11th International Conference on Advanced Materials
ICAM 2009
Rio de Janeiro Brazil
September 20 - 25

Ion Beam Applications to Fabricate Nanocomposites for Optical Properties

N. Kishimoto*, B. Zheng, H. Amekura and Y. Takeda

Quantum Beam Center, National Institute for Materials Science,
Tsukuba, Ibaraki 305-0003, Japan, e-mail: KISHIMOTO.Naoki@nims.go.jp
* Corresponding author.

Abstract – Nanocomposites of metal nanoparticles and metal-oxide nanoparticles have been fabricated by heavy-ion implantation combined with laser irradiation and thermal oxidation, respectively. Metal nanoparticle precipitation is effectively controlled by laser irradiation under ion implantation, and exhibits surface plasmon resonance with ultrafast optical response. Metal-oxide nanoparticles are created by post-implantation thermal oxidation, and provide photo-luminescence at room temperature.

Metal nanoparticles embedded in insulators are promising for plasmonics, e.g., ultrafast nonlinear switching or near-field optical waveguides. Metal-oxide nanoparticles in insulators are also attractive for photonics, e.g., luminescent devices or solar cells. Ion implantation is a promising tool to create/control nanoparticles both for the optical devices. Unlike SPM-based nanofabrication, the ion implantation is a robust and efficient method to possibly meet industrial production, having advantage of arbitrary atomic injection with the higher throughputs. Unlike chemical syntheses, the ion implantation provides superb spatial controllability to inject atoms into a solid. However, since the ion implantation methods primarily produce super-saturated solute states of the ion implants, the precipitation control for the particle size and distribution is requisite in addition to the ion implantation, without losing the original advantages.

Here, we introduce novel ion-beam-based methods combining with laser irradiation for metal nanoparticles [1] and with thermal oxidation for metal-oxide nanoparticles [2]. As for the combined laser irradiation, photons of 2.3 eV or 3.5 eV were irradiated into SiO_2, either sequentially or simultaneously with ion implantation of 60 keV Cu^- or 3 MeV Cu^{2+}. Simultaneous photon irradiation of 2.3 eV selectively enhanced nanoparticle precipitation in SiO_2, while sequential photon irradiation tended to dissolve pre-existent nanoparticles. The precipitation enhancement by co-irradiation is due to selective photon absorption by transient defects (STH) under the ion irradiation. Controlling laser irradiation enables us to handle nanoparticle assembly as a building block. Employment of post-implantation thermal oxidation succeeded in creating metal-oxide nanoparticles, such as CuO, Cu_2O, ZnO, etc, embedded in SiO_2. This combined method, i.e., non-equilibrium injection + oxidation, enables us to efficiently create semiconductor nanoparticle composites. These ion-beam-based methods may further lead to the 3D control of nanoparticle assembly.

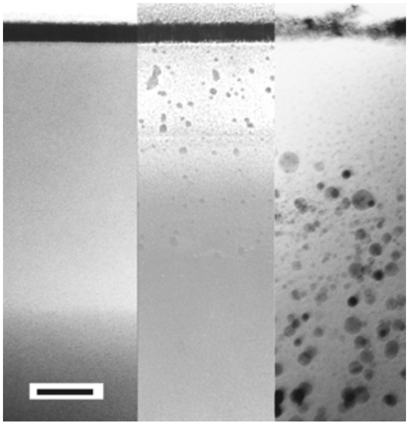

Figure 1: Cross-sectional TEM images of SiO_2 implanted with 3 MeV Cu ions(a), sequentially laser irradiated(b) and simultaneously laser irradiated (c).

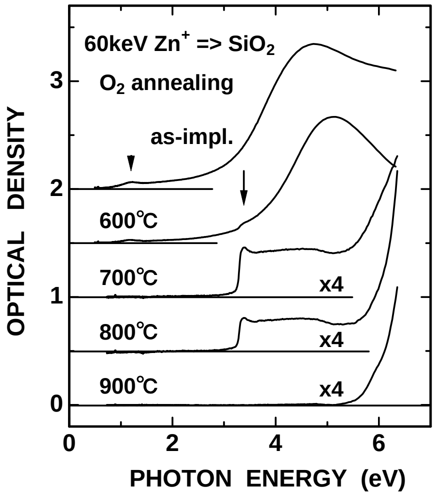

Figure 2: UV-vis absorption spectra of Zn-implanted SiO_2 followed by thermal oxidation at various temperatures.

References

[1] N. Kishimoto, O. A. Plaksin, K. Masuo, N. Okubo, N. Umeda, Y. Takeda, Nucl. Instrum. & Meth. in Phys. Res. B, 242 (2006) 186.
[2] H. Amekura, N. Umeda, H. Boldyryeva, and N. Kishimoto, Ch. Buchal, and S. Mantl, Appl. Phys. Lett., 90 (2007) Art. No. 083102.