Growth and characterization of phosphorus-doped ZnTe thin films by MBE

Saga University: Muhamad Mustofa, Katsuhiko Saito, Qixin Guo, Tooru Tanaka.
E-mail: 20720901@edu.cc.saga-u.ac.jp

1. Introduction

Multiband or intermediate band solar cell (IBSC) is viable approach to achieve high solar power conversion efficiencies [1]. Highly mismatched $ZnTe_{1-x}O_x$ (ZnTeO) alloy becomes one of the potential candidates for an absorber material in IBSC because a narrow, O-derived intermediate band (IB (E_-)) is formed well below the conduction band (CB (E_+)) edge of the ZnTe [2]. To increase the efficiency of solar cell, not only the multiband layer but also the other layer in solar cell structure needs to be improved, and especially the conductivity control of *p*-type ZnTe epitaxial layer is important. A *p*-type doping using nitrogen (N) radical during the growth by molecular beam epitaxy (MBE) has been reported, which has achieved high hole concentration more than 1×10^{20} cm^{-3} [3]. However, the controllability at low hole concentration is poor even though that is important to increase carrier collection efficiency. On the other hands, phosphorus (P) is expected as a good candidate since moderate hole concentration of 1.3×10^{18} cm^{-3} is achieved by P doping in metalorganic vapor phase epitaxy, showing a relatively shallow acceptor level at 63.5meV [4]. So far, we have found that P is not incorporated by the MBE growth of ZnTe using P_4 molecular beam. Therefore, in this study we investigated the MBE growth of P-doped ZnTe using InP as dopant source where P is supplied as P_2 molecular beam.

2. Experiment

P-doped ZnTe thin films were grown by MBE on Ga-doped ZnTe (100) substrates using InP as P source. The substrate temperature (T_{sub}) was set at 400 °C. The InP flux was changed from 10^{-5} Pa to 10^{-4} Pa, and the effect of the cap added on InP cell was investigated to avoid the In incorporation. The samples were also annealed at 300 °C for one hour in nitrogen ambient. Photoluminescence (PL) and secondary ion mass spectroscopy (SIMS) were performed to characterize the samples.

3. Results and discussion

Fig. 1 shows the PL spectra before and after annealing of P-doped ZnTe thin films grown with InP flux of 1×10^{-4} Pa. A sharp peak corresponding to an acceptor bound exciton peak (I_a) is observed at around 2.37 eV in both as-grown and annealed samples. The intensity of I_a emission increases after the annealing at 300°C for 1 hour, indicating the activation of P acceptor. Fig. 2 shows the SIMS result of P-doped ZnTe thin films grown under different InP beam flux. P was detected in the sample but the concentration was relatively unchanged with small increasement of InP flux.

[1] A. Luque et al, Phys. Rev. Lett. 78 (1997) 5014.　[2] K. M. Yu et al. Phys. Rev. Lett. 91 (2003) 246403.
[3] L. Zhang et al. Mat. Sci. Semicon. Proc. 29 (2015) 351. [4] T. Tanaka et al. J. Cryst. Grow.th 298 (2007) 437.

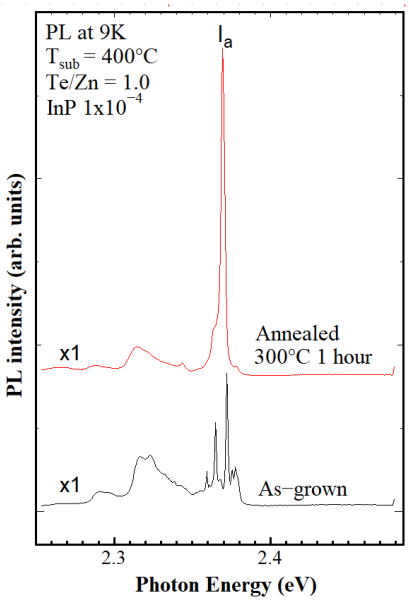

Fig. 1 PL spectra at 9 K for P-doped ZnTe thin films before and after annealing.

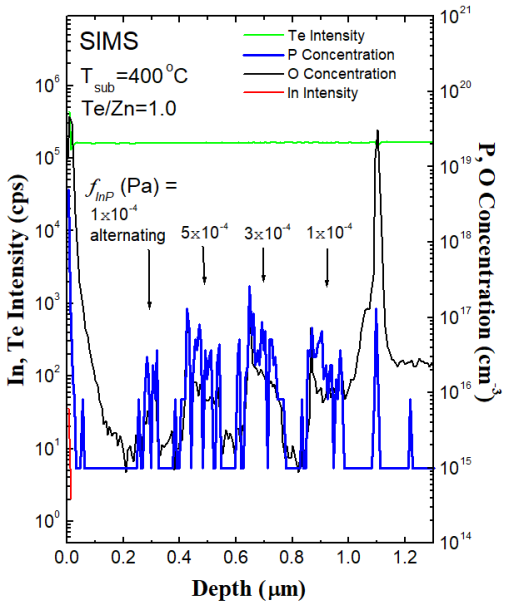

Fig. 2 SIMS result on P-doped ZnTe thin film grown under different InP beam flux.