Anisotropic spin lifetime depending on crystal orientation in GaAs/AlGaAs wire structures

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Spin-orbit (SO) interaction is important in the field of semiconductor spintronics because the SO-induced effective magnetic field allows us to manipulate spins without external magnetic fields [1]. Contrary to such benefits, ***k***-dependent SO fields induce spin dephasing such as the D'yakonov Perel' (DP) mechanism [2]. Persistent spin helix (PSH) becomes an effective way to suppress the spin relaxation due to the special symmetry of SO fields where Rashba and Dresselhaus SO fields are comparable to each other ($\alpha \approx \beta$). An observation of the helical spin mode in wires with highly focused Gaussian σ width was reported by a previous research [3]. However, the detailed analysis of the crystal orientation dependence on the spin relaxation in wires has not been unveiled. Here, we clarify the decay mechanism in each crystal orientations from the viewpoint of the relative relationship between spin precession length λ_{so} and σ width.

We use time-resolved Kerr rotation (TRKR) measurement with a sigma width $\sigma \sim 7$ μm to reveal the spin dynamics in wire structures which are fabricated along various crystal orientations. The [1-10] and [110] crystal orientations correspond to the wire angle of 0 and 90 degree, respectively. A 20-nm-thick GaAs/AlGaAs quantum well was grown on a (001)-oriented GaAs substrate. Wire structures were fabricated by reactive ion etching (RIE) with their widths *w* ranging from 1 to 20 µm. Our sample has large anisotropic SO field, namely different values of Rashba and Dresselhaus SO fields.

Fig. 1 (a) shows the time evolution of Kerr signal with different angle, and fig. 1 (b) is the summary data of experimentally measured spin lifetime. Spin relaxation time as a function of wire angle. In the wire along $x \parallel$ [1-10], the enhancement is not observed at all, while spin relaxation time is gradually enhanced with approaching the wire direction along $y \parallel$ [110]. Moreover, the narrower wires show stronger anisotropy than the wider ones. These trends are caused by the transition of spin decay from 2D to 1D. The effective magnetic field in which electrons moving along *x* direction is the strongest among all the directions, leading to the shortest λ_{so}. This indicates that spin relaxation is governed by the DP mechanism. In contrast, since weak effective magnetic field in [110] wire makes λ_{so} long, we can observe the helical spin mode which has much longer spin lifetime even by large σ.

[1] J. Nitta, T. Akazaki, H. Takayanagi, and T. Enoki, Phys. Rev. Lett. **78**, 1335 (1997).
[2] M. I. D'yakonov and V. I. Perel', Sov. Phys. JETP **33**, 1043 (1971).
[3] P. Altmann *et al.*, Phys. Rev. B, **92,** 235304 (2015).

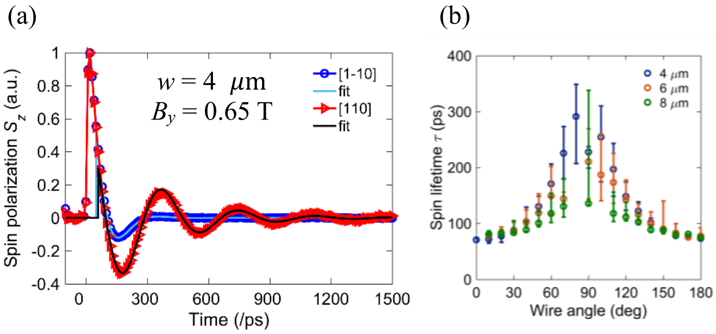

Figure 1 (a) The result of TRKR measurement. In [110] wire (w = 4 μm) , long-lived spin can be observed. We applied an external magnetic field along y axis. (b) Wire width dependence of spin lifetime as a function of wire angle.