The Spin Hall Effect of the Gapless Semiconductor $PbPdO_2$

이규준*, 추성민, 김수현, 최창호, 송기명[1], 허남정[1], 이성익, 정명화
서강대학교 물리학과
[1]인하대학교 물리학과

1. Introduction

After the discovery of the giant magneto-resistance(GMR) phenomenon, the interest in spintronics have increased. For a good material in spintronics application, the material should have a long mean free path and high spin polarization. These conditions for the spintronic materials are only partially satisfied by half-metals and magnetic semiconductors. A half-metal has a high spin polarization but due to its short mean free path, its application to spintronics is not so good. On the other hand the magnetic semiconductor has a long mean free path but it has a poor spin polarization. For this reason, the gapless semiconductor is a highly promising material for spintronics. For gapless semiconductors Hg-based compounds were mostly used, but due to their high toxicity and easy oxidation they were hard to use. X. L. Wang proposed in his paper a new kind of oxide gapless semiconductor, $PbPdO_2$.[1] In this work we are going to discuss the properties of the gapless semiconductor $PbPdO_2$. Additionally properties of the Co-doped material will be discussed also with the spin Hall effect of the spin gapless semiconductor.

2. Experiment

A polycrystalline sample of the $PbPdO_2$ was prepared by sintering high purity powders of PbO and PdO. Prepared powders were mixed up by using a mortar and was made in a pellet. The PbO and PdO were prepared according to their mole proportion with 10 mole% access of the PbO, because of the volatility of the lead. The pellet was sintered at 700 °C for 12 hours. The sintering and mixing process was repeated for 3 times. The $PbPd_{0.9}Co_{0.1}O_2$ sample was prepared in the same manner. The prepared samples were characterized with the X-ray diffraction. The specific heat and electrical resistivity of the two samples were taken by the physical property measurement system (PPMS, Quantum Design). The magnetic moment of the samples were taken by using the magnetic property measuring system (MPMS: Quantum Design).

3. Result and discussion

The electrical resistivity data of the pure and Co-doped $PbPdO_2$ are as seen in Fig. 1. The resistivity shows a metal-insulator-like transition. The resistivity decreases as the temperature decrease. At about 100 K the $PbPdO_2$ shows an increase in resistivity. The $PbPd_{0.9}Co_{0.1}O_2$ shows an increase in resistivity at 150K. In order to see that if this is truly a metal-insulator transition, we measured the specific heat which is not shown here. The specific heat shows no anomaly at the temperatures where the resistivity changes its slope, which can be an evidence of a gapless semiconductor.

The magnetization data are as shown in Fig. 2. The magnetic moment vs. magnetic field graph shows a ferromagnetic component in a diamagnetic and paramagnetic background for the $PbPdO_2$ and $PbPd_{0.9}Co_{0.1}O_2$, respectively. We propose that the ferromagnetic component originates from high spin orbit coupling, which can be manifested in the magnetoresistance data.

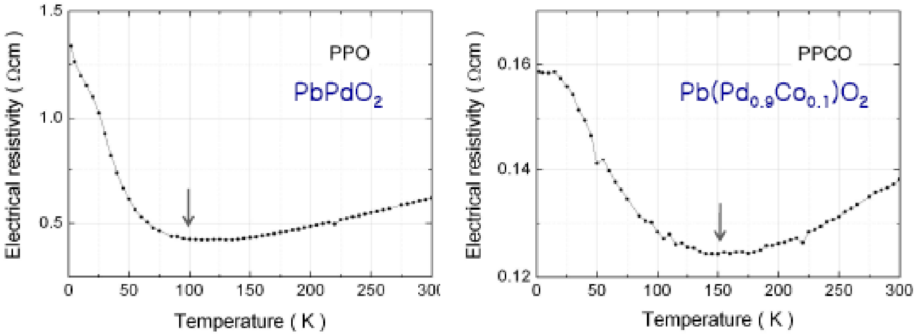

Fig. 1. Electrical resistivity versus temperature of $PbPdO_2$ and $PbPd_{0.9}Co_{0.1}O_2$.

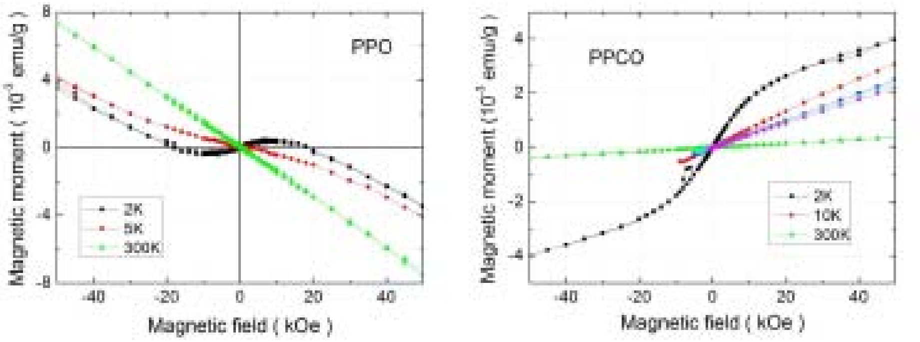

Fig. 2. Magnetic moment versus applied magnetic field of $PbPdO_2$ and $PbPd_{0.9}Co_{0.1}O_2$.

4. Conclusion

The $PbPdO_2$ and the $PbPd_{0.9}Co_{0.1}O_2$ are interesting materials with a promising future in the spintronics application. The possibly high spin-orbit coupling may let us observe the spin Hall-like effect. In this work we observed some properties of the $PbPdO_2$ and $PbPd_{0.9}Co_{0.1}O_2$, which showed evidence of an gapless semiconductor with ferromagnetic component as a result of strong spin-orbit interaction. Further research will be done on these materials to seek for new interesting phenomena.

5. Reference

[1] X. L. Wang, Phys. Rev. Lett. 100, 156404 (2008).