Supporting Information

V_2O_5: a 2D van der Waals Oxide with Strong In-plane Electrical and Optical Anisotropy

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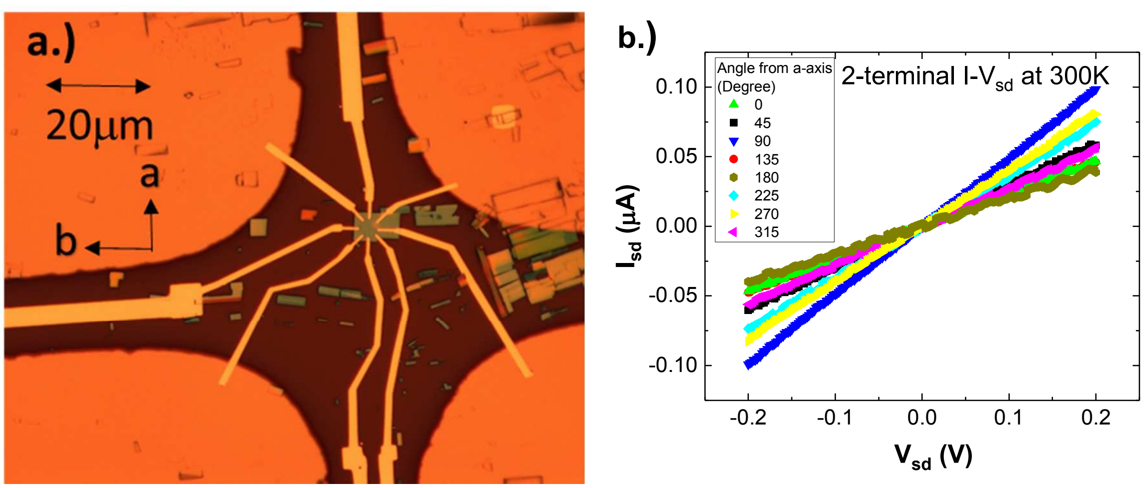
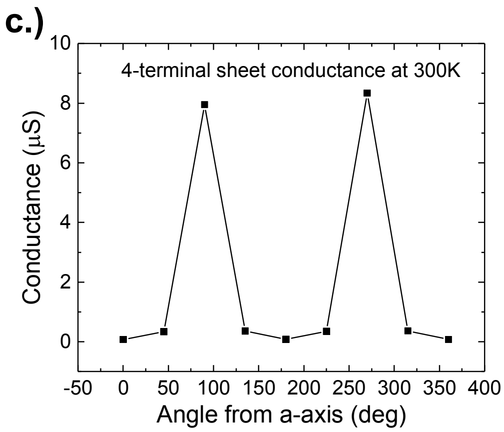
Anisotropic conductance measurement in additional V_2O_5 devices and QuickField simulation of anisotropic conductance

Initially, in probing electrical anisotropy, an eight-terminal device was fabricated and its results similar to measurement done on device as illustrated in the main paper is shown in Figure S1.





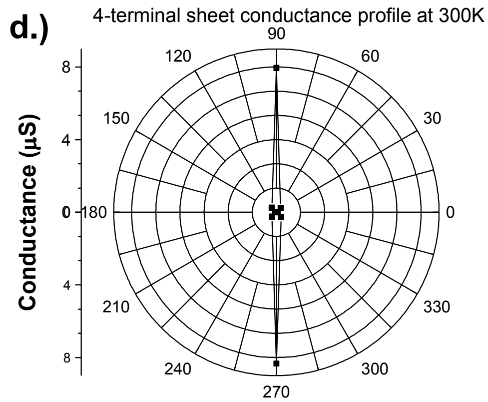
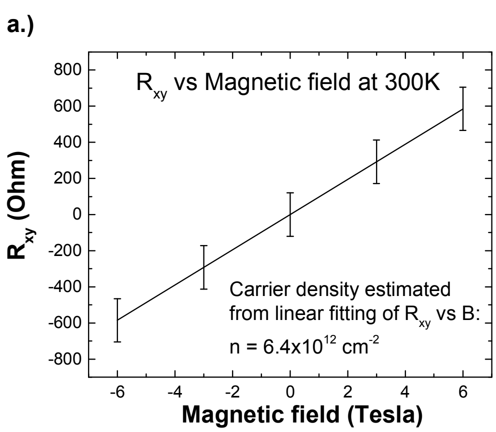


Figure S1. a) An optical image of the fabricated V_2O_5 device. b) Two-terminal I_{sd} *vs.* V_{sd} characteristics of the V_2O_5 device with eight contacts in a) measured along different directions. c) and d) Angle-dependence mapping of four-terminal conductance *vs.* the angle from principal a-axis in the eight contact device in a).

In a similar fashion to the device described in the main article, Hall measurement was conducted on the device as illustrated in Figure S2.a where the Hall mobility in the material can be estimated to be 7 cm^2/Vs.



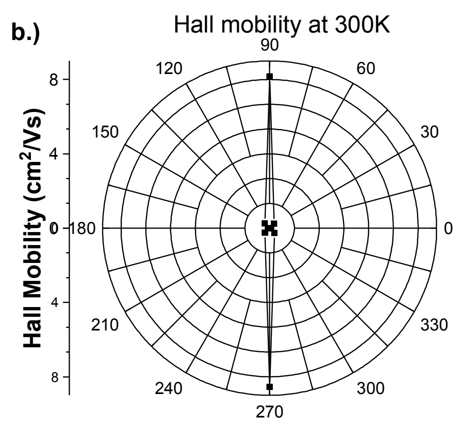


Figure S2. a) R_{xy} *vs.* perpendicularly magnetic field for the V_2O_5 sample in Figure S1 at 300K. b) Angle dependent Hall mobility profile map at 300K for the V_2O_5 sample in Figure S1.

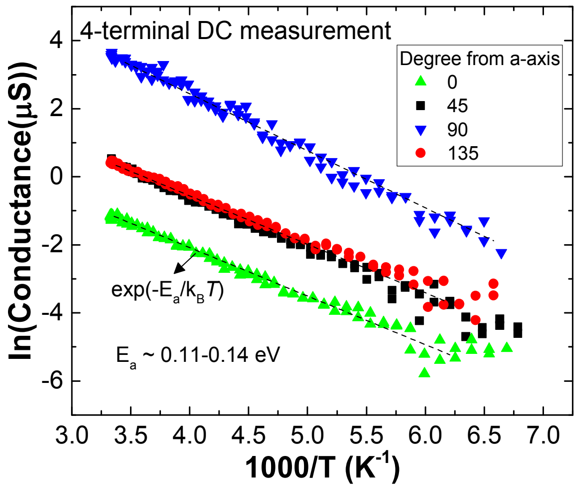


Figure S3. Arrhenius plot of the 4-terminal conductance *vs.* inverse temperature at different angle between the current and the *a*-axis of V_2O_5 nanoflake sample in Figure 3 of the main text.

In order to more accurately interpret the anisotropy of the conductance, the samples were simulated using software Quickfield. Two designs were created, a square shaped model with contacts in the corners and midpoints of the sides, and a much more detailed model designed after the realistic experimental setup as shown in Figure S1a. These designs were simulated over a range of conductivity anisotropy ratios, and 4-terminal conductance measurements were simulated at angles of every 45°.

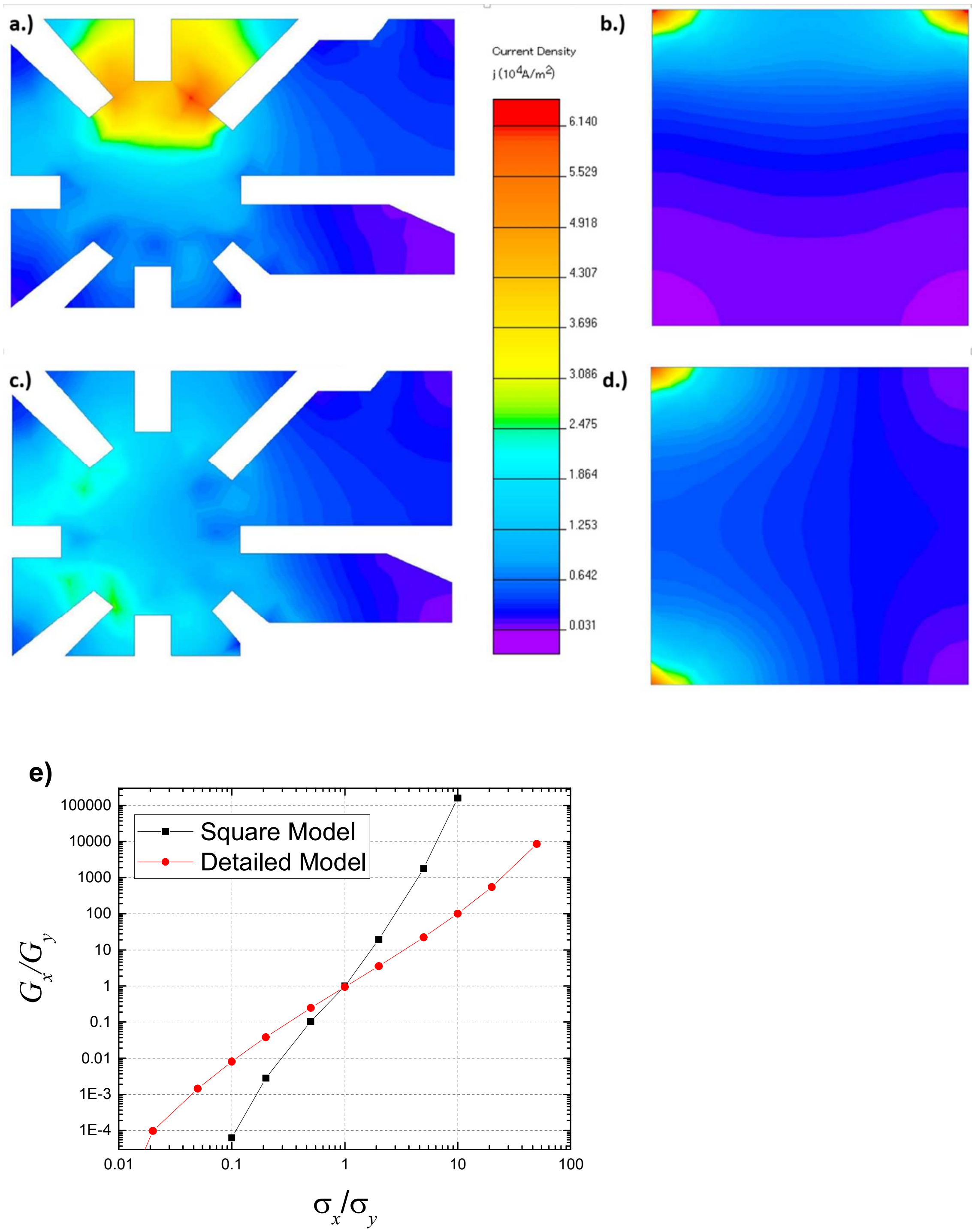


Figure S4. Current density of detailed model (a,c), and square (b,d) with voltage applied in horizontal direction(a,b) and vertical direction(c,d) for the parameter $\frac{\sigma_x}{\sigma_y} = 2$. e). Relationship of $\frac{G_x}{G_y}$ as a function of conductance ratio for the square model and the detailed model for the realistic rectangle sample.

The ratio $\frac{G_x}{G_y}$, where $G_{x,}$ G_y are the four probe conductance $\frac{I_{sd}}{V_{xx}}$, $\frac{I_{sd}}{V_{yy}}$ measured along the *x* or *y* direction, was compared between the two models across the range of conductance ratios, as shown in Figure S3. As demonstrated in Figure S3e, both the idealized square shaped model and the detailed rectangle shaped model give isotropic 4-probe conductance ($\frac{G_x}{G_y} = 1$), if the sample is isotropic ($\frac{\sigma_x}{\sigma_y} = 1$). So, for an isotropic material, the non-square shape of the sample and finite size of contacts do not influence the van der Pauw measurement much. However, as the sample becomes strongly anisotropic, much of the charge flow happens through the conduction probes in the experiment, which are not modeled in the simple idealized van der Pauw square set-up. This causes the anisotropic ratio from the van der Pauw measurement on an ideal square shaped sample to deviate strongly from that measured in a non-square shaped sample with finite sized contacts. This suggests that the calculations based off classic van der Pauw method need to be corrected through the assistance of the numerical calculation as shown here for materials with anisotropic conductivity.