# Interplay between Anomalous Metallic and Superconducting States Tuned by Disorder in Thin Flakes of Kagome Metal $KV_3Sb_5$

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**Supplementary Information**

## 1 Single crystal growth

Single crystals of $KV_3Sb_5$ were grown using the self-flux method. The raw materials are K chunks (purity 99%), V grains (purity 99.5%) and Sb powder (purity 99.5%). The flux is a eutectic mixture of KSb and $KSb_2$, which is further mixed with $VSb_2$. Elemental reagents were milled in an agate jar with a stoichiometric ratio(50 at.% $K_xSb_y$ and 50 at.% $VSb_2$ approximately). The mixture was then loaded into an alumina crucible, subsequently sealed in a stainless steel pipe. The whole preparation process was carried out in a glove-box filled with argon. Finally, the stainless steel pipe was heated to 1000 at 200$^o$C/h and kept for 24 h. The samples were cooled to 900$^o$C in 1 h and then further to 400$^o$C with a slow rate of 2$^o$C/h. Once cooled down to room temperature, the shiny plate-like single crystals of $KV_3Sb_5$ could be separated from the flux mechanically.

## 2 Thin flake fabrication

The $KV_3Sb_5$ thin flakes are exfoliated from the single crystal by Nitto tape. The tape with the flakes is then stuck onto $SiO_2$/Si substrate ($SiO_2$-300 nm; Si-500 $\mu$m) [1,2]. Several flakes with various thicknesses are left on the substrate after the tape is peeled off. In order to avoid the glue-contaminations, the left flakes are exfoliated again by a piece of fresh Nitto tape. The exfoliation process is carried out in the atmosphere. Typically the in-plane dimension of the fabricated samples can be as large as 200 $\mu$m. The thickness of the samples can range from a few nanometers to more than 100 nanometers. Then two $KV_3Sb_5$ flakes with the smooth surface are chosen by optical microscopy to proceed electrical transport measurements.

Table 1: Summary of the sample thickness with different contrasts shown in Fig. S1.

| Name | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| Thickness | 1.5 nm | 110 nm | 44 nm | 25 nm | 22 nm | 53 nm | 18 nm | 14 nm |

## 3 Characterization

The thin flakes are also characterized by the optical microscope, AFM, SEM, and Raman spectrum. The results are shown in Fig. S1, Fig. S2, Fig. S3, as well as Table 1. From Fig. S1 and Table 1, we can see that there is a good correspondence between the thickness and the contrast of thin flakes, which provides a good reference to estimate the thickness of the samples for the electrical transport measurements. The thicknesses of samples S-1 and S-2, which are chosen to conduct the electrical transport measurements, are both determined to be $22\pm2$ nm.

The SEM pictures shown in Fig. S2 reveal the very clean and flat surface of the thin samples, inducting the high quality of the exfoliation. More importantly, the Raman spectrum remains almost unchanged with the decrease of the sample thickness down to 18 nm. This illustrates that the thin samples of 18 nm can survive in air.

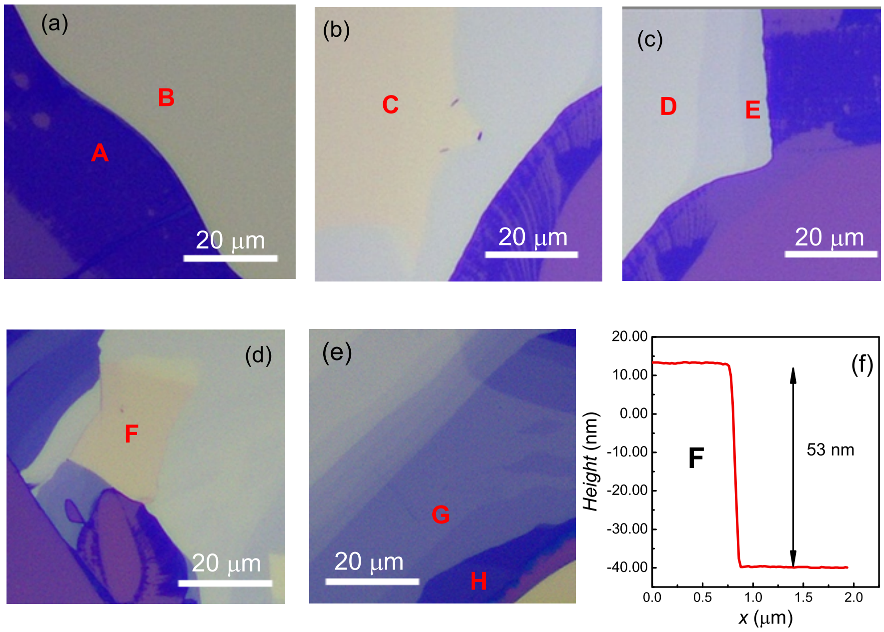


**Figure S1** (a-e) The pictures of the thin samples under optical microscope with different contrasts and thickness. The Thickness determined by AFM measurements are summarized in Table 1. (f) Cross-sectional profile of the thin sample F as shown in (d). The step is about 53 nm in height.

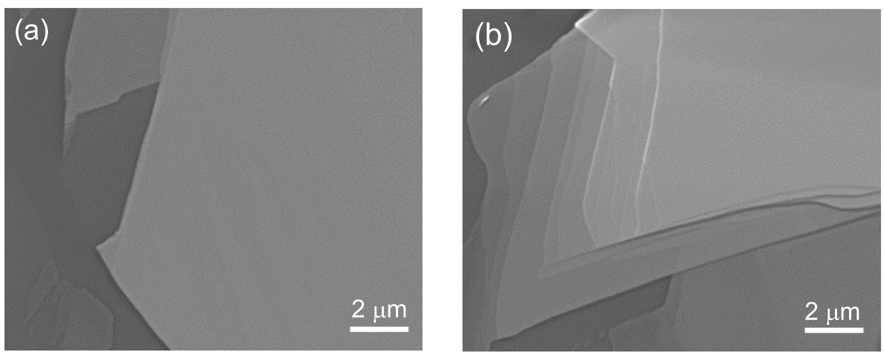

**Figure S2** (a,b) Scanning electron microscope (SEM) pictures for the exfoliated thin samples. The flat surfaces and layered micro-structures can be seen in these pictures.

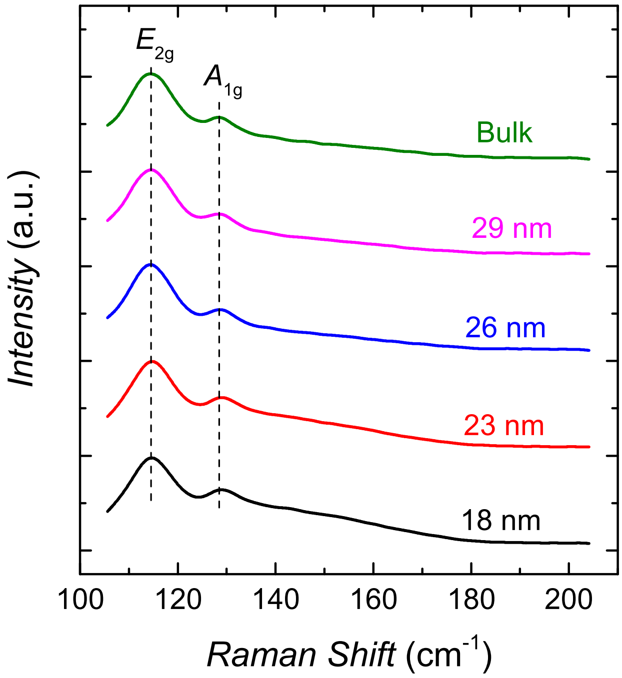


**Figure S3** Raman spectra of $CsV_3Sb_5$ thin flakes with different thickness. The dashed lines are guides for eyes.

## 4 Transport behaviors of the samples with different thickness

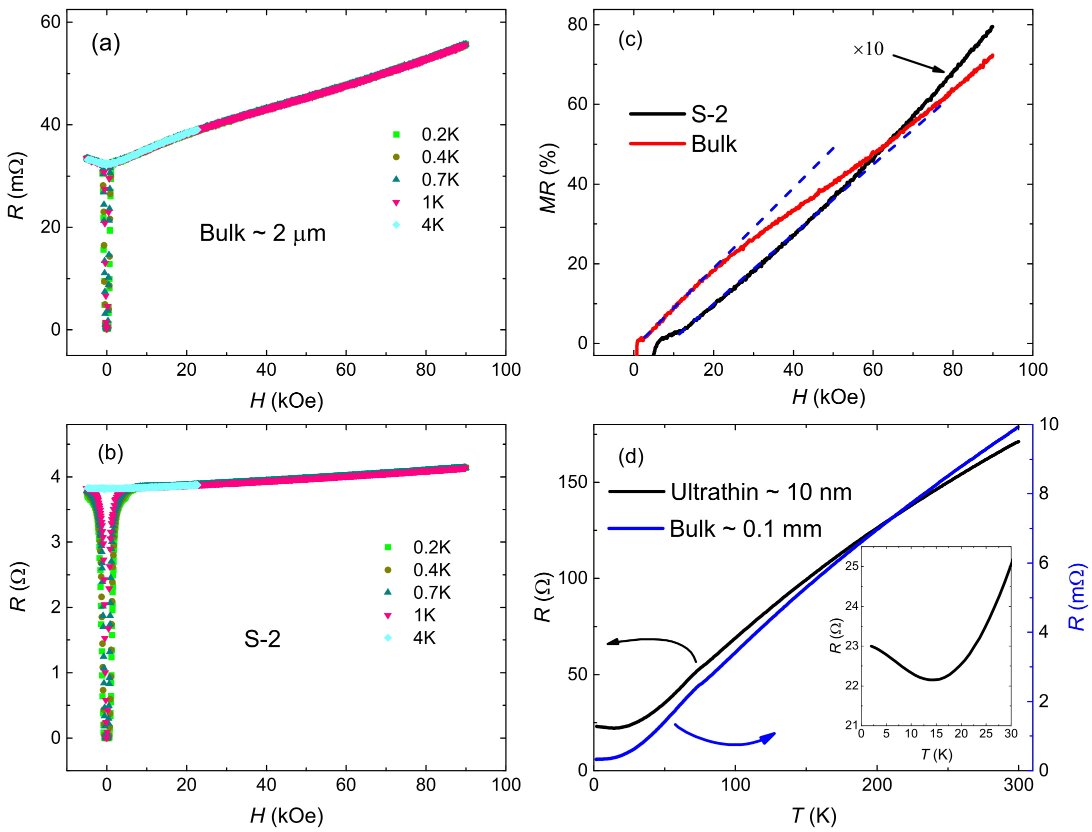


**Figure S4** (a,b) Magnetic field dependence of resistance for the bulk sample and S-2 respectively. (c) A comparison of the magnetoresistance data for the bulk and thin samples. The data of the thin sample S-2 is multiplied by 10 for clarity. The blue dashed lines are guides for eyes. (d) Temperature dependence of resistance of the ultrathin (left) and bulk (right) samples. The inset shows the enlarged view of the data for the ultrathin sample in the low temperature region.

## 5 Determination of zero-resistance temperature

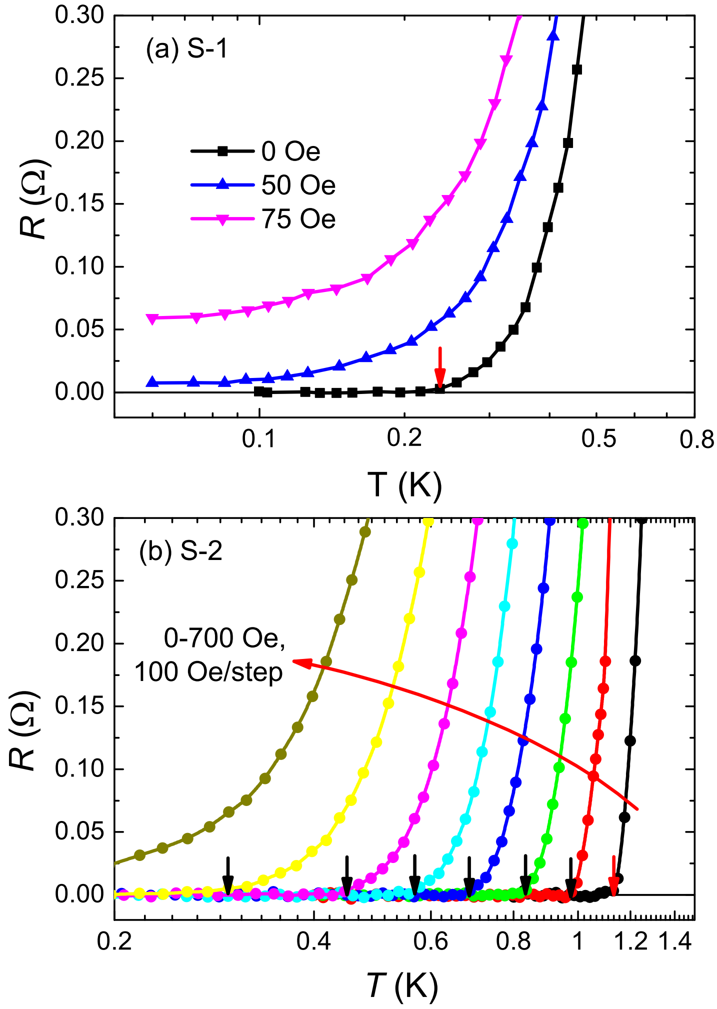


**Figure S5** (a,b) An enlarged view for the temperature dependence of resistance of two $KV_3Sb_5$ thin films (S-1 and S-2) under different magnetic field. The arrowed lines indicates the zero-resistance points for the SC transitions.

## 6 Raw data for the Arrhenius plots

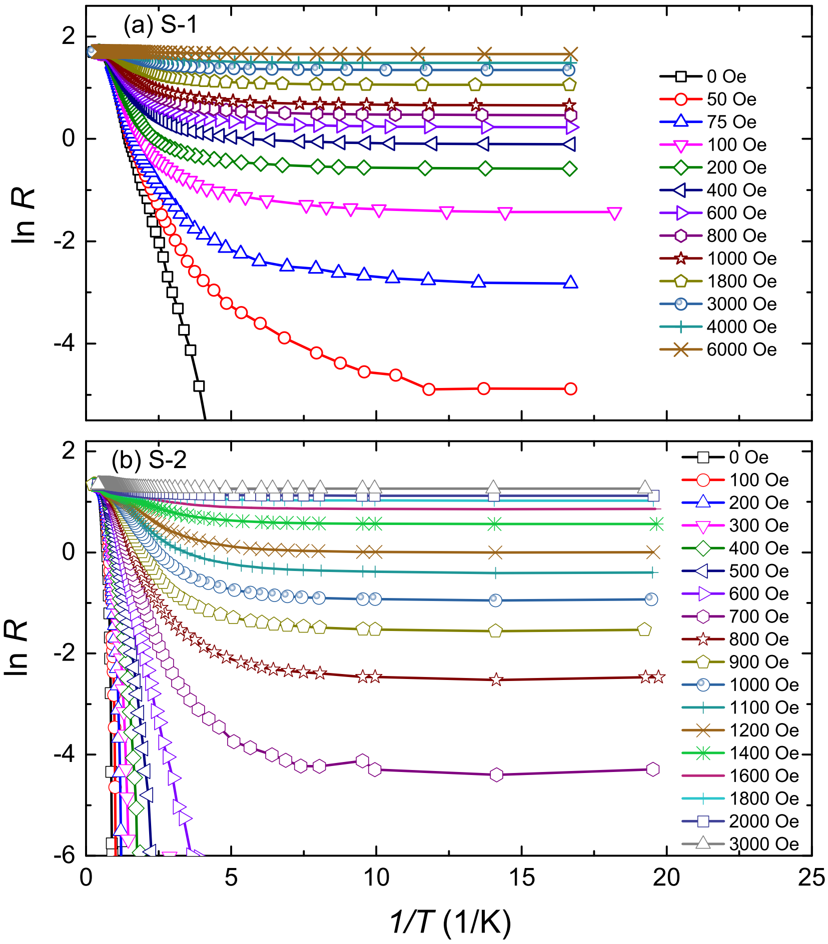


**Figure S6** Raw data for the Arrhenius plots of longitudinal resistivity ln$R$ vs $1/T$ under different fields for the sample S-1 and S-2.

## 7 Thermally activated energy in the TAFF state

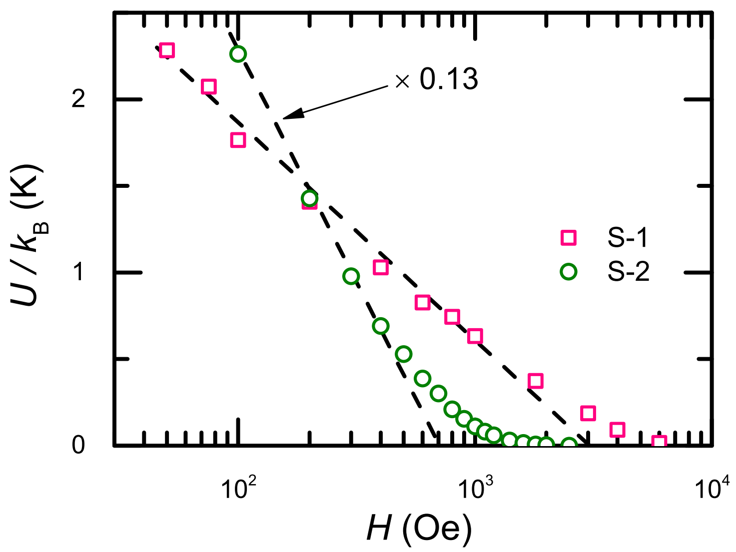


**Figure S7** Field dependence of thermally activated energy $U$. The black dashed lines are guide for eyes.

## 8 Comparison between the ultra-low temperature data with and without RC filter

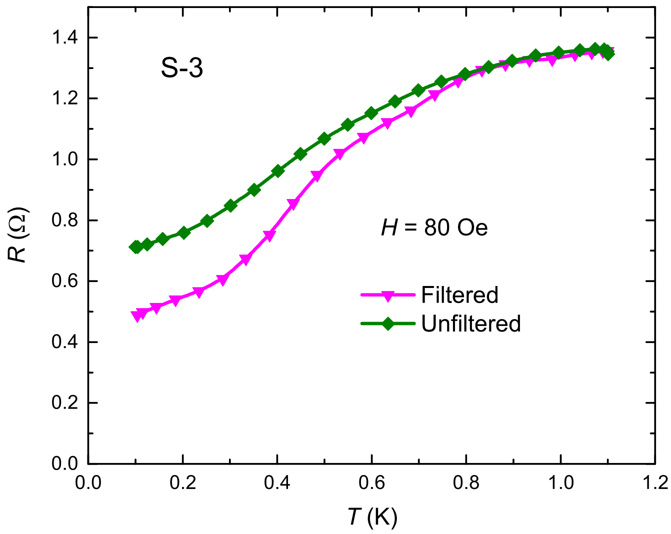


**Figure S8** Comparison of the resistance data of sample S-3 between the two situations, with and without RC filter equipped.

1. Novoselov, K. S. *et al.* Electric field effect in atomically thin carbon films. *Science* **306**, 666–669 (2004).

2. Jiang, D. *et al.* High-$T_c$ superconductivity in ultrathin $Bi_2Sr_2CaCu_2O_{8+x}$ down to half-unit-cell thickness by protection with graphene. *Nat. Commun.* **5**, 5708 (2014).