Numerous impacts of energetic fullerene clusters on silicon crystal surface: modification features

Vasily Lavrentiev*†[1], Jiri Vacik[1], Vladimir Vorlicek[2], Alexandr Dejneka[2], Lubomir Jastrabik[2], Dagmar Chvostova[2], Zdenek Potucek[2], and Hiroshi Naramoto[3]

[1]Nuclear Physics Institute AS CR – Rez 130, Husinec 250 68, Czech Republic
[2]Institute of Physics AS CR – Na Slovance 2, Prague 182 21, Czech Republic
[3]Japan Atomic Energy Agency – Tokai 319-1195, Japan

Abstract

Interaction of energetic clusters with solid surface attracts attention of material science community because of desire to utilize the interaction effects for controlled modification of surface structure and properties. During the interaction the energetic cluster injects huge energy into nm-sized region that then rapidly releases through several mechanisms such as enhanced sputtering, secondary ion and electron emission, great local heating and quenching, generation of shock waves. The latter effects significantly influence atomic structure around the excited region implying promising potential of cluster ion bombardment (CIB) in surface structure engineering. In this study we have tested this potential of CIB carrying out irradiation of silicon crystal surface by monoenergetic beams of the fullerene cluster ions. The samples of Si(100) were irradiated by C60 cluster ions with energies of 200 keV and 400 keV under normal ion incidence to fluences implying uniform modification of the surface. Several aspects of Si modification (sputtering, structure transformation, and optical properties) have been analyzed using set of the experimental techniques, such as atomic force microscopy, Rutherford backscattering with ion channelling, Raman scattering, transmission electron microscopy, spectroscopic ellisometry and photoluminescence spectroscopy. It was found that the applied CIB-treatment produces perfect thin layer of disordered Si (d-Si) with specific nanostructure and unusual optical properties. There is variation in the nanostructure within the layer suggesting major contribution of different effects along the depth during the C60 cluster impacts. In particular, top part of the layer consists of amorphous Si nanodots (NDs) which could be a result of thermal effects. The ND-like nanostructure is likely responsible for enhanced emission and absorption of visible light detected in optical experiments. Analysis of the modification results related to different CIB treatments of Si allowed us to discuss origin of nanostructure of the d-Si layer.

Keywords: Energetic cluster ions, surface, structure modification, amorhpous silicon, nanostructure

*Speaker
†Corresponding author: lavrent@ujf.cas.cz