Investigation of Large Thermopower of $Ga_{1-x}Mn_xAs$

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$Ga_{1-x}Mn_xAs$ is a kind of dilute magnetic semiconductors and shows ferromagnetism despite its low Mn concentrations, so that the mechanism of ferromagnetism had been attracted for decades. Some models, for instance, p-d Zener model[1] and double exchange model[2], has been proposed to explain ferromagnetism, but several experiments reported that these Fermi level positions conflicted with each other. We remarked large thermopower of $Ga_{1-x}Mn_xAs$ in the low temperature region (8-100K)[3] in this study. Normally, thermopower of semiconductors become large because of phonon drag while high carrier density causes decrease of it due to density saturation effect. However $Ga_{1-x}Mn_xAs$ shows high thermopower about 1mV/K despite its high carrier density of $10^{20}/cm^3$ orders. We aimed to examine this unique behavior by comparing experimentally measured thermopower of $Ga_{1-x}Mn_xAs$ with numerical calculated thermopower. We used phonon drag thermoelectric theory[4] as well as conventional diffusion thermopower theory for calculations of $Ga_{1-x}Mn_xAs$ thermopower(Fig1). In this study, the electron structure is considered based on k-p perturbation taking account of p-d exchange interaction. To investigate the cause of the large thermopower of $Ga_{1-x}Mn_xAs$ may help to reveal the electronic structure because thermopower reflect the detailed electronic structure.

$Ga_{1-x}Mn_xAs$ samples (x=0.058 and 0.081) were grown by low-temperature molecular-beam epitaxy changing Mn and carrier density. The carrier density was varied by Sn doping during sample growth. Mn density was estimated by the lattice constants obtained X-ray diffraction measurement. Sample thickness was typically 40 nm and 1×10mm Hall bar was processed for thermopower measurements. Fig2 shows measured temperature dependence of thermopower of our samples. It indicate that high carrier density saturation effect and peak shift to lower temperature as Mn density becomes thick. Although, experimentally obtained behaver is qualitatively similar to that shown in Fig1. The main factor of $Ga_{1-x}Mn_xAs$ large thermopower will be discussed.

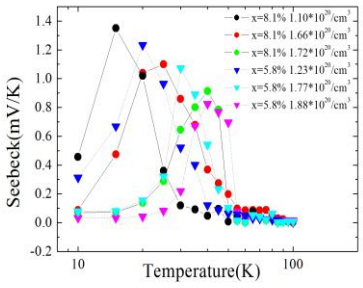

Figure 1 Calculated thermopower of Mn density x=0.058 and 0.081. Carrier density is changed to corporate with experiment.

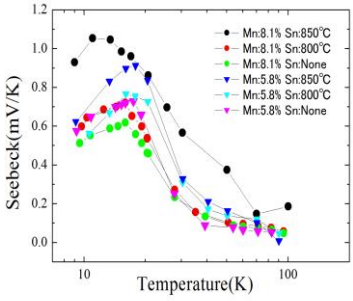

Figure 2 Thermopower of Sn doped $Ga_{1-x}Mn_xAs$(x=0.058, 0.081).

Table 1 Sample carrier density

sample	carrier density(cm^{-3})
Mn8.1% Sn None	$1.72*10^{20}$
Mn8.1% Sn800℃	$1.66*10^{20}$
Mn8.1% Sn850℃	$1.10*10^{20}$
Mn5.8% Sn None	$1.88*10^{20}$
Mn5.8% Sn800℃	$1.77*10^{20}$
Mn5.8% Sn850℃	$1.23*10^{20}$

Reference

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[2] S. Ohya, Nature Phys. **7**, 342–347 (2011)

[3] C. M. Jaworski, PRL **106**, 186601 (2011)

[4] C. Herring, Phys.Rev **96**, 5, (1954)