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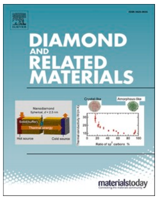

Effect of crystallographic orientation on the potential barrier and conductivity of Bessel written graphitic electrodes in diamond

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ABSTRACT

Ultrafast laser micromachining can be used to promote diamond graphitization, enabling the creation of electrically conductive wires embedded in the diamond matrix. In this context, the presence of a potential barrier in the conductivity of transverse graphitic wires fabricated by pulsed Bessel beams without sample translation across 500 μm thick monocrystalline CVD diamond has been studied. In particular, the role of the crystallographic orientation has been analysed. The morphology and the conductivity of the obtained electrodes have been studied using optical microscopy and current-voltage measurements, while the structural changes have been investigated by means of micro-Raman spectroscopy. By using different laser writing parameters, we have explored the features of different electrodes in a (100) and a (110) oriented diamond crystal respectively. We show that in addition to the use of specific pulse energies and durations (in the fs and ps regimes), the crystallographic orientation of the sample plays an important role in reducing or eliminating the potential barrier height of the IV electrical characterization curves. In a (110) oriented sample, it is possible to eradicate the potential barrier completely even for graphitic wires fabricated at low pulse energy and in the fs pulse duration regime, in contrast to the (100) oriented-crystal case where the barrier is generally observed. The effect of thermal annealing of the diamond samples on the resistivity of the fabricated micro-electrodes has also been investigated. In (110) oriented diamond, resistivities lower than 0.015 Ω cm have been obtained.

1. Introduction

Diamond is an excellent material platform thanks to its unique properties such as high thermal conductivity, good biocompatibility, high radiation stability, remarkable hardness and high chemical resistivity [1,2]. Moreover, the presence of NV centres in diamond has attracted a lot of attention due to their potential applications in quantum communication and sensing at nanoscale regime [3]. Another prominent feature of diamond is that it can be converted to graphite-like carbon thus creating conductive channels within a sample that is insulating in nature [4]. Such electrodes, which are used as electric field generators, find numerous applications in photonic chips [5], radiation detectors [6], microfluidic sensing systems [3] and biosensing [7]. There are many techniques for conductive electrode fabrication in diamond such as thermal annealing, ion beam lithography and laser writing. Annealing the diamond sample under vacuum around 1700 °C can lead to the formation of a graphitic layer on the surface resulting in the generation of a conductive region independent of surrounding gas pressure [8]. Ion beam lithography operates by irradiating diamond with ion beams at keV or MeV energy levels, promoting the creation of lattice defects. These defects enable the transformation of the damaged region into graphite if a critical threshold (graphitization threshold) [9,10] is exceeded.

Fabrication of microstructures in different transparent materials using ultrafast lasers has emerged as an excellent tool for the precise modification of the same. Thanks to the multiphoton absorption and avalanche ionization, the non-linear absorption of the ultrashort pulses helps in avoiding collateral damages due to thermal effects thus

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