FeO_x/$SrTiO_3$界面における二次元正孔ガス領域と$SrTiO_3$およびNb:$SrTiO_3$からなる縦型 p-i-n 接合の実現

Realization of vertical p-i-n junctions composed of a two dimensional hole gas region at an FeO_x/$SrTiO_3$ interface, $SrTiO_3$, and Nb:$SrTiO_3$

°Chenhao Xia[1], Le Duc Anh[1,2,3], Shingo Kaneta-Takada[1], Masaaki Tanaka[1,4], and Shinobu Ohya[1,3,4]

[1]*Dept. of Electrical Engineering and Information Systems, The Univ. of Tokyo*
[2] *PRESTO, Japan Science and Technology Agency*
[3]*Institute of Engineering Innovation, Graduate School of Engineering, The Univ. of Tokyo*
[4]*Center for Spintronics Research Network (CSRN), Graduate School of Engineering, The Univ. of Tokyo*
E-mail: xia-chenhao686@g.ecc.u-tokyo.ac.jp

Realization of two-dimensional hole gas (2DHG) at the $SrTiO_3$ (STO) interface has long been a material challenge since the discovery of its counterpart－the 2D electron gas (2DEG) [1]. Recently, by depositing a sub-nm-thin Fe layer on an STO substrate, we have demonstrated the first realization of an isolated 2DHG with an ultrahigh mobility up to 24000 cm^2/Vs at the STO interface, whose carrier type can be controlled by the Fe thickness [2]. This finding potentially provides a universal platform for oxide-based electronics.

In this work, we have made vertical p-i-n junctions composed of a p-type electrode of the 2DHG formed at the FeO_x/STO interface, non-doped STO, and Nb:STO. We first grew a thin STO layer (thickness t = 10 or 20 unit cells (uc)) on a 0.5 wt% Nb-doped STO (001) substrate using molecular beam epitaxy (MBE) with a background oxygen pressure of 2×10^{-4} Pa including 20% of ozone and at 750°C. Then, we deposited an ultrathin Fe layer (nominal thickness of 0.075 nm) on the STO layer and capped it with 1-nm-thick Al under a background pressure of 3×10^{-8} Pa at 50°C. When the sample was taken out of the MBE chamber, the Fe and Al layers became FeO_x and AlO_y, respectively. In this structure, the 2DHG formed at the FeO_x/STO interface and the Nb-doped STO substrate play the roles of the p-type and n-type electrodes, respectively. For the measurements, we deposited a 50-nm-thick Al layer on top of the sample, and then patterned the sample into circular-shape mesas with 300 µm, 400 µm and 500 µm in diameter using photolithography and ion milling. The device structure and measurement configuration are shown in Fig. 1(a). The I - V curves obtained for the sample with t = 20 uc at various temperatures is showed in Fig. 1(b), in which the strong rectification effect is clearly seen in the whole range of temperature up to 300 K. The rectification is, however, opposite in the low bias range ($|V|$ < 0.25 V), where a larger current is obtained in the reversed bias region. Meanwhile, in the high bias range ($|V|$ > 0.25 V), a larger current flows in the forward bias region as in conventional diodes. This extraordinary and intriguing properties can be understood by considering a current flow by band-to-band tunneling and thermionic emission in our devices. Detailed discussions on the mechanism will be given in the talk.

This work was supported by Grants-in Aid Scientific Research, the JST CREST (JPMJCR1777) and Spin-RNJ.

References: [1] Ohtomo and H. Y. Hwang, Nature **427**, 423 (2004).
[2] L. D. Anh *et al.*, Adv. Mater. **32**, 1906003 (2020).

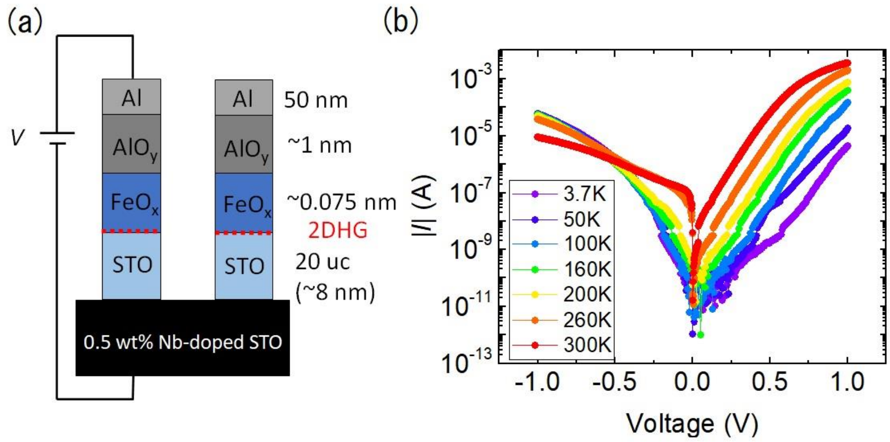

Figure 1. (a) Device structure and measurement configuration. (b) I - V curves measured at various temperatures for a diode device with the STO thickness of 20 u.c.