Full spin–orbit coefficient in semiconductor nanowires based on weak localization anisotropy under in-plane magnetic field

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Semiconductor nanowires in the presence of spin-orbit (SO) interaction is attracted much attention in spintronics as well as quantum and topological information processing as it suppresses randomization of spin orientation by geometrical confinement and exotic quasiparticles could emerge at semiconductor nanowire/superconductor junctions. To this end, one of the most important factors is the intrinsic stability of spin, characterized by SO coefficients. However, in nanowires, the intrinsic spin lifetime is concealed by the geometrical effect, namely the transition from weak antilocalization to weak localization (WL) in magnetotransport [1,2], causing difficulty in determining the full SO coefficient.

In this presentation, we present quantification of the full SO coefficient under weak localization in InGaAs-based narrow wires [3]. We measured magnetoconductance under various in-plane field angles at B_{in} = 1.5 T and T = 1.6 K. Figures 1(a)–1(c) respectively show color-coded magnetoconductance as functions of perpendicular B_z field and in-plane field angle θ_{in} in [-110]-, [010]- and [110]-oriented wires. The in-plane B_{in} field is rotated from [100] (θ_{in} = 0°) to [-100] (θ_{in} = 180°) through the [010] (θ_{in} = 90°) axis. In all wires, the conductance amplitude defined by Δσ increases by the increase of B_z, shown as color-code change from blue (minimum) to red (maximum) in Figs. 1(a)–1(c), being a clear indication of the WL signal and suppressed spin relaxation by lateral confinement. In addition, the amplitude of WL appears as anisotropic to the in-plane field angle θ_{in}. As indicated by the dashed lines in Figs. 1(a)–1(c), the θ_{in} at maximum WL amplitude depends on the wire directions, respectively corresponding to θ_{in} = 45°, 35°and 135° for [-110], [010], and [110] wires. The maximum WL amplitude corresponds to the most suppressed spin relaxation against the in-plane magnetic field angle, enabling the relative ratio between Rashba (α) and linear Dresselhaus (β_1) SO coefficients with no fitting. Furthermore, widely tuning the potential profile of the quantum well through the top gate can expose a Rashba-predominant region in magnetoconductance, where the α value can be extracted reliably from two-dimensional quantum correction theory. Finally, we quantify full SO coefficients including Rashba, linear Dresselhaus, and cubic Dresselhaus terms in the wire.

Reference: [1] Y. Kunihashi *et al.*, Phys. Rev. Lett. **102**, 266401 (2008). [2] A. Sasaki *et al.*, Nat. Nano. **13**, 703 (2014). [3] T. Nishimura *et al.*, Phys. Rev. B submitted (2021).

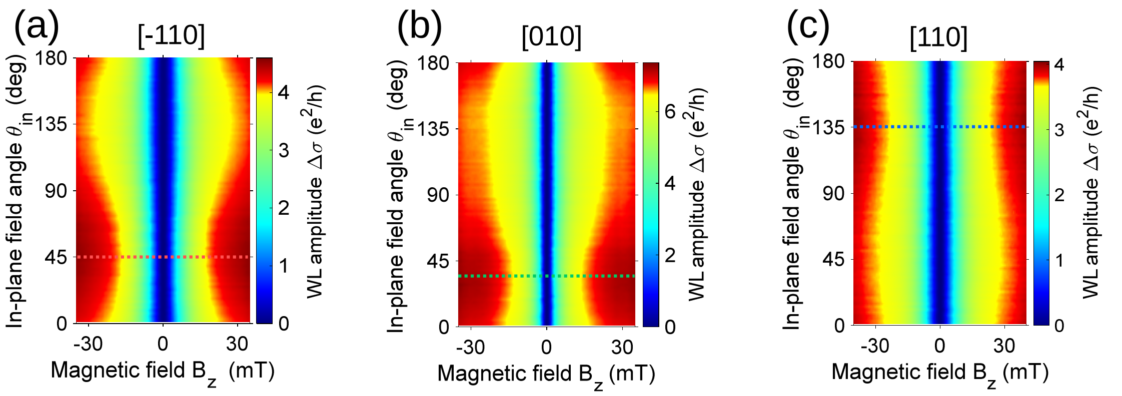

Fig. 1. Color-coded magnetoconductance as functions of perpendicular magnetic field B_z and in-plane magnetic field angle θ_{in} for (a) [-110], (b) [010] and (c) [110] wires at B_{in}= 1.5 T.