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Micro-beam and pulsed laser beam techniques for the micro-fabrication of diamond surface and bulk structures

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ABSTRACT

Micro-fabrication in diamond is applicable in a wide set of emerging technologies, exploiting the exceptional characteristics of diamond for application in bio-physics, photonics and radiation detection. Micro ion-beam irradiation and pulsed laser irradiation are complementary techniques, which permit the implementation of complex geometries, by modification and functionalization of surface and/or bulk material, modifying the optical, electrical and mechanical characteristics of the material.

In this article we summarize the work done in Florence (Italy), concerning ion beam and pulsed laser beam micro-fabrication in diamond.

1. Introduction

Micro-beam ion implantation in the MeV range and laser micro-fabrication are techniques exhibiting largely complementary features. The relatively short range of MeV implantation makes it useful for the fabrication of structures parallel to the surface of the sample at depths ranging from a few to tens of micrometers, with a vertical resolution limited by the width of the Bragg peak and a lateral one better than one micrometer, in the most recent high performance setups [1]. The types of structural modification allowable by ion implantation range from electrical [2] to optical [3–5], mechanical and chemical [6]. Laser material engineering, on the other hand, depending on wavelength, energy and pulse width, is useful in ablation or amorphization of the material [7,8], and is suitable for the modification of the surface or of the interior of the sample (up to centimeters, theoretically), with a lateral resolution comparable to that of the micro-beams but with a vertical definition (in the bulk) limited by the focusing aperture to about ten micrometers.

In diamond, these two techniques could pave the way to the integration of micro-devices with applications in particle detection, bio-sensing, micro-optics and quantum-optics. Both ion damaging (followed by appropriate annealing [9,10]) and sub-bandgap pulsed laser irradiation are capable of increasing the conductivity of the material by modification of the bonding hybridization, from sp^3 to sp^2 [11]. Thus, micro-beam writing can be employed in the fabrication of conductive channels or pads under the surface of diamond, while pulsed laser graphitization is suitable for fabrication of conductive columns, perpendicular to the surface, or of conductive channels, at the surface level. In this way, electrodes inside diamond can be implemented in three-dimensional diamond detectors, or in micro-electrodes arrays employed in studies of biological tissues [12,13], or in Stark-effect tuned optical micro-cavities [14], just to mention some of the possible applications. Moreover, the optical modification of the material induced by ion implantation can be used to implement light guides in micro-optical devices. Doping by ion implanting can be employed both

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