Ion beam micro-structuring of graphene allotropes for sensors

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Graphene based solids, are excellent candidates for the fabrication of sensors due to ability to detect at room temperature, excellent sensitivity, short reaction time, low cost, easy processing and mechanical stability. Furthermore, their doping leads to an improvement of its sensory properties. Ion-beam lithography is a highly localized precise technique for doping and modifying properties, with several advantages, such as the absence of chemical agents, absence of unwanted oxide formation, less of residual impurities, and cost-competitive production. Unfortunately, direct ion-beam lithography with heavy metal ions remains a challenge due to the difficulty of focusing a heavy ion beam into a micrometer-size spot. This promotes the dominance of mask-based ion beam lithography to micro-pattern the material with heavy ions.

For this reason, we attempted to prepare micro-scale capacitor-like structures (900x900 µm) in graphene oxide (GO) using energetic ion beams in two ways. One approach involved ion beam writing, while the second utilized ion beam implantation through a polymeric mask. The polymeric mask was prepared directly on the surface of the substrates by spin coating of PMMA, followed by proton beam writing and development in isopropyl alcohol. After the ion beam implantation, the mask was removed using acetone. The GO foils were irradiated by 2.5 MeV ion beams with an ion fluence of 1800 and 3600 $nC.mm^{-2}$. Subsequently, the shape of the created micro-structures and compositional changes of the irradiated materials were studied using Scanning Electron Microscopy/Energy-Dispersive X-ray spectroscopy methods, respectively. Complementary structure and compositional changes in the irradiated area were characterized by micro-Raman spectroscopy, X-ray Photoelectron Spectroscopy and Ion Beam spectroscopy. The irradiation of non-conductive materials leads to de-oxygenation, carbonization, and creation of new carbon bonds, resulting in increased electrical conductivity. The electrical and humidity sensing properties of the prepared micro-structures were also tested and compared to the commercial sensor and to each other. We can conclude that the structures prepared by carbon implantation through the PMMA mask show very similar properties to those prepared by carbon micro-beam writing.