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Characterization of Ag-Co metal nanocomplex synthesized by Ag and Co ions implantation into amorphous SiO_2

F. Hori[1*], S. Matsuo[1], R. Tanaka[1], A. Iwase[1], T. Matsui[1], N. Taguchi[2], S. Tanaka[2], S. Semboshi[3]
[1] Osaka Metropolitan University, Sakai, Osaka, 599-8570, Japan
[2] National Institutes of Advanced Industrial Science and Technology, 1-8-31 Midorigaoka, Ikeda, Osaka, 563-0026, Japan.
[3]Tohoku University, Sendai, Miyagi, 980-8577, Japan

1 Introduction

Nanoparticles are known to exhibit unique properties such as photonic, magnetic and chemical properties due to quantum effects caused by discrete energy levels resulting from low crystal periodicity. Moreover, the optical properties of nanoparticles depend on their size, shape, lattice structure, morphology, alloy composition and so on. Therefore, it is necessary to control these parameters to effectively utilize their properties. Ion irradiation into solid materials is one of useful methods to synthesis of nanoparticles with control such parameters.

So far, we have successfully synthesized new functional nanoparticles in glassy solid by using this method [1,2]. Since Ag-Ni alloys do not form solid solutions at room temperature, it is difficult to control the synthesis of composite particles. We found that it is possible to form Ag-Ni nanocomposite by this method [3]. Co-Ag system is known as bulk-immiscible at room temperature. Some research has been carried out to synthesize Co-Ag composite nanoparticles, and they have been reported as materials that exhibit properties such as catalytic activity [4]. We have tried to synthesis of Ag-Co nanocomposites in SiO_2 by Ag and Co ions sequential irradiation and to estimate the structure of formed nanoparticles. In this report, Co and Ag ions sequential irradiation have performed for SiO_2 glass, and the structure and properties of the complexes formed in the glass were investigated.

2 Experimental

Amorphous silica glass (SiO_2: 5 × 5 × 1 mm^3) was used as an implantation target. The target was irradiated with 380 keV Ag ions and 200 keV Co ions at room temperature by using ion implanter at TIARA, National Institutes for Quantum and Radiological Science and Technology (QST-Takasaki). Co ion is irradiated firstly and followed by Ag ion. The implantation energies 200 keV for Co ions and 380 keV for Ag ions were determined as the same projected range of Ag and Co. The irradiation fluence of Ag and Co io n are both 6×10^{16} /cm^2. To estimate the structure of synthesized nanocomposites in SiO_2, these samples were examined by XPS using X-ray at KEK-PF BL27A, grazing incidence X-ray Diffraction (GIXD). Also, the characteristic feature of these samples was measured by scanning TEM with energy dispersive X-ray spectroscopy (EDS) and UV-vis spectroscopy.

3 Results and Discussion

Figure 1 shows the UV-vis absorption spectra of Co, Ag and Co-Ag ions implantation samples. In general, it is known that some metal nanoparticles exhibit absorption peaks in the visible light band due to surface plasmon resonance (SPR) of electrons. In this figure, it can be seen absorption profile for each sample showing that formation of metal nanoparticle. SPR profile of Ag and Co irradiated sample is different from that of Co and Ag single implantation ones, despite implanting the same doses of Ag and Co. This indicates that the structure and electronic states of the formed nanostructures are different. It is clear from XRD results that a structure is formed in the glass, and a structure with an fcc structure has been confirmed in both implantation sequence.

Figure 2 shows STEM-EDS image of fabricated metal nanoparticles in SiO_2 with Co and Ag ions implantation and the distribution of Co and Ag in the part surrounded by the yellow square along the deposition depth direction. In these figures, the Co atoms appear to be distributed in the same positions as the Ag particles, indicating the formation of a Co-Ag complex, which is believed to result in an increase in particle size.

Figures 3 and 4 show that the XPS spectra of Ag and Co-Ag irradiated sample, respectively. The Ag-3$p_{3/2}$ and Ag-3$p_{1/2}$ peaks appear in both samples, indicating that the metal particles are composed of pure Ag-Ag metallic bonds. This result suggests that atoms of Ag contribute to the formation of pure Ag nanostructures with metallic bonds even for Co-Ag implantation. On the other hand, as

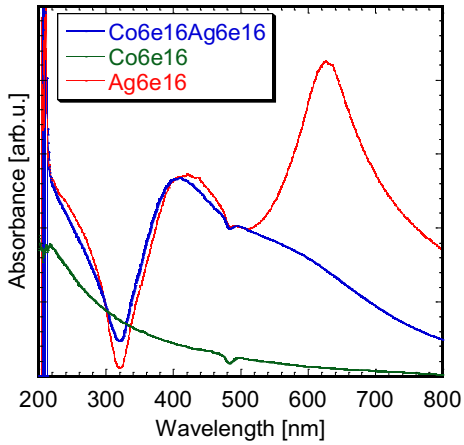

Fig. 1 UV-vis absorption spectra for the Ag, the Co and the Co-Ag implantation sample.

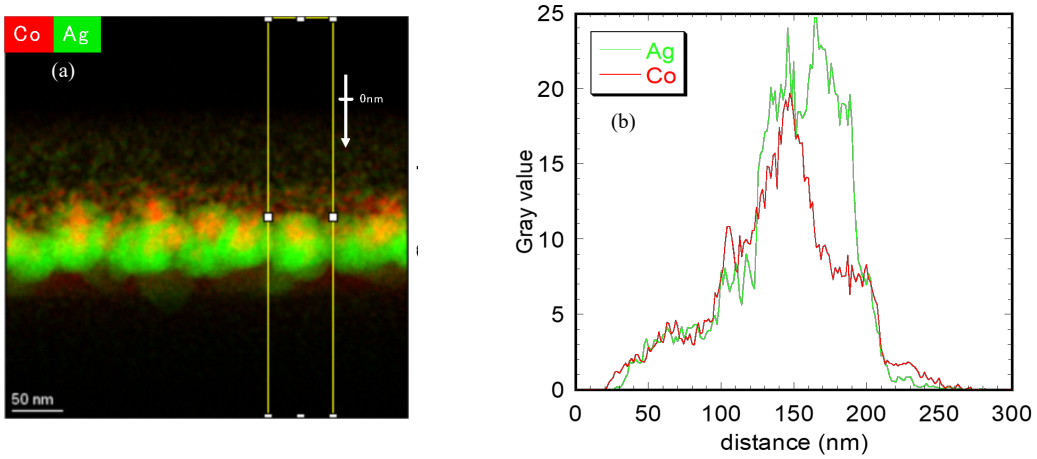

Fig. 2 STEM-EDS image for the Co-Ag implantation sample. (a) Co and Ag distribution in SiO_2 target, and (b) distribution profiles of Ag and Co atoms in the selected area of STEM image.

shown in figure 4, the core level of Co-2$p_{3/2}$ for Co-Co bonding energy slightly shifted for Co and Co-Ag implantation samples, showing not formed pure Co-Co metal bond with hcp structure. This result indicates that the implanted Co atoms do not necessarily form metal clusters with Co-Co bonds, but rather Co oxides or other Co complexes are formed. It is also considered that some of the Co atoms may have diffused and aggregated due to the influence of the Ag ions irradiated later.

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* horif@omu.ac.jp

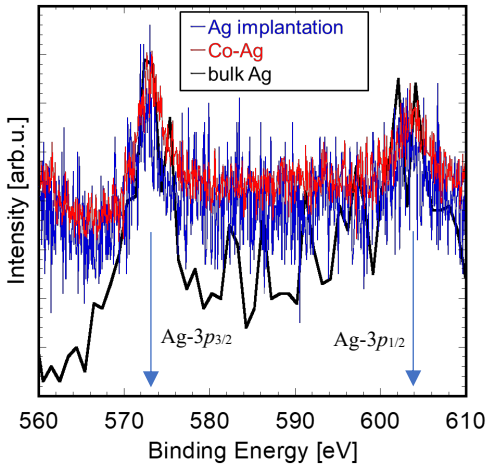

Fig. 3 XPS spectra of Co-Ag implanted SiO_2 focused on the core level of Ag-3$p_{3/2}$ and Ag-3$p_{1/2}$.

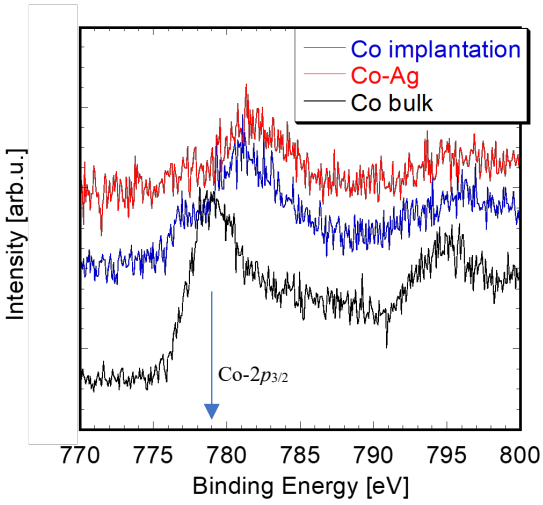

Fig. 4 XPS spectra of Co-Ag implanted SiO_2 focused on the core level of Co-2$p_{3/2}$.