Propagation and Quantization of Valley Current through One Dimensional Channel

K. Takahashi[1], Y. Nakayama[1], D.K. Ferry[2], J.P. Bird[3] and N. Aoki[1]

[1]*Department of Materials Science, Chiba University, Chiba 263-8522 Japan*

[2]*School of Electrical, Computer and Energy Engineering, Arizona State University, Tempe, AZ 85287, United States*

[3]*Department of Electrical Engineering, University at Buffalo, The State University of New York, Buffalo, NY 14260, United States*

n-aoki@faculty.chiba-u.jp

Valley Hall effect (VHE) is one of the unique effects observed in a two-dimensional system having broken structural symmetry, such as that which arises in monolayer transition metal dichalcogenides and in bilayer graphene (with a perpendicular electric field). These systems have been studied not only by optical but also by electrical methods. It is difficult to observe the valley current electrically since it is a charge-neutral current. The only way to observe the evidence of the valley current is to observe the non-local voltage (V_{NL}) that arises from the VHE (over and above that from resistance affected by the actual current). This is an inverse VHE. Recently, electrostatic on/off control of the valley current has been reported [1]. However, the nature of the VHE in quantum structures is not well understood. In this paper, we demonstrate clear evidence of the propagation of a valley current through the one-dimensional sub-bands of a monolayer MoS_2 constriction. Applying negative gate voltage to split gates leads to clear step-like features, which arise as we squeeze the channel electrostatically.

In order to observe the VHE, a Hall-bar structure composed of monolayer MoS_2, encapsulated between flakes of *h*-BN, was fabricated on a back gate of thin graphite. A split gate (SG) with 100-nm separation and a top gate (TG) were defined on the Hall bar to control the valley current as shown in Fig. 1(a). The width of the Hall bar is 1 μm and the non-local electrode is separated by 8 μm from the current path. The sample was cooled in a ^{3}He cryostat. Low frequency lock-in amplifiers were used to measure the non-local voltage. Figure 1(b) shows typical TG (broken line) and SG (solid line) dependencies of the VHE V_{NL}. In this case, +9 V was applied to the back gate to accumulate sufficient electrons in the Hall bar and observe the V_{NL}. V_{NL} remains constant until a negative gate voltage of -2.3 V led to the observed reduction in valley current. The V_{NL} is reduced in one step in the TG dependency, but is gradual in the case of the SG. It also shows distinct steps that are natural in such split-gate structures, and are very similar to the characteristics of quantum point contacts studied in a high electron mobility electron gas systems. However, the electron mobility of this sample is only about 500 cm^2/Vs at low temperature, and such step-like features are observed up to 16 K. This is thought to be due to the unique feature of valley current, which is expected to be suppressed by short-range scattering in the low mobility.

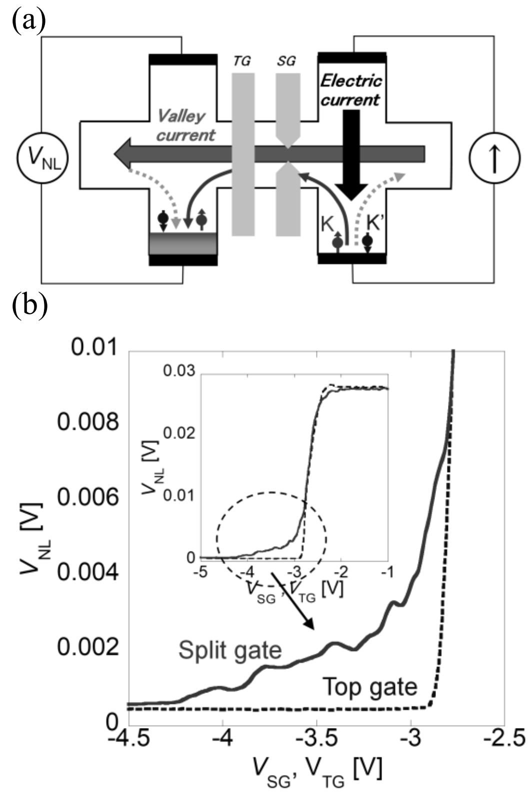

Fig.1. (a) Schematic view of Hall bar structure having TG and SG in the channel. (b) Top gate and split gate dependence of non-local voltage at 2 K.

References

[1] Lai Shen, *et al*. Nano Letters **23**, 1 (2023).