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Photoemission study of thermally diffused Mn/GaAs (001) interfaces

Gyongsok Song[1], Yoshitaka Osafune[1], Jongil Hwang[1], Masaki Kobayashi[1], Yasuhiro Ooki[1], Yukiaki Ishida[1], Kazuaki Ebata[1], Atushi Fujimori[1], Ken Kanai[2], Kotaro Kubo[2], Masashi Oshima[2], Jun Okabayashi[2]
[1]Department of Physics, University of Tokyo, 7-3-1, Hongo, Bunkyo-ku, Tokyo, Japan
[2]Department of Applied Chemistry, University of Tokyo, 7-3-1, Hongo, Bunkyo-ku, Tokyo, Japan

1. Introduction

Since the discovery of ferromagnetism in $Ga_{1-x}Mn_xAs$, diluted magnetic semiconductors (DMS's) have been extensively studied because of their potential in spintronics device applications.

Although the Mn doping into GaAs has been achieved by low temperature molecular beam epitaxy (MBE) method, we tried to fabricate $Ga_{1-x}Mn_xAs$ by thermal diffusion method. Already a thermal diffusion of Mn into GaAs and interfacial reaction at Mn/GaAs interface had been reported [1, 2], and they have suggested that anti-ferromagnetic Mn_2As is easy to form at the interface of Mn/GaAs by thick Mn deposition (>10 nm). To avoid the formation of Mn_2As, we have performed very thin deposition of Mn (0.5 nm) and a depth-profile study using photoemission spectroscopy combined with Ar^+-ion sputter etching to investigate the electronic structure of thermally diffused Mn/GaAs along the depth direction.

2. Experimental

Thermally diffused Mn/GaAs (001) was prepared by directly depositing Mn on a single-crystal GaAs substrate. Here, GaAs substrate has been grown by liquid phase epitaxy (Techno Chemics, Inc.). First, clean surface was obtained by 1 kV Ar^+-ion sputter etching followed by 400 °C 10 min annealing. After cleaning, 0.5 nm Mn was directly deposited on the substrate, which depositing rate was ~0.45 nm/min,, followed by post annealing at 600 °C for 10 min. 200 °C annealed sample was prepared as well.

X-ray photoemission spectroscopy (XPS) using a Mg $K\alpha$ source and resonant photoemission spectroscopy (RPES) using synchrotron radiation were performed at BL-18A of Photon Factory (PF). Photoelectrons were collected using a VG CLAM hemispherical analyzer. The total energy resolution including temperature broadening was estimated to be ~ 200 meV for UPS and 800 meV for XPS. For all the measurement, the base pressure was below 3×10^{-10} Torr. Ar^+-ion sputter etching was performed at 1 kV under Ar gas pressure up of 3×10^{-5} Torr. The incident angle of the ion beam was 45 ° from the surface normal.

3. Results and discussions

Comparison of the Mn 2*p* spectrum of Mn/GaAs (001) with those of other Mn compounds is shown in Fig 1. The Peak Position and the intensity ratio of the main peak (~640 eV) and the charge-transfer satellite (~646 eV), which indicate hybridization of Mn 3*d* with ligand As 4*p*, are quite similar to those of $Ga_{1-x}Mn_xAs$ grown by MBE [3].

Next we show the Mn 3*d* partial density of state (PDOS) evaluated from Mn 3*p* - 3*d* RPES in Fig. 2. The Mn 3*d* PDOS has the main peak (~ 5 eV), a broad satellite structure (~10 eV), and a slight intensity near the Fermi energy (E_F) (~1 eV) without a Fermi edge. Like the result of XPS, these features are quite similar to those of $Ga_{1-x}Mn_xAs$ [4], and different from those of Mn_2As [5].

Thus, we suggest that thermally diffused Mn atoms substituted for the Ga site, i.e. $Ga_{1-x}Mn_xAs$ was formed by the thermal diffusion method. Annealing temperature dependence was hardly observed.

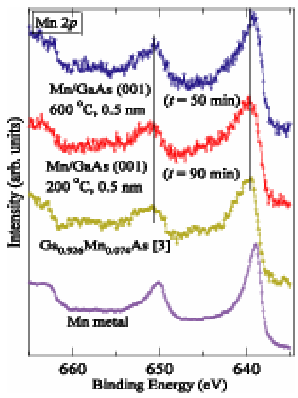

Fig. 1. Mn 2*p* spectrum of Mn/GaAs compared with other Mn compounds.

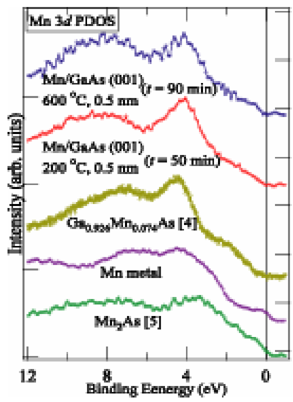

Fig. 2. Mn 3*d* PDOS of Mn/GaAs compared with other Mn compounds.

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*g-s-song@wyvern.phys.s.u-tokyo.ac.jp