Incorporating foreign elements in graphene using ultra-low energy ion implantation

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In order to functionalize 2D materials, their physico-chemical properties can be modified and tuned via diverse methods: coupling to the substrate, vacancies, adsorbed species (clusters and molecules), substitutional impurities (via precursors during growth) and intercalation (atomic and molecular). However, in the cases of incorporation of substitutional and intercalated elements the challenge is the poor control over the concentration and form of incorporation. An alternative approach is to incorporate the foreign species by implanting low-energy ions, precisely tuning the amount of implanted ions and their kinetic energy. Here, we demonstrate the integration of foreign elements in graphene using the state-of-the-art technique of ultra-low energy ion implantation. Our scanning tunneling microscopy and x-ray photoelectron spectroscopy experiments show the formation of nanobubbles for implanted noble gases (Ar and Ne), and various forms of incorporation for implanted transition metals (Mn). We are able to control the density of the nanobubbles with the ion mass, implantation energy and fluence. Moreover, we have identified the energy range for Mn incorporation with minimum damage to graphene for substitutional and intercalation purposes.

Figures

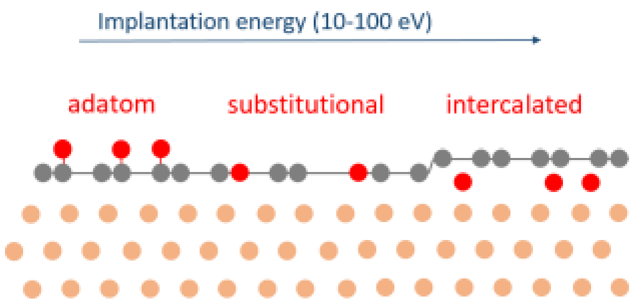

Figure 1: Representation of three forms of incorporation of dopant atoms (red) in graphene (gray) on a substrate (cream).