Taming of Ga droplets on DLC layers – Size tuning and local arrangement with nm accuracy

P. Philipp, L. Bischoff and B. Schmidt
Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, 01314 Dresden, Germany
p.philipp@hzdr.de

Metal nanoparticles (NPs) are of great interest due to their unique ability to localize and route light at the nano-scale by local surface plasmon resonance. The controlled fabrication of metal NPs is a major challenge for utilizing plasmonics in applications e.g. waveguiding or surface enhanced Raman spectroscopy. Common NP fabrication techniques like molecular beam deposition and ion beam synthesis are suffering from a broad particle size distribution and the incapability of controlled lateral placement of single NPs on a substrate.

In this work we present a new method for the fabrication of spherical Ga NPs on diamond-like carbon (DLC) substrates with high precision in their desired diameter and positioning. The basic principle is the pre-patterning of a DLC film by focused Ga^+ ion beam (Ga^+-FIB) irradiation and subsequent annealing. During thermal treatment the evolution of single Ga NPs with spherical shape on irradiated areas is driven by phase separation and surface segregation of Ga from the supersaturated DLC layer. The shape and size of implanted areas as well as the implanted fluence serve as a Ga reservoir for the NP evolution and strongly correlate with the NP diameter. For the formation of segregation seeds to avoid random segregation of the NPs small spots are additionally implanted within Ga irradiated areas. The NP evolution is than assessed to the seed position and the material for the Ga NP growth is gathered from the surrounding reservoir. Using this technique Ga NPs were fabricated with a diameter ranging from 50 nm up to several 100 nm. The arrangement in chains with defined interparticle distance (Fig. 1) as well as periodic two dimensional arrays of NPs (Fig. 2) are demonstrated.

Ga NPs produced by FIB implantation and subsequent annealing has the potential to meet the demands of plasmonic device fabrication. Prospective applications like plasmonic waveguiding or surface induced field enhancement arising from the narrow size distribution and accurate lateral position control of the Ga NPs are already under investigation. Furthermore the conversion of the above mentioned processing to other materials and substrates like silver or gold on sapphire is promising.

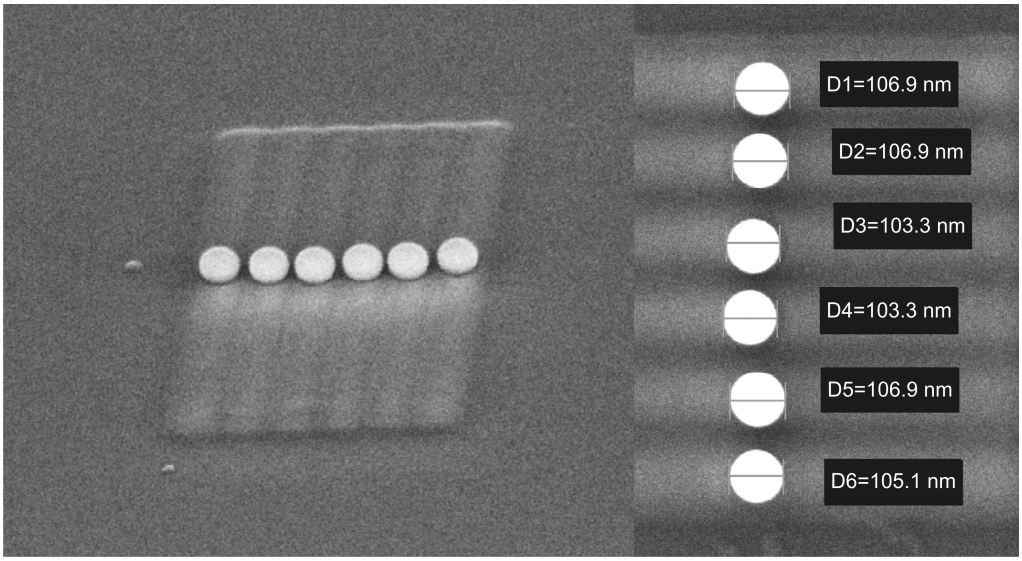

Figure 1: Gallium NP chain: Spherical Ga particles after annealing of a Ga^{+}-FIB implanted line structure on DLC. Left: SEM image under 63° angle. Right: Top-down SEM image showing the single sphere diameters.

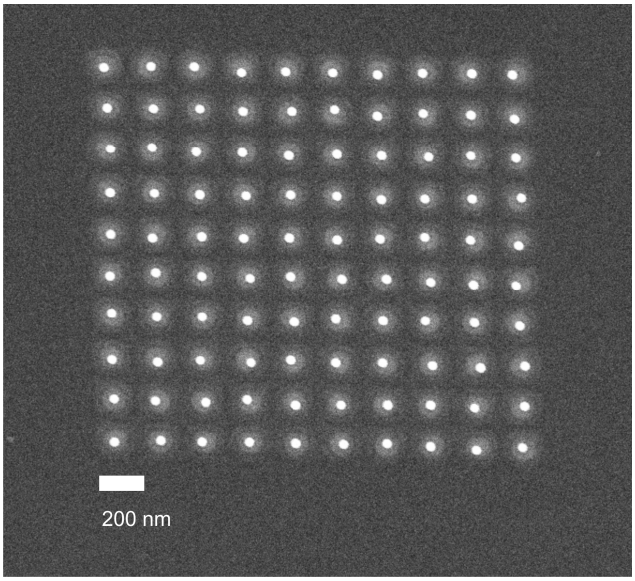

Figure 2: Two dimensional gallium NP array: SEM image of 10x10 gallium nano particles arranged in a raster with 200 nm spacing in x and y direction.