PD06

Magnetic and Electrical Properties of Annealed Amorphous $Ge_{1-x}Mn_x$ Semiconductor Thin Films Grown by Thermal Vapor Deposition

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Amorphous $Ge_{1-x}Mn_x$ semiconductor thin films grown by low temperature vapor deposition were annealed, and their electrical and magnetic properties have been studied. The amorphous thin films are 1,000 ~ 5,000 Å thick. Mn concentration of thin films was determined using an energy dispersive X-ray spectroscopy. Amorphous $Ge_{1-x}Mn_x$ semiconductor thin films were annealed at 300℃, 400℃, 500℃, 600℃ and 700℃ for 3 minutes in high vacuum chamber. Structural analysis was carried out by using an X-ray diffractometer and a transmission electron microscope. Surface morphology was examined by using an atomic force microscope. The electrical properties were measured using a Hall effect device and a standard four-point probe. Magnetization characteristics were analyzed by using a magnetic property measurement system. X-ray diffraction analysis reveals that as-grown $Ge_{1-x}Mn_x$ semiconductor thin films are amorphous and are crystallized by annealing. Crystallization temperature of amorphous $Ge_{1-x}Mn_x$ semiconductor thin films varies with Mn concentration. Amorphous $Ge_{1-x}Mn_x$ semiconductor thin films have p-type carriers and the carrier type is not changed during annealing, but the electrical resistivity increases with annealing temperature. Magnetization characteristics show that the as-grown amorphous $Ge_{1-x}Mn_x$ thin films are ferromagnetic and the Curie temperatures are around 130K. Curie temperature and saturation magnetization of annealed $Ge_{1-x}Mn_x$ thin films increase with annealing temperature. Magnetization behavior and X-ray analysis implies that formation of ferromagnetic Ge_3Mn_5 phase causes the change of magnetic and electrical properties of annealed $Ge_{1-x}Mn_x$ semiconductor thin films.

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PD07

Magnetic Properties of Self-organized InMnAs Nanodots

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Epitaxial-grown InAs quantum dots have attracted lots of interests because of their controllable morphology and self-assembling ability [1]. Recently, Mn-doped InAs quantum dots grown by MBE have been reported to have a room-temperature ferromagnetism [2]. However the magnetic properties of InMnAs nanodots, whose morphology can be well controlled by growth condition, still need further investigation.

In the present work, $In_{1-x}Mn_x$ As (x=0.12-0.40) nanodots with a maximum height at 5nm-50nm were grown on (001) semi-insulating GaAs substrates by MBE with a substrate temperature (T_s) at 350-400℃. The surface reconstruction of the samples during growth was monitored in situ with the reflection high-energy electron diffraction (RHEED). The RHEED pattern changed from a 2×4 streaky pattern for high-temperature GaAs buffer to a 1×1 spotty pattern for InMnAs nanodots. Surface morphology was investigated by both AFM (Fig. 1) and FE-SEM.

Magnetic properties were measured by a DC-SQUID magnetometer. For most of the samples, two Curie temperatures are detected from the M-T curves. According to the Stranski-Krastanov growth mode, the two magnetic phase transitions are considered as the Curie temperature of 2D growth mode (T_{cL}) and 3D growth mode (T_{cH}), respectively (shown in Fig. 2). T_{cL} is found to be quite independent on Mn doping and surface morphology, and it is about 45K. The stableness of T_{cL} can be explained with the limit of dissolving for Mn in epitaxial-grown InAs. For the samples with enough Mn doping, T_{cH} is also quite stable (about 310K). However when Mn doping is as few as 20%, TcH can decrease to 260K.

AFM and SEM images indicate that T_s is the key to the morphology. At relative lower T_s, the average size of the nanodots is smaller and the density is higher. In this case, the M-T relation is similar to that of thin film. And at relative higher Ts, the average size is much larger, and the average distance between dots are much larger. In this case, the M-T relation shows a *spin-glass-like behavior.*

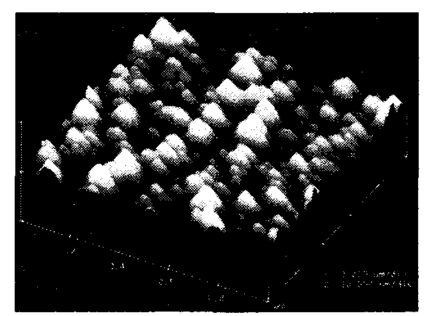

Fig. 1. AFM image of sample 2.

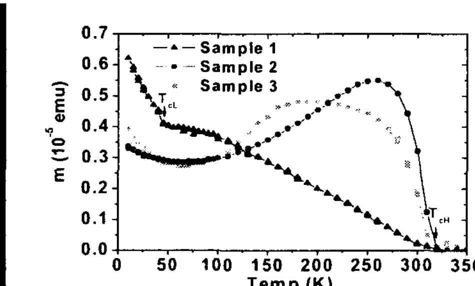

Fig. 2. M-T curves of three samples with different morphologies.

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