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IBIC characterization of an ion-beam-micromachined multi-electrode diamond detector

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ABSTRACT

Deep Ion Beam Lithography (DIBL) has been used for the direct writing of buried graphitic regions in monocrystalline diamond with micrometric resolution. As part of the development and the characterization of a fully ion-beam-micromachined solid-state ionization chamber, a device with interdigitated electrodes was fabricated by using a 1.8 MeV He^+ ion microbeam, which scanned a 40 μm thick homoepitaxial detector grade diamond sample grown by chemical vapor deposition (CVD). In order to evaluate the ionizing-radiation-detection performance of the device, charge collection efficiency (CCE) maps were extracted from Ion Beam Induced Charge (IBIC) measurements carried out by probing different arrangements of buried micro-electrodes.

The analysis of the CCE maps allowed an exhaustive evaluation of the detector features, in particular the individuation of the different role played by electrons and holes in the formation of the induced charge pulses.

Finally, a comparison of the performances of the detector with buried graphitic electrodes with those relevant to conventional metallic surface electrodes evidenced the formation of a dead layer overlying the buried electrodes as a result of the fabrication process.

1. Introduction

In recent papers [1,2] we described the fabrication of buried graphitic channels in monocrystalline diamond by Deep Ion Beam Lithography (DIBL). This technique consists of a selective damage of the crystal induced by MeV ion beams, which are focused down to a micrometer spot size and raster scanned on the sample along predefined linear patterns intersecting slowly-thinning metallic masks.

The damage induced by ions is localized mainly at their end of range, i.e. a few micrometers below the surface. The regions which experience a vacancy density overcoming a critical level, usually referred to as "graphitization threshold", convert to a graphitic phase upon thermal annealing; elsewhere, the diamond structure is recovered.

With this method, highly conductive (resistivity of the order of 1 mΩ cm) graphitic channels can be realized in single crystal diamond; their length is limited by the range of the micro-ion beam scanning system (typically several hundred micrometers); their minimum width is given by the beam spot size and their formation depth is defined by the nuclear stopping range of the ions in diamond (typically a few micrometers). Moreover, the presence of metallic masks, which modulate the nuclear stopping power of the ions, determines the emersion of the channels' terminals at the surface, enabling the bonding of the graphitic channels to external electronic systems or the selective etching of the graphite for subsequent diamond micromachining processes [3].

The realization of highly conductive, optically opaque, chemically reactive graphitic channels embedded in a highly resistive, optically transparent and chemically inert diamond matrix is of potential interest in many sectors, e.g. for the realization of diamond 3D microstructures [4], microfluidic channels, innovative biosensors [5,6], IR emitters [7] or bolometers [8]. An additional field of application is that of exploiting the DIBL to realize novel 3D architectures for ionizing radiation detection in order to increase their charge collection efficiency and to enhance their radiation hardness.

In order to characterize the carrier transport and recombination features of micromachined diamond detectors with buried electrodes, an analytical technique is needed to map the charge collection efficiency at a micrometer level of resolution, with a well

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