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In-situ depth profile resonant photoemission study of GaN:Mn prepared by thermal diffusion of Mn

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Introduction

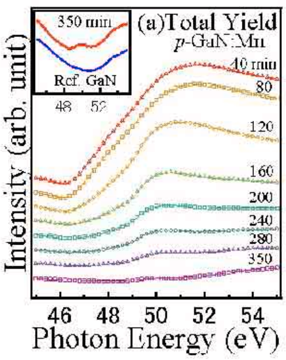
Recent theoretical studies have predicted that Mn-doped GaN shows ferromagnetism with high Curie temperatures. After the theoretical predictions, GaN-based diluted magnetic semiconductors (DMSs) such as $Ga_{1-x}Mn_xN$ have been widely studied experimentally. Although most of $Ga_{1-x}Mn_xN$ samples have been grown by molecular-beam epitaxy, Reed *et. al.* [1] have reported that Mn-doping into GaN was achieved by thermal diffusion method and such a sample showed ferromagnetism. However, the diffusion profile of the sample and its electronic structure have not been studied so far. The investigations of the diffusion profile and the electronic structure are needed to understand the origin of the ferromagnetism in the GaN:Mn samples prepared by thermal diffusion.

We have performed an *in-situ* depth profile photoemission study of GaN:Mn prepared by the thermal diffusion method. 3 nm-thick Mn was deposited on a clean *p*-GaN surface at room temperature. The sample was then annealed at 500 °C for 6 hours. This procedure was done in the photoemission spectrometer chamber and the photoemission measurement was performed *in situ* without exposing the sample to atmosphere. Resonant photoemission spectroscopy (RPES) using synchrotron radiation is a powerful tool to investigate the electronic structure of solids because one can extract the Mn partial density of states (PDOS) from the valence band using the element selectivity of the RPES. The depth profile study has been performed by repeating the RPES and Ar-ion sputter-etching. The sputter-etching rate is 0.2 Å/min

Result and Discussions

Figure 1 (a) shows the depth profile of total electron yield recorded in the Mn 3*p*-3*d* core-excitation region. An absorption edge due to metallic Mn at 46.2 eV was reduced while an edge at 49 eV appeared with sputtering. Comparing the absorption spectrum after 350 min sputtering with that of reference GaN as shown in the inset, it has been revealed that a Mn-derived peak is located at 50 eV

Figure 1 (b) and (c) show valence-band photoemission spectra in the Mn 3*p*-3*p* core-excitation region in the sputtering series. In the spectra for 40 min sputtering (Fig. 1 (b)), a clear Fermi edge was observed with an Auger emission due to Mn $M_{2,3}M_{4,5}M_{4,5}$ as indicated by triangles in the figure. In the spectra for 350 min sputtering, the Fermi edge disappeared and Mn 3*d* resonant photoemission effect without the Auger signal was observed, which rises from interference between the normal photoemission and 3*p*-to-3*d* transition followed by a 3*p*-3*d*-3*d* super-Coster-KrÖnig decay. This indicates that the character of Mn 3*d* states changed from itinerant character to localized one with sputtering. In RPES, because Mn 3*p*-3*d* absorption occurs at photon energies above 49 eV, one can obtain Mn 3*d* PDOS by subtracting the off-resonant spectrum (48.5 eV) from the on-resonance (50 eV) one. The Mn 3*d* PDOS thus obtained is shown at the bottom panel of Fig. 1 (c). The Mn 3*d* PDOS indicates a peak at 5 eV, a shoulder at 2 eV and a satellite structure at 10 eV. The line shape is close to that in MBE-grown $Ga_{1-x}Mn_xN$ [2]. These results suggest that the $Ga_{1-x}Mn_xN$ is formed in the deep region of this sample prepared by thermal diffusion method.



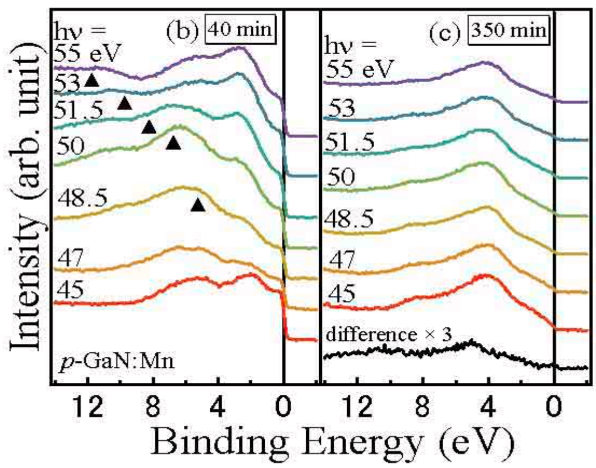


Fig.1 (a) Mn 3p-3*d* total electron yield in depth profile. (b) , (c) Resonant photoemission spectra recorded around Mn 3*p*-3*d* core-excitation threshold.

References

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