CC08

Magnetoresistance and Hall Effect in Spin-Polarized Two-Dimensional Electron Gas with Spin-Orbit interaction

T. Kato[1], Y. Ishikawa[1], H. Itoh[2], and J. Inoue*[1]
[1]Department of Applied Physics, Nagoya University, Nagoya 464-8603, Japan
[2]Department of Pure and Applied Physics, Kansai University, Suita 564-8680, Japan
*Corresponding author: inoue@nuap.nagoya-u.ac.jp, Phone: +81 52 789 4445, Fax: +81 52 789 3298

The spin-orbit interaction (SOI) in semiconductors allows optical and electrical controls of spins, and because of this has recently attracted much attention in the field of spintronics. The SOI gives rise to unusual Hall effects, such as the anomalous Hall effect (AHE) and anisotropic magnetoresistance (AMR) in ferromagnets, and spin Hall effect (SHE) in normal conductors.

The intrinsic (uniform) spin-orbit interaction (SOI), such as Rashba type in two-dimensional electron gas (2DEG) gives rise to interesting spin-dependent transport phenomena. Theoretical prediction of a universal spin Hall conductivityin Rashba-split 2DEG has attracted much attention [1], however, it vanishes identically in the diffusive transport regime [2]. The theory indicates the importance of the vertex corrections to the conductivity in the presence of impurity scattering of conduction electrons, and suggests re-examination of the other spin-dependent transport properties induced by the intrinsic SOI.

We analyse the anomalous Hall conductivity (AHC) and anisotropic magnetoresistance (AMR) in the diffusive transport regime by introducing ferromagnetic exchange splitting into Rashba-split 2DEG. The Kubo formula is adopted, and the vertex corrections to the longitudinal and Hall conductivities are self-consistently calculated in the Born and ladder approximations.After obtaining full expressions of the conductivities, results have been obtained by numerical integration over momentum. Analytical expressions for AHC and AMR have also been obtained by expanding up to the second order of SOI. We have also performed numerical simulation for AMR in which tight-binding model is adopted for 2DEG with SOI. The conductivity has been estimated by changing the size of sample region in the simulation.

It is shown that AHC vanishes identically unless the life-time is spin-dependent. The result is brought about by a cancellation of the non-vertex part of AHC by the vertex part, and shows striking similarities between AHE and SHE [3]. When a spin dependent life-time is introduced, we find finite AHC being proportional to the square of the difference between up and down spin life-times. Experimental analysis of the AHE in the magnetic semiconductors may be re-examined in view of the present results.

The AMR shows the same feature with AHC since it vanishes identically when the life-time is spin-independent. The numerical simulation, in which random potentials are treated exactly, shows the same results.

Summarizing the results, we may conclude that the AHE, SHE and AMR have the same feature that they vanishes unless the life-time is spin-dependent in the diffusive transport regime. Results obtained in the present work may give deeper understanding of AHE and AMR caused byintrinsic SOI.

We acknowledge financial support from the Next Generation Super Computing Project, Nanoscience Program, and the 21st Century COE Program "Frontiers of Computational Science".

REFERENCES

[1] J. Sinova et al., Phys. Rev. Lett. **92**, 126603 (2004).
[2] J. Inoue et al., Phys. Rev. B **70**, 41303 (2004).
[3] J. Inoue et al., Phys. Rev. Lett. **97**, 046604 (2006).

CC09

Magnetism of Linear Fe, Co, and Ni Nanowires Encapsulated in Zigzag (n, 0) Carbon Nanotubes (CNT) with n=5 to 9: A First-Principles Study

Y.-R. Jang[1]* and J. I. Lee[2]
[1]Department of Physics, University of Incheon, Incheon 402-749, Korea
[2]Department of Physics, Inha University, Incheon 402-751, Korea
*Corresponding author: yrjang@incheon.ac.kr, Phone: +82 32 770 8227, Fax: +82 32 766 8018

The interaction between carbon nanotubes (CNT) and transition metal (TM) atoms has been studied in relation to the formation of continuous nanowires (NW) on the CNT [1]. It is expected that the ferromagnetic NW surrounded by the CNT can be effectively protected from oxidization, thus it leads to the stabilization of ferromagnetic NW and possible application to nanodevices. A calculation on the magnetism of Fe NW wrapped by armchair (5, 5) CNT [2] showed that the magnetic moment was comparable to that of freestanding Fe NW and larger than that of bulk Fe. In this paper, we investigated the magnetic properties of linear TM (Fe, Co, and Ni) NW encapsulated in zigzag (n, 0) (n=5, 6, 7, 8, and 9) CNT using the first-principles plane wave calculation [3] with the generalized gradient approximation (GGA) [4].

The magnetic moments per atom for TM NW in the zigzag (n, 0) CNT with n=7, 8, and 9 were slightly smaller than those of freestanding TM NW with the same bond length, but the values were decreased abruptly for the TM NW in (6, 0) and (5, 0) CNT. For Fe NW surrounded by (n, 0) CNT, the magnetic moments per atom were 3.28, 3.32, and 3.27 μ_B for n=9, 8, and 7, respectively, and it showed sudden decrease to 2.42 and 2.05 μ_B for NW in (6, 0) and (5, 0) CNT. It was 2.19 μ_B for bare Co NW without CNT but they were 2.17, 2.14, 2.06, 1.01, and 1.00 μ_B with (n=9 to 5, 0) CNT. For Ni NW surrounded by (n=9 to 7, 0) CNT, the magnetic moments were 1.07, 1.03, and 0.63 μ_B, respectively, but the Ni NW in (n, 0) CNT with n=5 and 6 showed nonmagnetic ground states. These results suggest that the magnetic properties of linear TM NW in zigzag CNT are mainly determined by the size of CNT, i.e., theinteraction between the TM NW and CNT, and also by the electronic property (metallic or semiconducting) of surrounding CNT.

REFERENCES

[1] Y. Zhang, N. W. Franklin, R. J. Chen, and H. Dai, Chem. Phys. Lett. **331**, 35 (2000).
[2] Chulsu Jo, J. I. Lee, and Y.-R. Jang, phys. stat. sol. (c) **1**, 3264 (2004).
[3] G. Kresse and J. Hafner, Phys. Rev. B **47**, 558 (1993).
[4] J. P. Perdew, J. A. Chevary, S. H. Vosko, K. A. Jackson, M. R. Pederson, D. J. Singh, and C. Fiolhais, Phys. Rev. B **46**, 6671 (1992).