New developments on the fabrication of high density and low density diamond-based MEA

A. Battiato[1,2,4], E. Bernardi[1,2,4], V. Carabelli[3,4], E. Carbone[3,4], S. Gosso[3,4], P. Olivero[1,2,4], A. Pasquarelli[5], F. Picollo[2,1,4*]

1 Physics Department and NIS Inter-departmental Centre, University of Torino, via P. Giuria 1, 10125 Torino, Italy
2 INFN section of Torino, via P. Giuria 1, 10125 Torino, Italy
3 Department of Drug Science and Technology and NIS Inter-departmental Centre ,University of Torino, Corso Raffaello 30, 10125 Torino, Italy
4 Consorzio Nazionale Inter-universitario per le Scienze fisiche della Materia (CNISM), Section of Torino
5 Institute of Electron Devices and Circuits, Ulm University, 89069 Ulm, Germany
* Corresponding author. E-mail address: picollo@to.infn.it

Abstract

In the present work we report about the development of our activity on diamond modification devoted to Multi Electrode Arrays realization. High energy (MeV) ion implantation has been used to obtain biosensors having different configuration with the employment of suitable masks and techniques. Our diamond-based devices are developed for amperometric measurements and chromaffin cells were chosen as first target of analysis. The investigation of the mechanisms involved in the catecholamine (adrenaline) secretion is in fact crucial in neuroscience research in order to achieve a better understanding of the signal transmission among neurons.

1 Diamond microfabrication

The development of a diamond-based device has the aim of addressing to different extents, which are not met by conventional biomaterials (silicon, metals and metals oxides, polymers), robustness and reproducibility in performance over repeated bio-sensing cycles, bio-compatibility and long term stability for *in vitro* measurements.

Our three-dimensional lithographic technique (Deep Ion Beam Lithography – DIBL) in diamond is based on the combination of ion beams with energy of the order of MeVs with other advanced lithographic techniques based on laser beams and ion beams with energy of the order of keVs (Focused Ion Beam – FIB). The innovative fabrication scheme allows to modify diamond properties tuning the conductivity and the chemical reactivity of this material.

The biosensors are fabricated implanting He^+ ions (energy range: 0.8 – 2 MeV) on high-purity monocrystalline CVD (Chemical Vapour Deposition) diamond samples. Suitably aligned metal masks and variable-thickness contact masks were employed to define "highly damaged" regions, i.e. converted from sp_3 diamond bonds to sp_2 graphitic-like bonds, with emerging end-points with micrometric resolution.

The damage profile of the above-mentioned ions in the diamond lattice is reported in Fig.1, as derived from the SRIM-2008.04 Monte Carlo Simulation code by setting a displacement energy value of 50 eV. The damage profile is derived by assuming a simple linear dependence of the defect density from the implantation fluence, i.e. ignoring complex non-linear processes such as self-annealing and defect-defect interaction. In such a drastically simplified approach it is nonetheless possible to have a satisfactory estimation of the thickness of the buried graphitized layer which is formed upon thermal annealing, by setting a "graphitization" threshold for the vacancy density of ~$9 \cdot 10^{22}$ cm^{-3} [1], as shown in Fig.1.

After diamond implantation, a thermal annealing at 900 °C for 2 hours was performed in order to convert the damaged region into graphite.

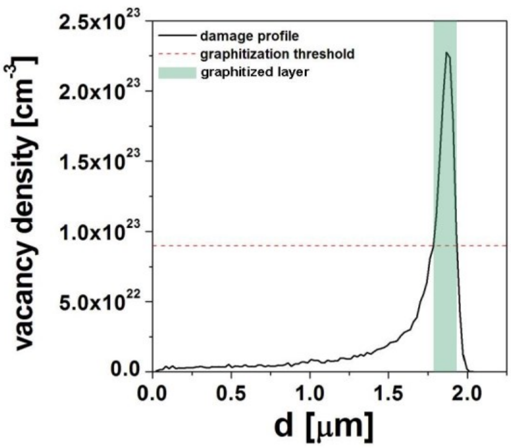

Fig. 1. Damage density profile (black continuous line) for a 1.1 MeV He^+ implantation at a fluence of $1 \cdot 10^{17}$ cm^{-2}. The graphitization threshold is reported in the red dashed line. The graphitized layer formed upon thermal annealing is highlighted in the green box.

This fabrication process provides buried highly conductive graphitic micro-channels (resistivity ~1 mΩ·cm) embedded in a highly insulating (resistivity ~10^{14} Ω·m) and chemically inert diamond matrix,