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Effects of high-power laser irradiation on sub-superficial graphitic layers in single-crystal diamond

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A B S T R A C T

We report on the structural modifications induced by a $\lambda = 532$ nm ns-pulsed high-power laser on sub-superficial graphitic layers in single-crystal diamond realized by means of MeV ion implantation. A systematic characterization of the structures obtained under different laser irradiation conditions (power density, number of pulses) and subsequent thermal annealing was performed by different electron microscopy techniques. The main feature observed after laser irradiation is the thickening of the pre-existing graphitic layer. Cross-sectional SEM imaging was performed to directly measure the thickness of the modified layers, and subsequent selective etching of the buried layers was employed to both assess their graphitic nature and enhance the SEM imaging contrast. In particular, it was found that for optimal irradiation parameters the laser processing induces a six-fold increase the thickness of sub-superficial graphitic layers without inducing mechanical failures in the surrounding crystal. TEM microscopy and EELS spectroscopy allowed a detailed analysis of the internal structure of the laser-irradiated layers, highlighting the presence of different nano-graphitic and amorphous layers. The obtained results demonstrate the effectiveness and versatility of high-power laser irradiation for an accurate tuning of the geometrical and structural features of graphitic structures embedded in single-crystal diamond, and open new opportunities in diamond fabrication.

1. Introduction

Diamond is well known for its range of extreme mechanical, thermal and optical properties, which make it an attractive material for a variety of applications [1]. Nevertheless, diamond is a metastable allotropic form of carbon at standard pressure and temperature, and can be converted into graphite if an energy barrier is overcome [2]. Several approaches have been developed to induce this phase transition, among which ion-beam-induced graphitization [3–9] and laser-induced graphitization [10,11] play a prominent role. The former approach takes advantage of the ion-induced defect creation caused by nuclear collisions to amorphize the material and the subsequent thermal annealing to convert amorphized regions into a graphitic phase [3]. The latter approach is based on complex non-equilibrium dynamics induced by high-power light absorption, which were modelled with different theoretical approaches based on the non-radiative recombination of electron–hole pairs [11] or on a non-thermal ultrafast non-equilibrium

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