Determination of Spin-Orbit Scattering Lifetime at the Interface of $LaAlO_3/SrTiO_3$ from the Superconducting Upper Critical Fields

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The intrinsic mechanism of the spin-orbit coupling at the $LaAlO_3$ / $SrTiO_3$ interface remains a debatable issue. Rashba-type spin-orbit coupling is an appealing candidate that has been demonstrated by several magnetotransport results. On the other hand, the atomic spin-orbit coupling was also shown to play an important role, particularly when the Fermi level is close to the Lifshitz point. Unlike previous works, we focus on the measurements of the anisotropic and superconducting upper critical fields in gated $LaAlO_3$ / $SrTiO_3$ devices. By rigorous fittings of the H_{c2}-T curves using both the Werthamer-Helfand-Hohenberg theory and Klemm-Luther-Beasley model, the spin-orbit scattering lifetime can be determined with high precision in superconducting state. We found that the extracted spin-orbit scattering lifetime monotonically increases with the transport lifetime that spanned over two orders of magnitude in the regime with sheet density higher than that at Lifshitz point. Those results suggest the dominant role of Elliott-Yafet type spin-relaxation. The comparison to the weak localization fittings on magnetoconductance reveals a striking difference, suggesting the model dependence on the determination of the spin-orbit scattering lifetime.