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Electrical characterization of a graphite-diamond-graphite junction fabricated by MeV carbon implantation

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ABSTRACT

The Deep Ion Beam Lithography technique has been extensively adopted in recent years for the fabrication of graphitic electrodes in bulk diamond with a wide range of technological applications. Particularly, it has been recently shown that a high current can be driven in devices consisting of micrometer-spaced sub-superficial graphitic electrodes. This effect has been exploited to stimulate electroluminescence from color centers placed in the active region of the device.

A deep understanding of the conduction mechanisms governing charge transport in micro-regions of defective diamond comprised between graphitic electrodes is necessary in order to fully exploit the functionality of these opto-electronic devices, as well as to assess the ion-beam-micromachining of diamond as a convenient technique for the fabrication of solid-state micro-devices.

In this work, a temperature-dependent characterization of the electrical properties of a sub-superficial graphite-diamond-graphite junction is presented and discussed. The ohmic behavior observed at low bias voltages is ascribed to a donor level with an activation energy of (0.217 ± 0.002) eV, a value compatible with previous reports on nitrogen-related defects. A transition to a high-current regime above a critical voltage V_C was also observed, and interpreted in terms of the Space-Charge-Limited Current model. The temperature-dependent measurements allowed to investigate the role of charge trapping in the charge injection mechanism of the junction. By fitting the temperature dependence in the high-current regime it was possible to determine the relevant trap level of the associated Poole-Frenkel mechanism, leading to a value of (0.278 ± 0.001) eV from the conduction band. The Poole-Frenkel conduction model in high-current regime enabled also a preliminary investigation in the effects of ion implantation on the modification of the dc dielectric constant of diamond.

1. Introduction

In recent years, the progresses in the quality of diamond synthesis by chemical vapor deposition (CVD) has paved the way for the full exploitation of the extreme properties of this material in innovative and challenging technological applications. The outstanding electronic properties of diamond (high carriers mobility, saturation velocity, breakdown voltage, thermal conductivity), combined with its bio-compatibility, radiation hardness and optical transparency have led to the development of solid state devices for applications ranging from electronic devices [1–2] to radiation detectors [3–4] and devices for quantum technologies [5–7].

Together with the steady progresses in the development of efficient techniques for the electronic doping of diamond devices by homoepitaxial growth [7,8] or ion implantation [9–11], the fabrication of all-carbon devices by means of the local graphitization of its lattice upon laser irradiation [12,13] or MeV ion implantation [14,15] has been extensively explored. The latter technique consists of the selective conversion of a diamond volume to a graphitic phase upon the introduction of radiation damage produced by MeV or keV ion beams (typically focused to a micrometer spot size). In this way, it enables the direct fabrication of electrodes embedded in insulating diamond in arbitrary geometries, and thus the current injection [16,17] in specific micrometer-sized regions of the diamond bulk.

In particular, the Deep Ion Beam Lithography (DIBL) technique has been exploited to fabricate radiation detectors [18,19], cellular biosensors [20], waveguides [21], photonic structures [22], mechanical resonators [23], IR emitters [24] and more recently electrically-stimulated

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