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Bessel beam fabrication of graphitic micro electrodes in diamond using laser bursts

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A B S T R A C T

We present the fabrication of conductive graphitic microelectrodes in diamond by using pulsed Bessel beams in the burst mode laser writing regime. The graphitic wires are created in the bulk of a 500 μm thick monocrystalline HPHT diamond (with (100) orientation) perpendicular to the sample surface, without beam scanning or sample translation. In particular, the role of different burst features in the resistivity of such electrodes is investigated for two very different sub-pulse durations namely 200 fs and 10 ps, together with the role of thermal annealing. Micro-Raman spectroscopy is implemented to investigate the laser-induced crystalline modification, and the results obtained by using two different laser repetition rates, namely 20 Hz and 200 kHz, are compared. A comparison of the micro-Raman spectra and of the resistivity of the electrodes fabricated respectively with 10 ps single pulses and with bursts (of sub-pulses) of similar total duration has also been made, and we show that the burst mode writing regime allows to fabricate more conductive micro electrodes, thanks to the heat accumulation process leading to stronger graphitization. Moreover, the microfabrication of diamond by means of the longest available bursts (~ 46.7 ps duration) featured by 32 sub-pulses of 200 fs duration, with intra-burst time delay of 1.5 ps (sub-THz bursts), leads to graphitic wires with the lowest resistivity values obtained in this work, especially at low repetition rate such as 20 Hz. Indeed, micro electrodes with resistivity on the order of 0.01 Ω cm can be fabricated by Bessel beams in the burst mode regime even when the bursts are constituted by femtosecond laser sub-pulses, in contrast with the results of the standard writing regime with single fs pulses typically leading to less conductive micro electrodes.

1. Introduction

Fabrication of microstructures in diamond for various novel applications such as radiation detectors [1], microfluidic chips [2] and photonic circuits [3] is attracting a lot of attention thanks to the unique properties of this crystal such as high scratch resistance, remarkable hardness with a Mohs index of 10, increased chemical resistivity, high radiation stability and high thermal conductivity [4,5]. Thanks to its good biocompatibility, diamond is used as a strong candidate for biosensing as well [6]. One of the high impact works that is being investigated widely is the incorporation of Nitrogen Vacancy (NV) centres in the diamond bulk for quantum communication and nanoscale magnetometry [2]. A common feature in all these applications is the presence of graphitic electrodes which act as conductive pathways for different kinds of sensors. The main techniques to fabricate such conductive channels are annealing [7] where the electrodes are fabricated mainly on the surface of the diamond substrate, focused ion beam [8,9] which specialises in fabrication within the bulk but close to the surface depending on the energy of the ion beam, and laser writing [10–14] which gives freedom to write in any geometry at any depth with desired length. Therefore, laser writing can also be used for designing and fabricating 3D structures as well within the diamond bulk.

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