Electric Spin Conversion Phenomena

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Introduction

Spin conversion is a concept of transformation between quasi-particles in solids via a spin degree of freedom. It has been so far reported that there is a variety of spin conversion methods, such as magnetic, electric, optical, thermal and dynamical. The spin conversion is revealed in nano-sized materials and can be generated in a hetero-interface. Currently, there is a number of studies on the spin conversion by using various approaches. The purpose of this talk is to introduce electric spin conversion phenomena. An example of the electric spin conversion is spin Hall and inverse spin Hall effects, where conversion of pure spin current from/to charge current is realized, and spin conversion in a heterostructure between inorganic semiconductors and metals provides a new stage of spin-related physics. Here, I introduce the latest topics of the spin conversion in semiconductor and molecular spintronics in this talk.

Electric spin conversion

Spin Hall effect (SHE) is a phenomenon, where pure spin current can be generated by a flow of electric current. The direction of the pure spin current is perpendicular to the direction of the electric current, which is an origin of the name, “spin Hall effect” (it should be noted that the physical origin of the SHE is completely different from that of the Hall effect). The SHE has been theoretically [1] and experimentally [2] investigated. The inverse spin Hall effect (ISHE) is the reciprocal effect of the SHE, which was discovered by using a dynamical spin pumping [3]. The both effects allows electric spin conversion to charge, and now are widely utilized in spintronics. The origin of the effects is a spin-orbit interaction (SOI), and a material with a large SOI is a good material stage for the effects. Thus, the heavy metals, such as Ta, W, Pt and Pd, and semiconductors with a large SOI are good detectors for pure spin current, since electric spin conversion in them can be easily realized.

The electric spin conversion in Pt, GaAs, p-type Si has been reported based on this concept [3-5]. Recently, the electric spin conversion in conductive polymer, PEDOT:PSS was also achieved, although the SOI in organic polymer is quite small [6]. The spin Hall angle, an index of the electric spin conversion, in the polymer is ca. $10^{-7,}$ which is 5-6 orders of magnitude smaller than that of Pt, Ta and so on. This is quite surprising in molecular spintronics. Since sufficient amount of spin accumulation allows the spin conversion, the spin conversion can be also realized in the other molecular materials. One example is the spin conversion in single-layer graphene, where the spin Hall angle was estimated to be ca. 6×10^{-7}, which is comparable to that of PEDOT:PSS [7].

The other notable achievement is the detection of pure spin current propagation in inorganic semiconductors. In the previous studies, the injected pure spin current into nonmagnetic materials was rapidly converted to the electric current, since the spin diffusion length of the materials are quite short in many cases. When we replace the materials to materials with good spin coherence, the long-range propagation of pure spin current can be realized and the propagating spin current can be adsorbed in heavy metals equipped with the spin coherent materials, resulting in the electric conversion. The first success was the detection of transport of pure spin current in p-type Si, where pure spin current was generated by using a dynamical spin pumping method and the pure spin current was detected by a Pd electrode [8]. The similar experimental concept was also utilized in realizing dynamical spin transport in graphene [9], Al [10] and recently in PBTTT [11].

Summary

Electric spin conversion is now applied in various materials, and is recognized as a quite attractive phenomenon in order to investigate various spin-related physics.

References

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