External magnetic field dependent current in a single-electron transistor using Pd nanogap electrodes and an Au nanoparticle

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Spin-dependent single-electron tunneling, which is based on interplay between single-electron changing effect and tunnel magnetoresistance (TMR) effect, has attracted much attention owing to its unique phenomena such as the enhancement and the oscillation of TMR.[1-3] These phenomena have been observed in ferromagnetic tunnel junctions and ferromagnetic granular structures.[1-3]

Recently, we have reported a chemically-assembled single-electron transistor (SET) using Pt-based nanogap electrodes and an Au nanoparticle, which showed clear and ideal Coulomb diamonds.[4] To realize the chemically-assembled SET, robust Pt-based nanogap electrodes with a 10-nm-scale ultrafine linewidth were fabricated by electron-beam lithography (EBL) and electron-beam (EB) evaporation, and an alkanethiol-protected Au nanoparticle was chemisorbed between the gap using alkanedithiol self-assembled monolayer (SAM).[4] This SET structure consisting of paramagnetic source/tunnel barrier/metallic Coulomb island/tunnel barrier/paramagnetic drain, as double barrier magnetic tunnel junctions, could be utilized to study spin-dependent single-electron tunneling when an external magnetic field is applied.

Here, we demonstrate external magnetic field dependent current in a chemically-assembled SET based on Pd nanogap electrodes and an Au nanoparticle.[5] Pd was used as a paramagnetic material for nanogap electrodes instead of Pt in this study. Pd nanogap electrodes with a gap separation of around 10 nm were fabricated on Si substrates by a combination of EBL and EB evaporation.[4,6] An Au nanoparticle with a core diameter of 5.8 nm was then introduced between the gap using alkanedithiol SAM.[4] Finally, an SET structure consisting of Pd source/tunnel barrier/Au island/tunnel barrier/Pd drain (Pd/Au/Pd) with gate was realized. The electrical characteristics of the fabricated SET were measured at 9 K with and without an external magnetic field. In the absence of a magnetic field, clear Coulomb blockade was observed, indicating that single-electron charging effect was visible in this device. When a magnetic field was applied to the SET, an increase and decrease in current compared to the one without magnetic field were observed in accordance with applied drain voltage, which could be attributed to spin-dependent single-electron tunneling in the Pd/Au/Pd SET structure.

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1) K. Ono *et al.*, *J. Phys. Soc. Jpn.* **65**, 3449 (1996).
2) K. Yakushiji *et al.*, *Appl. Phys. Lett.* **78**, 515 (2001).
3) K. Yakushiji *et al.*, *J. Appl. Phys.* **91**, 7038 (2002).
4) Y. Y. Choi, T. Teranishi, and Y. Majima, *Appl. Phys. Express* **12**, 025002 (2019).
5) M. Yang *et al.*, *in preparation*.
6) M. Yang, R. Toyama, P. T. Tue, and Y. Majima, *Appl. Phys. Express* **13**, 015006 (2020).