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Epitaxial MnP thin films: epitaxial growth, magnetic and electrical properties

Jeongyong Choi[a], Sungyoul Choi[a], M.H. Sohn[b], Hyoyeol Park[c], Yongsup Park[d], Hyun-Min Park[d], S.C. Hong[a], Sunglae Cho[a,e,*]

[a]*Department of Physics, University of Ulsan, San 29, Muger 2-dong, Ulsan, 680-749, South Korea*
[b]*Korea Electrotechnology Research Institute, 28-1, Seongju-dong, Changwon, Kyongnam, 641-120, South Korea*
[c]*Department of Semiconductor Application, Ulsan College, Ulsan, 680-749, South Korea*
[d]*Korea Research Institute of Standards and Science, Yuseong Daejeon, 305-600, South Korea*
[e]*Nanodevice Research Center, Korea Institute of Science and Technology, Seoul 136-791, Republic of Korea*

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Abstract

We have grown 500 Å MnP on undoped GaAs(1 0 0) substrate using solid-source molecular beam epitaxy. In order to characterize the crystal structure of MnP, we performed in-situ reflection high energy electron diffraction and θ–2θ XRD X-ray diffraction studies. From the measurements of superconducting quantum interference device, Quantum Design, MnP thin film shows ferromagnetic ordering at around 291.5 K. It shows a metallic resistivity in MnP thin film.

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Keywords: MnP thin film; Lifshitz; MBE (molecular beam epitaxy)

1. Introduction

For the past many decades, MnP has been widely studied because of its unique magnetic properties. It is known that a single crystal of MnP, which has a strong magnetic anisotropy, has helicoidal magnetic ordering below 47 K and ferromagnetic (FM) ordering between 47 K and $T_C = 291.5$ K [1,2]. Furthermore, MnP has the Lifshitz point where paramagnetic, ferromagnetic, and helicoidal phases meet [3]. The Lifshitz point which has various magnetic properties has been extensively studied [4].

The crystal structure of MnP is orthorhombic with lattice constants of $a = 5.916$ Å, $b = 5.260$ Å, and $c = 3.173$ Å, which is distorted from the NiAs-type hexagonal crystal structure [1]. Up to now, the single crystals of MnP which was grown by the Bridgman method have been used for physical property study [1,5–7].

In this article, we report on the epitaxial growth of MnP thin films using solid source MBE (molecular beam epitaxy) and its magnetic and electrical properties.

2. Experiment

We have grown MnP thin film directly on semi-insulating GaAs(1 0 0) substrate by MBE. Standard and cracking effusion cells are used for Mn and P evaporations, respectively. The growth was monitored with RHEED (reflection high energy electron diffraction). The growth temperature of MnP was 500 °C and growth rate of Mn was 0.25 Å/s under phosphorus ambience. We have grown 500 Å MnP thin film. The crystal structure of the grown film was investigated using XRD (Model D/max-RC, Rigaku Co., Tokyo, Japan) measurement.

*Corresponding author. Department of Physics, University of Ulsan, San 29, Muger 2-dong, Ulsan, 680-749, South Korea.
Tel.: +82 52 259 2322; fax: +82 52 259 1693.
E-mail address: slcho@mail.ulsan.ac.kr (S. Cho).

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3. Result and discussion

Fig. 1 shows the logarithmically scaled θ–2θ XRD pattern of MnP thin film grown on GaAs(1 0 0) substrate.

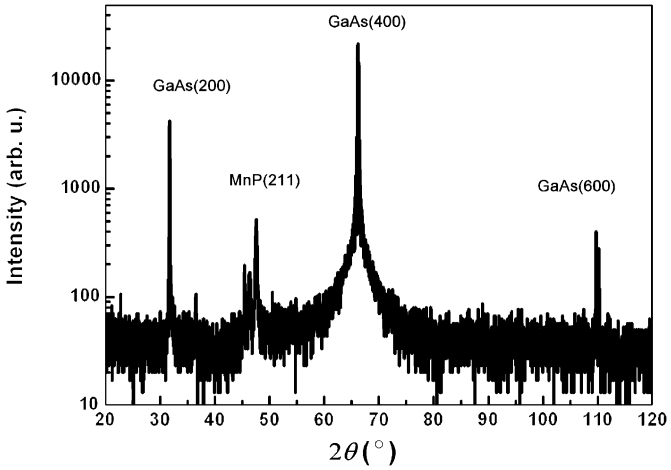
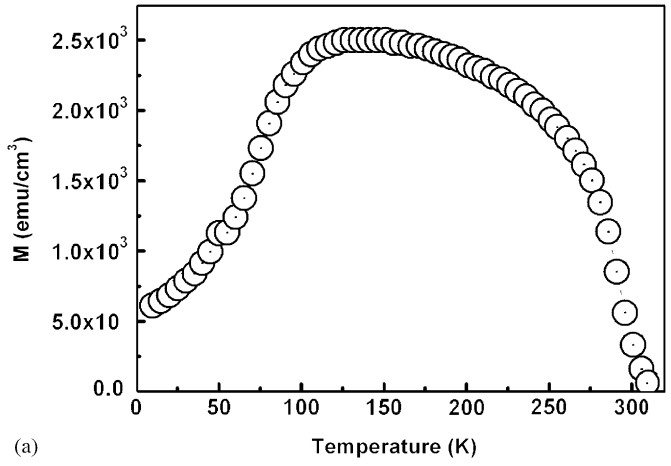
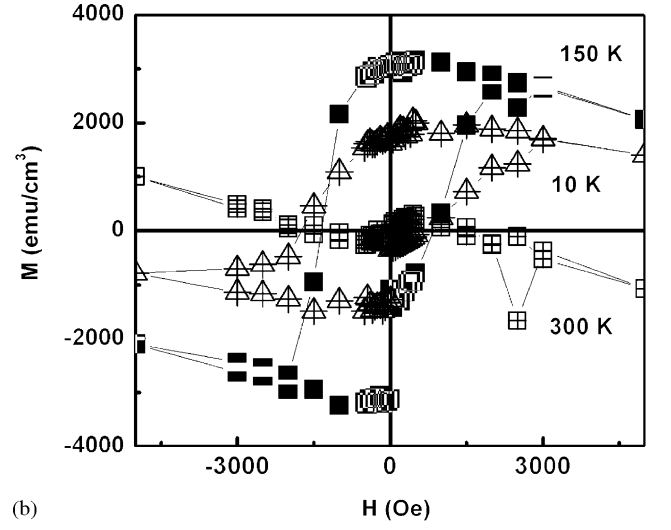


Fig. 1. XRD pattern of MnP thin flim.



(a)



(b)

Fig. 2. (a) M–T and (b) M–H curves of MnP thin flim.

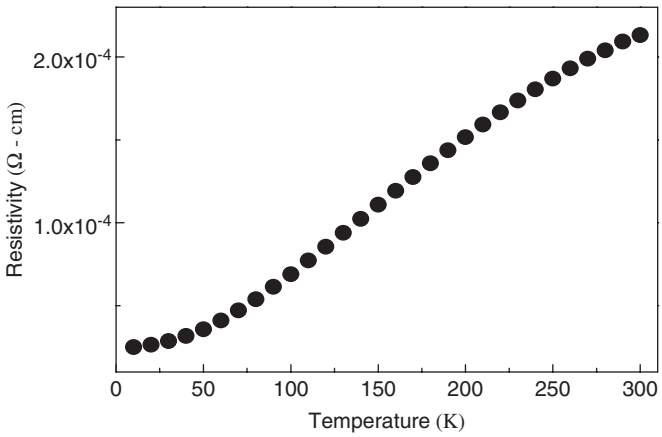


Fig. 3. Temperature-dependent resistivity of MnP thin film.

GaAs substrate peaks and MnP peak are observed without any other secondary peaks. The growth direction of MnP on GaAs(1 0 0) substrate was (2 1 1).

We have investigated the magnetic properties using MPMS (magnetic property measurement system, Quantum Design Inc.). MnP thin flim has FM ordering at around 300 K, as shown in Fig. 2. Interestingly, we have observed a slight magnetization (M) change below 100 K and a FM ordering below 47 K, which is similar with the reported helicodal magnetic data below 47 K in bulk MnP [1,2]. The change of transition temperature between FM and helicoidal magnetic states from 47 to 100 K may be caused by strain due to lattice mismatch between epitaxial MnP film and GaAs substrate.

We have observed a metallic temperature dependent resistivty data in MnP thin film with the negative magneto-resistances, determined from PPMS (physical property measurement system, Quantum Design Inc.), as shown in Fig. 3. Electrical resistivity increases with temperature. MnP has an electronic structure of the metal.

4. Conclusion

We have grown the epitaxial MnP thin films on semi-insulating GaAs(1 0 0) substrate using solid-source MBE system. FM ordering was observed below about 300 K. Helicoidal magnetic state was observed at low temperature. MnP flim has a metallic resistivity data.

Acknowledgements

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