清华大学高等研究院

Institute for Advanced Study, Tsinghua University

物理学术报告 Physics Seminars (biweekly)

Title: **Physics of Spin Hall Effect**

Speaker: **Prof. Guang-Yu Guo**
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Time: **3:15pm, Wednesday, September 11, 2013**
(2:45~3:15pm, Tea, Coffee, and Cookie)

Venue: **Conference Hall 322, Science Building, Tsinghua University**

Abstract

Spin Hall effect (SHE) refers to the generation of transverse spin current in a solid by an electric field. Spin current generation is an important issue in the emerging spintronic technology. Thus, SHE has recently attracted considerable interest both theoretically and experimentally since the theoretical proposals of the intrinsic SHE [1-2]. In this talk, I will first give an introduction to SHE, and then describe ab initio band theoretical approaches to the various issues in the field of SHE, in particular, Berry phase theory and ab initio relativistic band structure method [3,4]. This will be followed by a review on our recent relativistic band theoretical studies on the intrinsic SHE in Pt, Al [4], Pd, Au [5] and Mo. In particular, our ab initio calculations revealed that the resonant contribution from the spin-orbit splitting of the doubly degenerated d bands near the Fermi level gives rise to a large intrinsic spin Hall conductivity in Pt and Pd.

Furthermore, our electronic structure calculations for various transition metal impurities in gold indicated possible orbital-dependent Kondo effect in Fe impurity in Au [6]. Thus, the gigantic SHE observed recently in FePt/Au system [7] was attributed to resonant skew scattering due to multi-orbital Kondo effect [6]. Our estimated spin Hall angle is about 0.1, in agreement with the measured value [7]. Indeed, our subsequent quantum Monte Carlo simulations for a realistic three-orbital Anderson impurity model demonstrated two Kondo temperatures in Fe in Au: one very low Kondo temperature for Fe deg-states and the other high Kondo temperature for Fe t2g-states [8]. It was also found that the spin-orbit interaction and hence the SHE is strongly renormalized by the quantum spin fluctuation. This explains why the gigantic SHE in Au with Fe impurities was observed in recent experiments, while it is not visible in the anomalous Hall effect. Moreover, latest experiments on Au films with well controlled Fe impurity concentrations confirmed that the spin Hall angle is about 0.07 and independent of Fe impurity concentration [9], thereby indicating the extrinsic nature of the SHE observed in FePt/Au systems.

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[1] S. Murakami, N. Nagaosa, and S.-C. Zhang, Science 301, 1348 (2003);
[2] J. Sinova et al., Phys. Rev. Lett. 92, 126603 (2004);
[3] G. Y. Guo, Y. Yao and Q. Niu, Phys. Rev. Lett. 94, 226601 (2005);
[4] G. Y. Guo, S. Murakami, T. W. Chen, and N. Nagaosa, Phys. Rev. Lett. 100, 096401 (2008);
[5] G. Y. Guo, J. Appl. Phys. 105, 07C701 (2009) ;
[6] G. Y. Guo, S. Maekawa, and N. Nagaosa, Phys. Rev. Lett. 102, 036401 (2009);
[7] T. Seki et al., Nature Mater. 7, 125 (2008) ;
[8] B. Gu, J.-Y. Gan, N. Bulut, T. Ziman, G. Y. Guo, N. Nagaosa and S. Maekawa, Phys. Rev. Lett. 105, 086401 (2010).