T-1

Magnetic and transport properties of n and p-type-doped Mn_xGe_{1-x} single crystals

Sungyoul Choi, Jeongyong Choi, Jiyoun Choi, Soon Cheol Hong, and Sunglae Cho

Department of Physics, University of Ulsan, Ulsan, 680-749, South Korea

Chi-Un Jung and K. Rhie

Dept of Physics, Korea Univ., Chochiwon, 339-700, South Korea

Yongsup Park, Kyu-Won Lee, and Hyun-Min Park

Materials Evaluation Center, Korea Research Institute of Standards and Science,

Taejeon, 305-600, South Korea

1. Introduction

Recently, Mn substitution has yielded ferromagnetism in germanium, a group IV semiconductor with a band gap of 0.65 eV (at 300 K), with T_c = 116 K in an MBE-grown film [1] and 285 K in bulk single crystal [2]. And, Cr_xGe_{1-x} (x=0.01) showed ferromagnetic ordering at 126 K [3]. Here we report magnetic and transport properties of *n* and p-type doped Mn_xGe_{1-x} single crystals.

2. Experiment

Single crystals Mn_xGe_{1-x} were prepared from high-purity (99.999%) germanium (Ge), manganese (Mn), and arsenide (As) powders as with particle sizes < -200 mesh to maximize the surface area and thereby enhance the reaction kinetics. First, the powders were weighed and loaded into thick walled quartz ampoules. The ampoules were then evacuated (<10^{-6} Torr) and sealed. After encapsulation, the sealed ampoule was mixed, loaded into a vertical furnace (using the vertical gradient solidification method), and heated slowly to form single phase. The ampoule was heated to 1050 ℃ at 30 ℃/h followed by a 170 h-soak. For single crystal

growth, the temperature was slowly cooled at 1 ℃/h to a point below the melting temperature (937 ℃for Ge) and thereafter at 100 ℃/h. We used Ga and As as n and p-type dopants, respectively, for Mn_xGe_{1-x} crystals.

3. Results and Discussions

The lattice constant increases linearly with Mn concentration due to the larger Mn atomic radius compared with Ge, strongly indicating that Mn ions are being incorporated into the host Ge lattice. $Ge_{0.94}Mn_{0.06}$ showed antiferromagnetic (AFM)-ferromagnetic (FM) and FM-paramagnetic (PM) transitions at ~ 150 and 285 K, respectively. We have also fabricated n-type (~$1x10^{18}cm^{-3}$) $Ge_{0.95}Mn_{0.05}$ single crystal with As addition. $Ge_{0.95}Mn_{0.05}$:As showed FM-PM transitions at ~ 289 K, as determined from temperature dependent magnetization and resistance measurements. Interestingly, at the low temperature FM was observed. The coersive fields were 328 and 646 Oe at 5 and 250 K, respectively. We will also discuss the magnetic and transport of Ga-doped p-type Mn_xGe_{1-x}.

4. Reference

1. Y. D. Park, A. T. Hanbicki, S. C. Erwin, C. S. Hellberg, J. M. Sullivan, J. E. Mattson, T. F. Ambrose, A. Wilson, G. Spanos, and B. T. Jonker, Science 295, 651 (2002).
2. S. Cho, S. Choi, S. C. Hong, Y. Kim, J. B. Ketterson, B. J. Kim, Y. C. Kim, and J. H. Jung, Phys. Rev. B 66, 033303 (2002).
3. S. Choi, S. C. Hong, S. Cho, Y. Kim, J. B. Ketterson, C. U. Jung, K. Rhie, B. J. Kim, and Y. C. Kim, Appl. Phys. Lett. 81, 3606 (2002).