsec long pulse with an energy of about 160 mJ/pulse at 10 Hz repetition rate. In order to focus the UV laser and reach the required energy density per pulse an appropriate UV focusing system was needed. The laser beam with a transverse size of about 20×10 mm^2 , was directed onto a homogenizer single matrix. The homogenized beam was then directly projected via a thin and plain convex lens onto the sample. The sample was placed in a holder and rigidly fixed to a x-y movable stage. The x and y positions were controlled by two step motors via a computer.

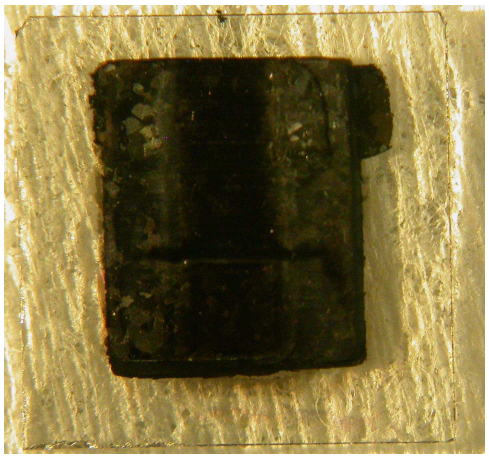

Figure 1. Optical microscopy image of detector-grade poly-crystal CVD diamond with dimensions 5x5x0.3 mm^3 with photo-generated graphite electrical contact made on the both sides.

The focused image was a square of 3 mm^2 at the sample surface and having a local laser fluence of about 5 J/cm^2 quite constant within the radiation spot. The device was treated in air at room temperature and the surface was scan at a velocity of about 0.3 mm/s to obtain a graphite electrode with a final total area of about 9 mm2 large enough to realize a pad detector.

This treatment was repeated on the other side of the surface sample (Figure 1) in order to realize a solid state radiation detector in planar configuration. The device was fixed between two gold made clamps in order to apply the high voltage by

a SMA connector and enclosed in an aluminum box to electrically shield it.

The reference device was a commercially available poly-crystal diamond detector of the same size 5x5x0.3mm^3 and material quality but with DLC/Pt/Au electrical contacts fabricated on both faces (planar configuration) with proprietary contact technology [1]. The detector was glued on a printed circuit board in one side and the two electrodes wire bonded to a SMA connector and enclosed also in an anodized aluminum box.

A low intensity ^{60}Co gamma-ray source was placed above the detectors at a distance of 1 cm in air at room temperature. The front-side electrode was used as the signal output and connected, through ORTEC charge sensitive preamplifier and spectroscopy amplifier (100mV/fC total gain and 0.5 μs shaping-time), to an oscilloscope and waveforms were recorded by GPIB protocol.

Figure 2 shows the response of the two devices to gamma radiations. The response is very similar showing that the nanographitic layer is not a source of minority carriers trapping. This preliminary result is very important to establish the good charge injection and collection properties of the contacts, in addition to mechanical adhesion and mechanical stability already demonstrated on thermal grade diamond in 2010.

This promising technique must be further consolidated by showing that the nano-graphite layer is also polarization free. Anyway, no evidence of polarization (decrease of signal with time) or inefficiency (low counting rate) is evident in this first observations. Work is in progress in order fully characterize the contact in terms of speed, radiation damage and aging.

We characterized the devices also measuring the current-voltage curve. Particular care was taken to minimize leakage current and shield the apparatus from external interference because the measured currents are very small. The diamond detector can be considered a metal-semiconductor-metal (MSM) structure, because diamond is like a semiconductor with energy gap of 5.47 eV. The MSM device is essentially two metal/semiconductor Schottky diodes connected back to back and at any polarity of the applied voltage one barrier is reverse biased and the other one is forward biased. Using the thermionic emission theory we can fit the current-voltage characteristics by the following formula:

$$I = I_0 A[e^{\frac{|V|}{\beta}} - 1], \tag{1}$$

where A is the contact surface. The two fit parameters I_0 and β are related to intrinsic contacts properties. These properties are the ϕ_b is

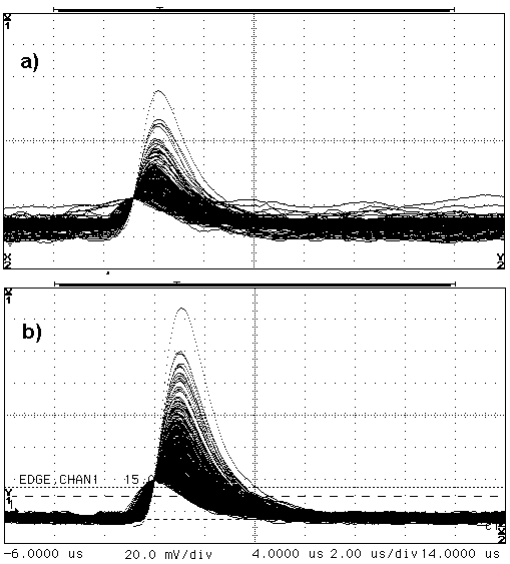

Figure 2. Single gamma response to ^{60}Co gamma source from reference diamond detector (waveforms a) and from diamond detector with laser-graphitized electrodes (waveforms b) for an applied voltage of about 300 V.

the Schottky barrier height and the ideality factor n:

$$I_0 = A^* T^2 e^{-\frac{\phi_b}{kT}} \text{ and} \beta = \frac{nkT}{e}, \tag{2}$$

where A*=120 A/cm^2 K is the effective Richardson constant for diamond, T is the temperature, k is the Boltzmanns constant, e is the electron charge. The Schottky barrier height turnout to be about 1.1 eV. The ideality factor of a MSM device measures the conformity to pure thermionic emission (n=1) and our preliminary measurements show relatively large n for both devices. This can be explained assuming formation of defect states in the inter-facial layer between diamond and contact, which act like a potential barrier for free charge carriers.

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