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Fabrication of monolithic microfluidic channels in diamond with ion beam lithography

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ABSTRACT

In the present work, we report on the monolithic fabrication by means of ion beam lithography of hollow micro-channels within a diamond substrate, to be employed for microfluidic applications.

The fabrication strategy takes advantage of ion beam induced damage to convert diamond into graphite, which is characterized by a higher reactivity to oxidative etching with respect to the chemically inert pristine structure. This phase transition occurs in sub-superficial layers thanks to the peculiar damage profile of MeV ions, which mostly damage the target material at their end of range.

The structures were obtained by irradiating commercial CVD diamond samples with a micrometric collimated C^+ ion beam at three different energies (4 MeV, 3.5 MeV and 3 MeV) at a total fluence of 2×10^{16} cm^{-2}. The chosen multiple-energy implantation strategy allows to obtain a thick box-like highly damaged region ranging from 1.6 μm to 2.1 μm below the sample surface. High-temperature annealing was performed to both promote the graphitization of the ion-induced amorphous layer and to recover the pristine crystalline structure in the cap layer. Finally, the graphite was removed by ozone etching, obtaining monolithic microfluidic structures.

These prototypal microfluidic devices were tested injecting aqueous solutions and the evidence of the passage of fluids through the channels was confirmed by confocal fluorescent microscopy.

1. Introduction

'Lab-on-a-chip' technology is an emerging field exploited for a wide range of applications. The benefits of these platforms for the study of biological systems or chemical reactions have been widely reviewed in previous works [1–6]. Microfluidic lab-on-a-chips consist of small devices equipped with channel having size in the range of micrometres, which facilitates handling of volumes below the microliter range.

Microfluidic systems can be integrated with analytical detection techniques [7,8], such as electrochemical and optical methods including absorption, chemoluminescence and fluorescence. Moreover, they can be employed in biosensing devices both as active component for cell activity monitoring [9–11] or as perfusion system for drug/solution transport [12].

The vast majority of microfluidic devices consist, however, of simple planar microchips fabricated by photolithography on standard substrates such as glass, silicon or polymers.

The employment of diamond as a substrate material would represent a significant improvement for hard environment applications (i.e. high temperature, strong acid or basic solutions) since it guarantees to the final device high chemical inertness, mechanical stability, wide transparency window from IR to near UV and long term biocompatibility [13,14]. To this scope, the fabrication of microfluidic structures in diamond has already been explored with standard lithographic techniques, for which the definition of three-dimensional structures typically requires multiple processing steps in non-monolithic polycrystalline substrates [15–17].

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