Observation of Nonreciprocal Transport in Two-Dimensional Hole Gas at the Surface of Hydrogen-Terminated Diamond Surface

Kyoto Univ.[1], Center for Spintronics Research Network, Kyoto Univ.[2],

Osaka Metropolitan Univ.[3], Institute for Chemical Research, Kyoto Univ.[4],

°Fujio Sako[1], Ryo Ohshima[1,2], Yuichiro Ando[3], Naoya Morioka[2,4],

Hiroyuki Kawashima[4], Riku Kawase[4], Norikazu Mizuochi[2,4] and Masashi Shiarishi[1,2]

E-mail: sako.fujio.26z@st.kyoto-u.ac.jp

Hydrogen-terminated (H-) diamond (Fig. 1) hosts two-dimensional hole gas (2DHG) at its surface. The triangular potential at the surface gives rise to sizable Rashba-type spin splitting in the *E*-*k* dispersion [1] in the system consisting of light elements, or C and H. Spin-momentum locking in the Rashba-type band structure results in conversion from an electric current to spin polarization in the transverse direction, which attracts much attention as a means of realizing high-efficiency charge-to-spin conversion. Magnetic moment of the polarized spin interacts with magnetic field, and nonreciprocal transport takes place under an external magnetic field parallel to the spin polarization. In this study, nonreciprocal transport in 2DHG at H-diamond surface was examined.

In the Rashba system, longitudinal resistance R is expressed as $R = R_0\{1 + \gamma B_{\mathrm{ext}} I \sin(\varphi)\}$ [2], where γ is a magnitude of the modulation of resistance, B_{ext} is an external magnetic field, I is an electric current, and φ represents the azimuthal angle of an external magnetic field to the electric current. Under the external magnetic field at $\varphi = 90$ °, an alternative current $I = I_0 \sin(\omega t)$ induces the second harmonic resistance $R^{2\omega}\cos(2\omega t)$, which is described as

$$R^{2\omega} = -\gamma B_{\mathrm{ext}} I_0 / 2. \qquad (1)$$

A Hall-bar shaped H-diamond (001) sample with gold electrodes was prepared by using e-beam lithography and e-beam deposition. A gate voltage V_{G} was applied by using an ionic gating technique, where an electric double layer can be formed onto the 2DHG. Figure 2a shows the B_{ext} dependence of the $R^{2\omega}$ at 5 K, which was measured under the condition of $\varphi = 90$ °and $V_{\mathrm{G}} = -1.8$ V. The odd component of the $R^{2\omega}$ that is proportional to the B_{ext} is noticeable, which signifies successful observation of the nonreciprocal transport. The slope of the $R^{2\omega}$-B_{ext} characteristic ($R^{2\omega} / B_{\mathrm{ext}}$) is proportional to the I_0 (see Fig. 2b) as expected from Eq. (1). The nonreciprocity is enhanced at lower temperature because thermal fluctuation of spin is suppressed, and γ became the maximum value of 0.22 $A^{-1}T^{-1}$ at 15 K, which is comparable to 0.22 $A^{-1}T^{-1}$ at 2 K in WTe_2 [3] and 0.52 $A^{-1}T^{-1}$ at 1.5 K in InSb / CdTe [4]. The details will be discussed in the presentation.

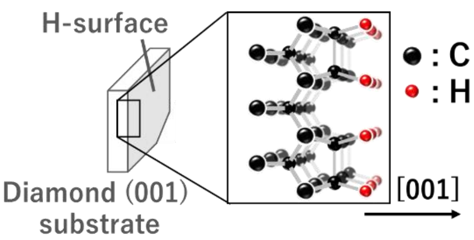

Fig. 1: Structural image of hydrogen-terminated diamond.

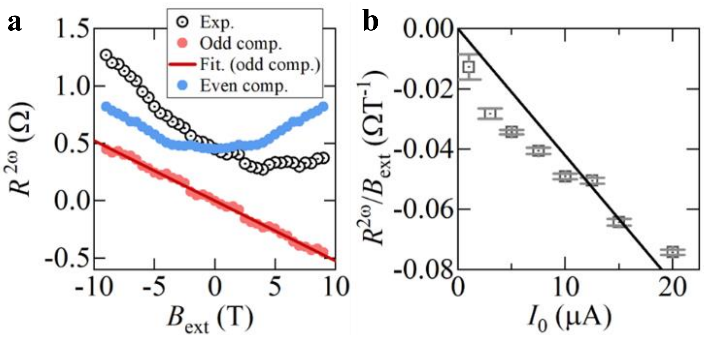

Fig. 2: a) B_{ext} dependence of $R^{2\omega}$. Black open dots are experimental data, and blue / red solid dots are odd- / even-components, respectively. b) I_0 dependence of $R^{2\omega} / B_{\mathrm{ext}}$.

[1] G. Akhgar *et al., Nano Lett.* **16**, 3768 (2016). [2] T. Ideue *et al., Nat. Phys.* **13**, 578 (2017).
[3] P. He *et al., Nat. Commun.* **10**, 1209 (2019). [4] L. Li *et al., Adv. Matt.* **35**, 2207322 (2023).