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Electroluminescence from a diamond device with ion-beam-micromachined buried graphitic electrodes

J. Forneris [a,b,c,*], A. Battiato [a,b,c], D. Gatto Monticone [a,b,c], F. Picollo [b,c,a], G. Amato [d], L. Boarino [d], G. Brida [d], I. P. Degiovanni [d], E. Enrico [d], M. Genovese [d], E. Moreva [d], P. Traina [d], C. Verona [e], G. Verona Rinati [e], P. Olivero [a,b,c]

[a] Physics Department and NIS Interdepartmental Centre, University of Torino, Torino, Italy
[b] Istituto Nazionale di Fisica Nucleare (INFN), Sez. Torino, Torino, Italy
[c] Consorzio Nazionale Interuniversitario per le Scienze Fisiche della Materia (CNISM), Sez. Torino, Torino, Italy
[d] Istituto Nazionale di Ricerca Metrologica (INRiM), Torino, Italy
[e] Department of Industrial Engineering, University of Roma "Tor Vergata", Roma, Italy

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ABSTRACT

Focused MeV ion microbeams are suitable tools for the direct writing of conductive graphitic channels buried in an insulating diamond bulk, as demonstrated in previous works with the fabrication of multi-electrode ionizing radiation detectors and cellular biosensors. In this work we investigate the suitability of the fabrication method for the electrical excitation of color centers in diamond. Differently from photoluminescence, electroluminescence requires an electrical current flowing through the diamond sub-gap states for the excitation of the color centers. With this purpose, buried graphitic electrodes with a spacing of 10 μm were fabricated in the bulk of a detector-grade CVD single-crystal diamond sample using a scanning 1.8 MeV He^+ micro-beam. The current flowing in the gap region between the electrodes upon the application of a 450 V bias voltage was exploited as the excitation pump for the electroluminescence of different types of color centers localized in the above-mentioned gap. The bright light emission was spatially mapped using a confocal optical microscopy setup. The spectral analysis of electroluminescence revealed the emission from neutrally-charged nitrogen-vacancy centers (NV^0, $\lambda_{ZPL} = 575$ nm), as well as from cluster crystal dislocations (A-band, $\lambda = 400–500$ nm). Moreover, an electroluminescence signal with appealing spectral features (sharp emission at room temperature, low phonon sidebands) from He-related defects was detected ($\lambda_{ZPL} = 536.3$ nm, $\lambda_{ZPL} = 560.5$ nm); a low and broad peak around $\lambda = 740$ nm was also observed and tentatively ascribed to Si-V or GR1 centers. These results pose interesting future perspectives for the fabrication of electrically-stimulated single-photon emitters in diamond for applications in quantum optics and quantum cryptography.

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1. Introduction

Color centers in diamond are attracting an ever-growing interest due to their appealing photon-emission properties (high stability and quantum efficiency at room temperature) for applications in quantum optics and photonics [1].

The development of diamond devices based on the functionalities of sub-superficial graphitic micro-electrodes has been investigated in several recent works [2,3]. The fabrication method relies on the direct writing in the single-crystal diamond bulk of amorphized channels by the selective damage induction associated with the Bragg's peak of MeV ions. The crystal volume in which the radiation-induced vacancy density exceeds a threshold value converts to nano-crystalline graphite upon thermal treatment at temperatures above 900 °C, while the diamond lattice is partially recovered where the radiation damage density is lower [4,5].

Since the radiation damage from MeV ions is prominently induced at the ion end of range, the fabrication method has been proved to be effective for the fabrication of conductive graphitic electrodes located several micrometers below the surface of the electrically insulating and optically transparent diamond dielectric. The fabrication process is characterized by a spatial resolution which is limited only by the ion beam spot size and by the ion lateral straggling in the material. The technique has been effectively

* Corresponding author at: Physics Department, University of Torino, via P. Giuria, 1-10126 Torino, Italy.

E-mail address: jacopo.forneris@unito.it (J. Forneris).

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