C-6

MAGNETIC PROPERTIES OF Cr-DOPED AlN FILMS

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1. Introduction

Diluted magnetic semiconductors (DMSs) are regarded as the key materials for the spin-dependent semiconductor electronics, or spintronic[1,2]. A number of recent works have focused on wide band gap semiconductors as being the most promising ones for achieving high Curie temperature. Following theoretical predictions, many efforts have been made toward DMS with high T_c, and room temperature ferromagnetism has been observed in dope oxides and nitrides such as ZnO, GaN, AlN. The important developments that focused attention on wide band gap semiconductors were the works on the Mn- Cr- doped AlN based on AlN with the band gap of 6.2 eV. In this study, we present the experimental result of the structure and the magnetic properties of the Cr-doped AlN thin films.

2. Experiments

Samples of composition AlCrN were deposited simultaneously on (111) oriented silicon, Corning glass in a reactive DC magnetron sputtering system. The composite target included a high purity (99.999%) aluminum disk with a diameter of 3 inches and a number of square Cr pieces 5 x 5 mm, which were placed symmetrically on the surface of the Al disk. The Cr contents were controlled by varying the number of Cr pieces.

3. Results and Discussion

The x-ray results indicated that the films deposited with 2 and 3 Cr chips (Called samples A and B respectively) were single phase with the hexagonal AlN structure, whereas the film deposited with 4 Cr chips (Called samples C) had the second phase of Cr cluster. The lattice parameters calculated from XRD spectra were a = 3.136 and 3.153 Å, c = 4.958 and 4.942 Å for samples A and B, respectively. It means that the presence of Cr in AlN matrix resulted an increase of a - axis but decrease of c - axis of the hexagonal cell (for AlN, a = 3.114 and c = 4.986 Å). The magnetization of the films grown on Si (111) substrates was measured by VSM system at room temperature. Fig. 2 and 3 shows magnetization as a function of external magnetic field applied parallel to the film plane. The diamagnetic contribution from substrate had been subtracted from data. They exhibit a

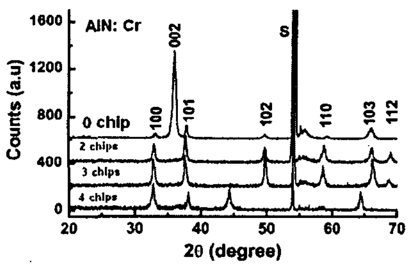

Fig. 1. X-ray diffraction patterns of Samples A, B, C, and an undoped AlN thin film.

conventional ferromagnetic hysteresis loop. The saturated magnetization M_s of the sample A is

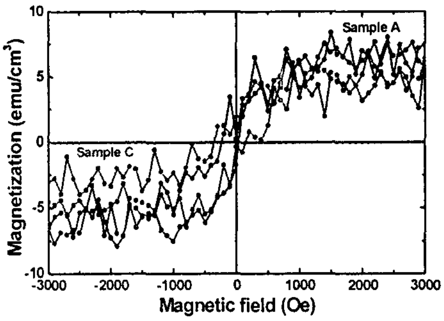

Fig. 2. Hysteresis loop of sample A and B

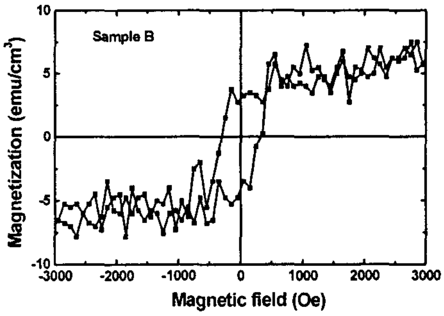

Fig.3. Hysteresis loop of sample B

about 6 emu/cm^3 and the magnetization increases to 8 emu/cm^3 at the sample B and then it decreases to 4 emu/cm^3 at the sample C. It indicates that the increase of Cr above the limitation value hindered rather than helped the ferromagnetic properties in AlN structure. The M_s of sample B is 10 times larger than reported value by Yang *et al.*[3] and it shows that the fraction of Cr atoms, which are magnetically active, is small, less than 20 %. The magnetization and XRD results imply that the doped limit of Cr is 3 chips with this synthesis method.

At present, there seems to be no single theoretical model which can explain the ferromagnetism in all DMS material. The magnetic properties of AlCrN will be explained with band structure calculated by full-potential linear muffintin orbitals.

4. Summary

Single phase AlCrN thin films were obtained. The lattice parameter of the a-axis increased while the lattice parameter of the c-axis decreased with an increase of Cr content. Within the doping limit, the saturated magnetization increased with increasing of Cr content. All the samples shows strongly ferromagnetic properties. The ferromagnetic properties is very strong compared to reported value.

5. Acknowledgement

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6. References

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