Advances in ultra-low energy ion implantation of low dimensional materials

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Abstract

Doping of 2D-materials by ion implantation has unique requirements regarding ion energy, ion energy spread, ion beam optics, sample preparation and sample electrical conductivity. Efficient substitutional incorporation of low energy ions into the graphene lattice requires energies well below 50 eV.

We use a low energy mass selected ion beam system with a UHV implantation chamber. A 30 keV mass selected ion beam is guided through differential pumping stages and homogenized using a beam sweep. The beam is then decelerated in a UHV-chamber down to energies of as low as 10 eV. With the help of focusing and defocusing lenses an area of severeal mm^2 up to about 2.5 cm^2 can be uniformly irradiated with these ultra-low-energy (ULE) ions with beam current up to severeal µA. Up to now ion sources are available for isotopically pure beams of B^+, C^+, N^+, F^+, P^+, S^+, Mn^+, Se^+, W^+ and Au^+. Ion sources for elements like Al, Fe, As and rare earth elements are under development.

The implanted areal concentration and elemental composition can be verified with in-situ Auger spectroscopy and more quantitative with Rutherford backscattering by implantion into amorphous carbon films as test samples. For heavier elements the detection limit is below 10^{14} ions/cm^2. Implanted ^{11}B can be analyzed with the $^{11}B(p,2\alpha)\alpha$ nuclear reaction with a detection limit of about $1 \cdot 10^{14}$ B/cm^2. Examples for doping of monolayer graphene with $^{11}B^+$, $^{14}N^+$ and P^+ ions will be presented.

References

[1] U. Bangert et al., Nano Lett. 2013, 13 (2013) 4902-4907

Figures

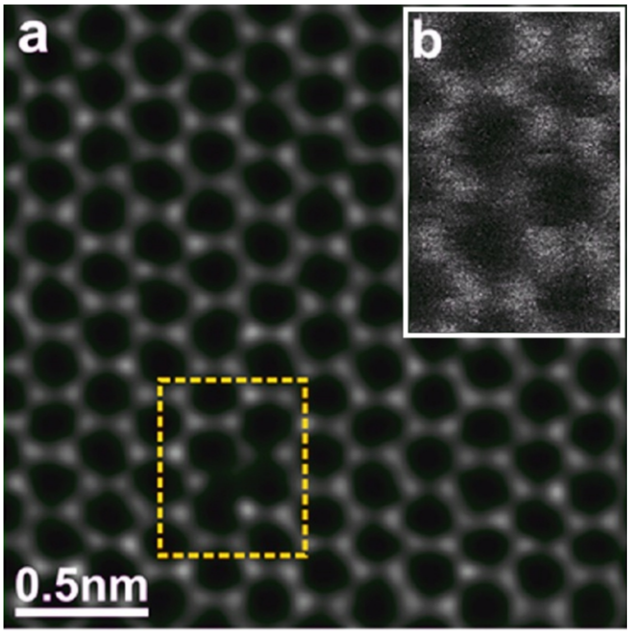

Figure 1: (a) Double Gaussian filtered atomic resolution HAADF image of substitutional B-atom in graphene. (b) Raw HAADF signal obtained from the framed area in (a) [1].

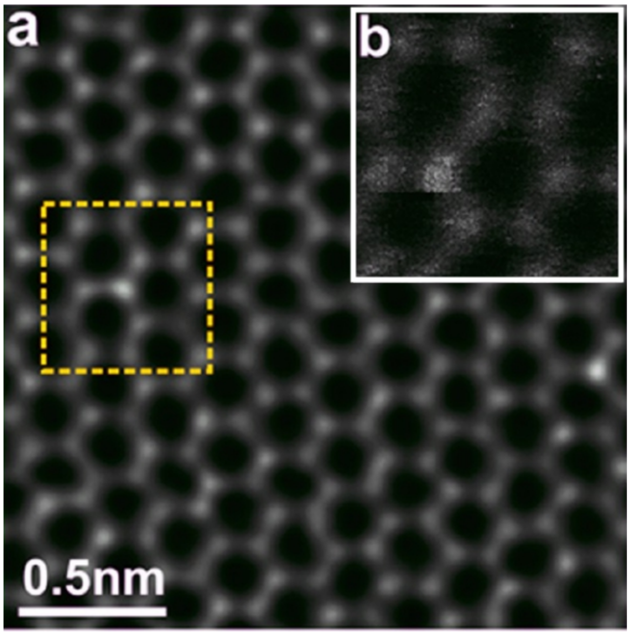

Figure 2: (a) Double Gaussian filtered atomic resolution HAADF image of substitutional B-atom in graphene. (b) Raw HAADF signal obtained from the framed area in (a) [1].