Thermo-physical effects on ion-induced shape modification of gold nanoparticles in amorphous silicon nitride, silicon dioxide and at the interface between silicon nitride and silicon dioxide

P. Mota-Santiago[1], G. Rizza[2], F. Kremer[3], Ch. Dufour[4], C. Notthoff[1], A. Hadley[1], P. Kluth[1]

[1]Department of Electronic Materials Engineering, Research School of Physics and Engineering, Australian National University, Canberra, ACT 2601, Australia

[2]Ecole Polytechnique, Laboratoire des Solides Irradies (LSI), CEA/DSM/IRAMIS-CNRS, 91128 Palaiseau Cedex, France

[3]Centre for Advanced Microscopy, Australian National University, 131 Garran Road, Acton 2601, Australia

[4]CIMAP, CEA/CNRS/ENSICAEN/Universite de Caen, 6 Boulevard du Marechal Juin, 14050 Caen cedex 4, France

The design of metal-dielectric nanocomposites is of great interest because of their optical response that can be tuned by engineering the volume, geometry, orientation, metal species and the dielectric function of the surrounding medium. While many fabrication methods are available (among the most widespread are: chemical synthesis of metal colloids and core-shell particles, self-organization, electron beam lithography and nanoimprinting), irradiation of metallic nanoparticles (MNPs) embedded in a dielectric medium with energetic ions has demonstrated the possibility to transform near-spherical particles into well-aligned, high aspect-ratio nano-rods, a process known as "ion-shaping". The ion-induced shape transformation process of MNPs has been studied predominantly with amorphous silicon dioxide as the host matrix for various metallic nanoparticle species. It has recently been suggested that the elongation process of Au NPs is linked to the ion track formation process in silicon dioxide and is governed by Au diffusion into the under-dense track core region [1]. If this is true, the relationship between the nanoparticle and the ion track core region dimensions should be more relevant than the relationship with the total ion track radius, as previously proposed [2].

In the present work, we present the shape transformation of nearly spherical Au nanoparticles upon irradiation with 185 MeV Au ions at different fluences in two configurations: (i) embedded in, (ii) and at the interface of amorphous silicon nitride and silicon dioxide. We have previously characterised the morphology of ion tracks formed in both amorphous silicon nitride and silicon dioxide which show a similar morphology, yet differences in the formation process were observed. Ion shaping experiments carried out using the two materials will help to test and expand the currently proposed models that are still controversial. Depending on the host material configuration we observed either transformation into facetted nanoparticles when embedded in amorphous silicon nitride, high aspect-ratio nano-rods when embedded in silicon dioxide, and long nano-rods with preferential elongation into the amorphous silicon dioxide layer when located at the interface. Complementary numerical calculations based on the three-dimensional version of the inelastic thermal spike model were carried out to simulate the thermal environment for the three configurations. The combination of experimental and numerical results suggests that the ion-shaping process is strongly influenced by the thermo-physical properties of the three materials.

[1]A. A. Leino *et al, Mat. Res. Lett.* 2:1, 37-42 (2014)

[2] G. Rizza *et al, Phys. Rev. B* 86, 035450 (2012)