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TEM and Optical Studies of Ni/NiO Nanoparticles in Ni-ion-implanted Al_2O_3

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Metallic nanoparticles embedded in insulators have been extensively studied because of pronounced optical effects, including surface plasmon resonance (SPR) absorption and strong third-order nonlinear optical (NLO) susceptibility [1]. These composites have drawn much attention due to applicability for all-optical-memory or switching devices and single electron transistors [2-4], etc. Therefore, thermal stability of the metallic nanoparticles is practically important, e.g., under laser irradiation in use for optical devices. In our study, the metallic Ni nanoparticles embedded in Al_2O_3 single crystals have been synthesized by ion implantation. The microstructure and optical properties of nanoparticles before and after annealing have been studied.

Metallic Ni nanoparticles in the near surface region of Al_2O_3 single crystals have been synthesized by ion implantation to a fluence of $1\times10^{17}/cm^2$. NiO nanoparticles formed after annealing at 900℃ for 1h in air. Transmission electron microscopy (TEM), X-ray photoelectron spectroscopy (XPS) and optical absorption spectroscopy have been utilized to characterize the nanostructure and optical properties of nanoparticles in Al_2O_3. The TEM images showed that Ni nanopartilces with size ranging 1-5 nm in the near surface of Al_2O_3 grew to NiO nanoparticles with size ranging 6-25 nm after annealing. XPS results proved the charge states of these nanoparticles. A SAD pattern showing Ni nanoparticles with lattice parameter $a = 0.352$ nm. A high-resolution electron microscopy (HREM) image indicated the Ni-implanted area had been entirely amorphized. The amorphous area of Al_2O_3 matrix was partially recrystallized after annealing. A broad absorption band peaked at 400 nm was observed, which was ascribed to the surface plasmon resonance absorption of Ni nanoparticles. After annealing at 900℃, the SPR absorption band disappeared and a UV absorption band peaked at 306 nm due to NiO can be observed.

Reference

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[5] This work was supported financially by the NSAF Joint Foundation of China （10376006）and by Program for New Century Excellent Talents in University.

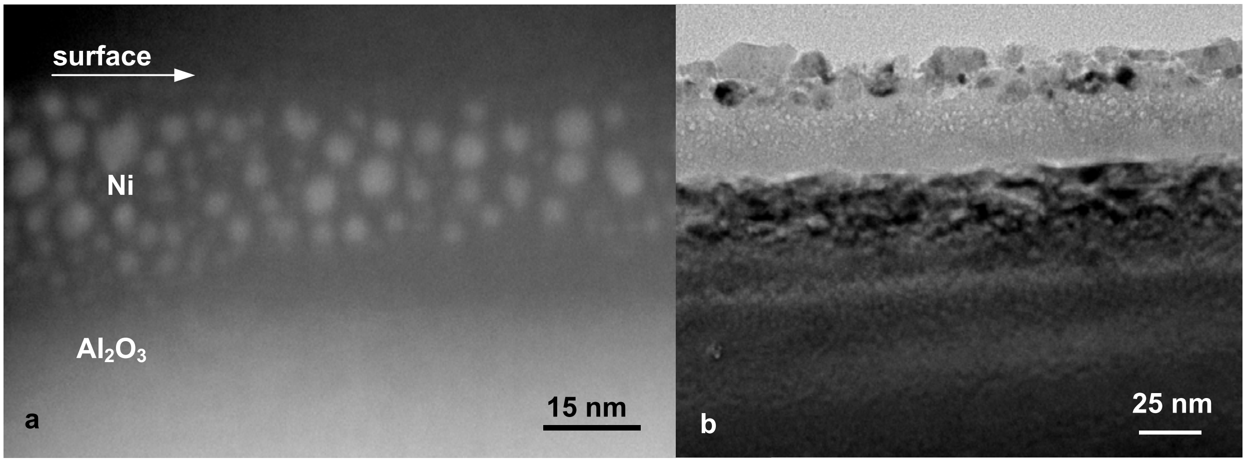

Fig. 1. A HAADF STEM cross-sectional image (a) showing nearly spherical Ni nanoparticles with size of 1-5 nm in diameter in the near surface region of Al_2O_3; A bright-field cross-sectional image (b) showing NiO nanoparticles with size of 6-25 nm formation after annealing at 900℃ for 1h in air.

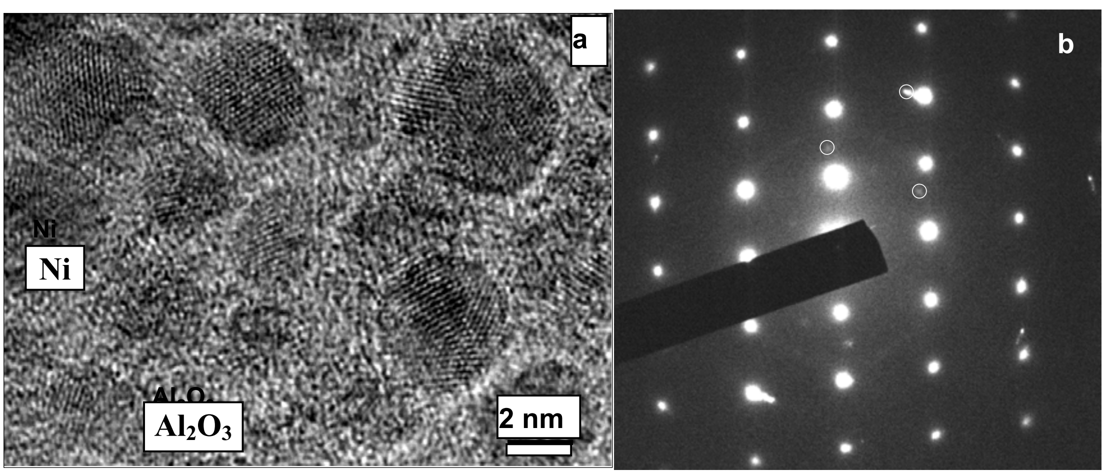

Fig. 2. A HREM image (a) indicating the Ni-implanted area entirely amorphized; A SAD pattern (b) indicating Ni nanoparticles with lattice parameter a = 0.352 nm.

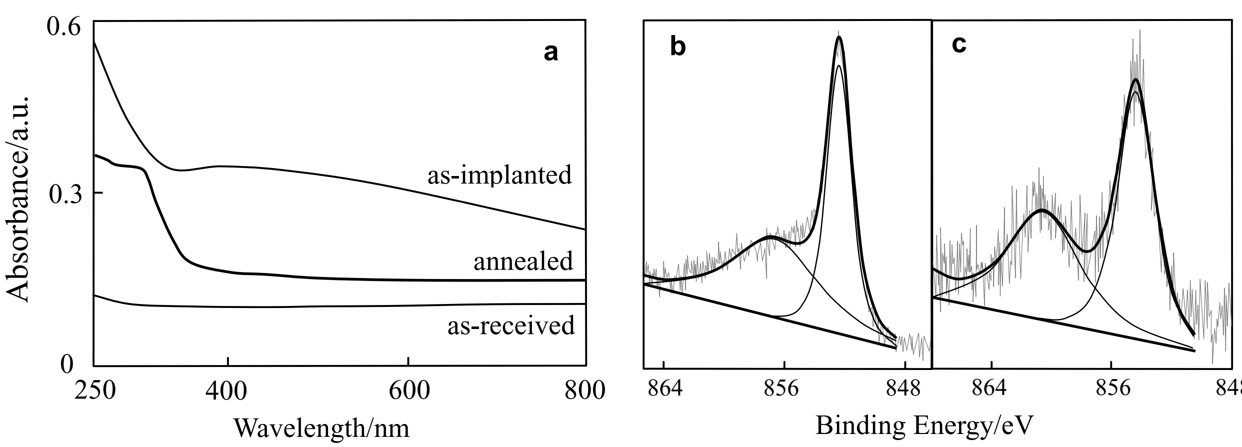

Fig. 3. Absorption spectra (a) showing the SPR band of Ni nanopraticles peaked at 400 nm and the band of NiO nanoparticles peaked at 306 nm; XPS spectra of $Ni_{2p3/2}$ core level showing the charge states of Ni^0 and Ni^{2+} (NiO) before (b) and after (c) annealing, respectively.

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