Spin Hall Effect and Large Anisotropic g-Factor of Bismuth

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Bismuth has played an important role in solid-state physics [1-3]. Many key phenomena were first discovered in bismuth, such as diamagnetism, Seebeck, Nernst, Shubnikov-de Haas, and de Haas-van Alphen effects. These phenomena result from particular electronic states of bismuth. The strong spin-orbit interaction (~1.5eV) causes strong spin-dependent interband couplings resulting in an anomalous spin magnetic moment. We investigate the spin Hall effect and the angular dependent Landau spectrum of bismuth paying special attention to the effect of the anomalous spin magnetic moment. It is shown that the spin Hall insulator is possible and there is a fundamental relationship between the spin Hall conductivity and orbital diamagnetism in the insulating state of the Dirac electrons [4,5]. Based on this theoretical finding, the magnitude of spin Hall conductivity is estimated for bismuth by that of orbital susceptibility. The magnitude of spin Hall conductivity turns out to be as large as $10^4\Omega^{-1}\mathrm{cm}^{-1}$, which is about 100 times larger than that of Pt [5].

It is also shown that the ratio of the Zeeman splitting to the cyclotron energy, which reflects the effect of crystalline spin-orbit interaction, for holes at the *T*-point can be larger than 1.0 (the maximum of previous theories) and exhibit strong angular dependence, which gives a possible solution to the long-standing mystery of holes at the *T*-point.

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