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Density-Dependent *in situ* Photoemission Spectroscopy of the Zinc-Blende Type MnAs Dots on GaAs (001)

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1. Introduction

Manganese based ferromagnetic thin films such as MnAs and $Ga_{1-x}Mn_xAs$ have recently been epitaxially grown on GaAs substrates using molecular beam epitaxy (MBE). MnAs grows epitaxially onto GaAs in the hexagonal NiAs-type structure [1]. For MnAs/GaAs, the interfaces are thermodynamically stable since the material shares As atoms and the growth process is completely compatible with the existing III-V MBE technology. Another attractive and prospective crystal structure for MnAs is the zinc-blende type structure. Recently, there were several reports on controlling nanoscale structures into zinc-blende type MnAs such as Mn δ doping in GaAs and MnAs/GaAs multiplayer [2,3]. The successful fabrication of the zinc-blende type MnAs nanoscale dots on sulfur-passivated GaAs (001) would open up the opportunities to investigate new spintronic devices. The density dependence of the dots is, however, strongly required to reveal the characterization of the zinc-blende type MnAs because of the high-concentration limit of $Ga_{1-x}Mn_xAs$. Further progress in the research of the zinc-blende type MnAs is expected in the growth of thicker films, as suggested by hypothetical band-structure calculations [4,5]. From this point of view, we have attempted the growth of the zinc-blende type MnAs films by increasing the MnAs dot density and characterized the electronic structure using *in situ* photoemission spectroscopy.

2. Experimental

The nanoscale MnAs dots were fabricated on sulfur-passivated n^+-GaAs (001) substrates by a conventional solid-source MBE. To terminate the surface of GaAs substrates by sulfur, the substrate was first dipped into an $(NH_4)_2S_x$ solution for 1 hour, then rinsed with pure water. The growth temperature of the MnAs dots on the substrate was set to 200 °C. For the investigations of the density dependence of the MnAs dots, we prepared several samples with different dot densities in order of 10^{12} cm^{-2} deduced by the atomic force microscopy (AFM) images. Zinc-blende type structure has been confirmed by transmission electron microscopy (TEM) images. The size of each dot was 10 nm diameter and 5 nm height.

Sample growth and photoemission spectroscopy were performed at beamline 1C using MBE and a GAMMMADATA-SCIENTA SES100 spectrometer. Total energy resolution was about 100 meV since the measurements were done at room temperature. Samples were transferred from MBE to the photoemission chamber under 10^{-10} Torr vacuum to perform '*in situ*' measurements.

3. Results and discussion

Figure 1 shows the density-dependent photoemission spectra of MnAs dots taken at 80 eV photon energy in order to increase the relative photoionization cross-sections of Mn 3d to As 4p. With increasing the dot density, the Fermi edge gradually appears. It suggests that the dots are contacted each other and conductive pass appears by percolation between the dots, resulting in the occurrence of insulator-to-metal transition, which is consistent with AFM observation. Main peaks are located at 4 eV below from the Fermi level and substructures appear around 6 eV for all spectra. Almost the same line shapes of the valence band are obtained except for the Fermi edge. Line shapes are different from that of NiAs-type MnAs films, which suggests the possibility that the MnAs dots form the zinc-blende type structure even after the percolation. Metallic transition also links to the magnetic properties [6]. It is revealed that the metallic samples behave as ferromagnetic, although the samples with dot density less than the percolation density show non-ferromagnetic (superparamagentic) behavior.

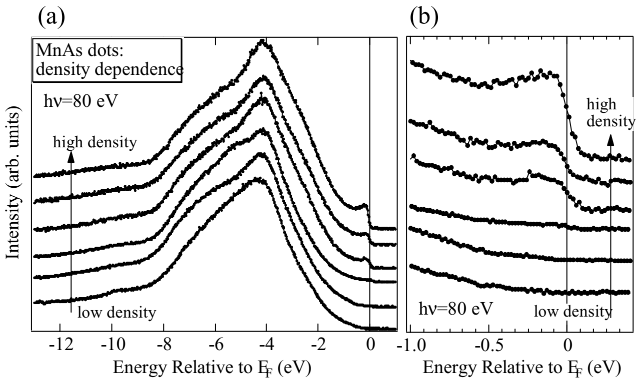

Fig.1, Density-dependet *in situ* photoemission spectra of MnAs nanoscale dots at hν=80 eV. (a) Wide range spectra. (b) Narrow range spectra.

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