# Supporting Information for

# Superlubric Sliding of Graphene Nanoflakes on Graphene

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Figure S1. Additional STM images of the as-produced graphene film on Ru(0001).

Figure S2. STM images showing the graphene being split and the resulting graphene nanoflakes (GNFs).

Figure S3. STM images showing the sliding behavior of GNFs on graphene at 5 K.

Figure S4. The estimation of van der Waals force between the tip and graphene flakes.

## Figure S1:

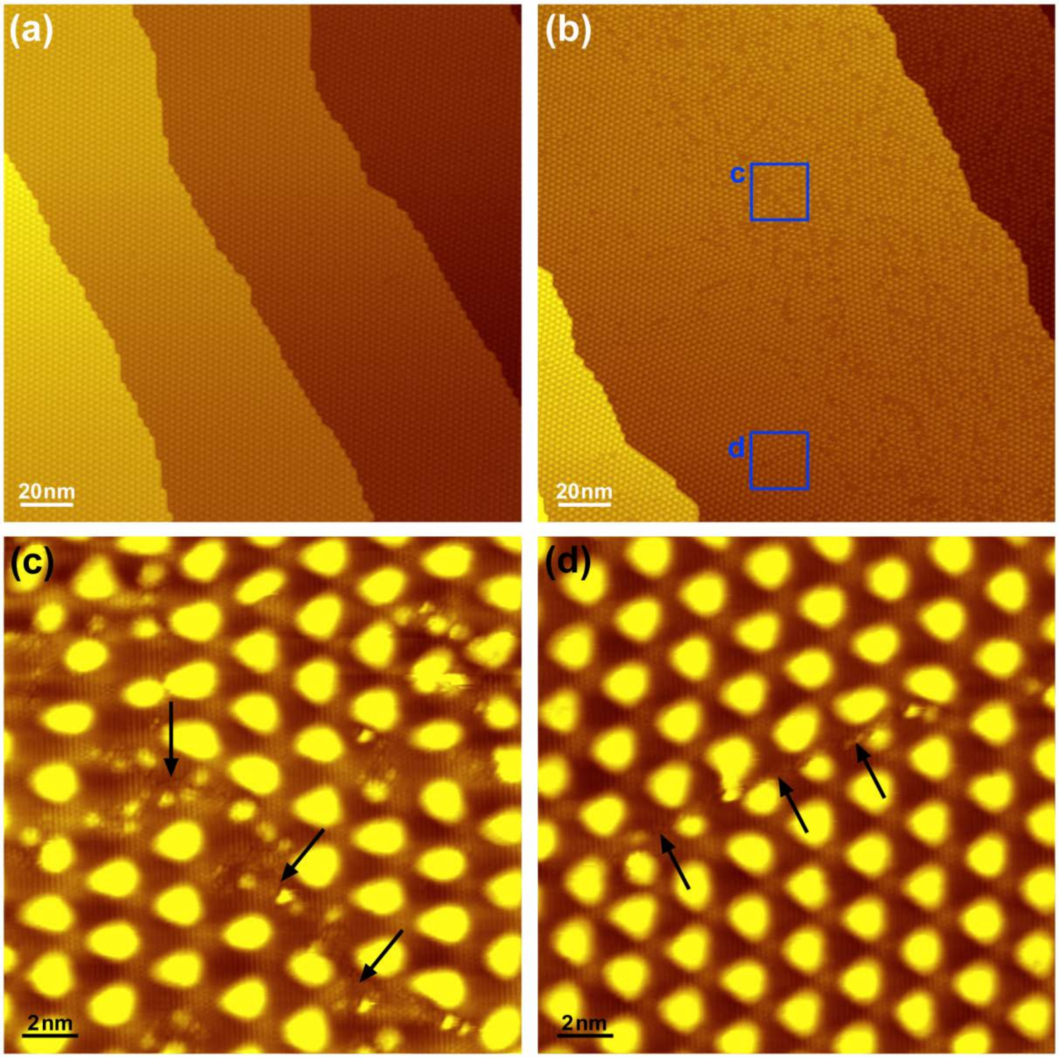


**Figure S1.** STM images of the as-produced graphene film on Ru(0001). (a,b) Some areas of the film are almost defect-free (a), while others contain numerous line defects (b). (c,d) Expanded view of the areas encircled by squares in (b), showing atomic structures of the defects, where broken and stretched bonds are expected to occur, as indicated by arrows. The graphene film will be split along the line defects after water exposure, while those defect-free areas such as in (a) will remain intact. Imaging parameters: (a,b) $V_s$ = 400 mV, $I_t$ = 15 pA; (c,d) $V_s$ = 15 mV, $I_t$ = 300 pA.

## Figure S2:

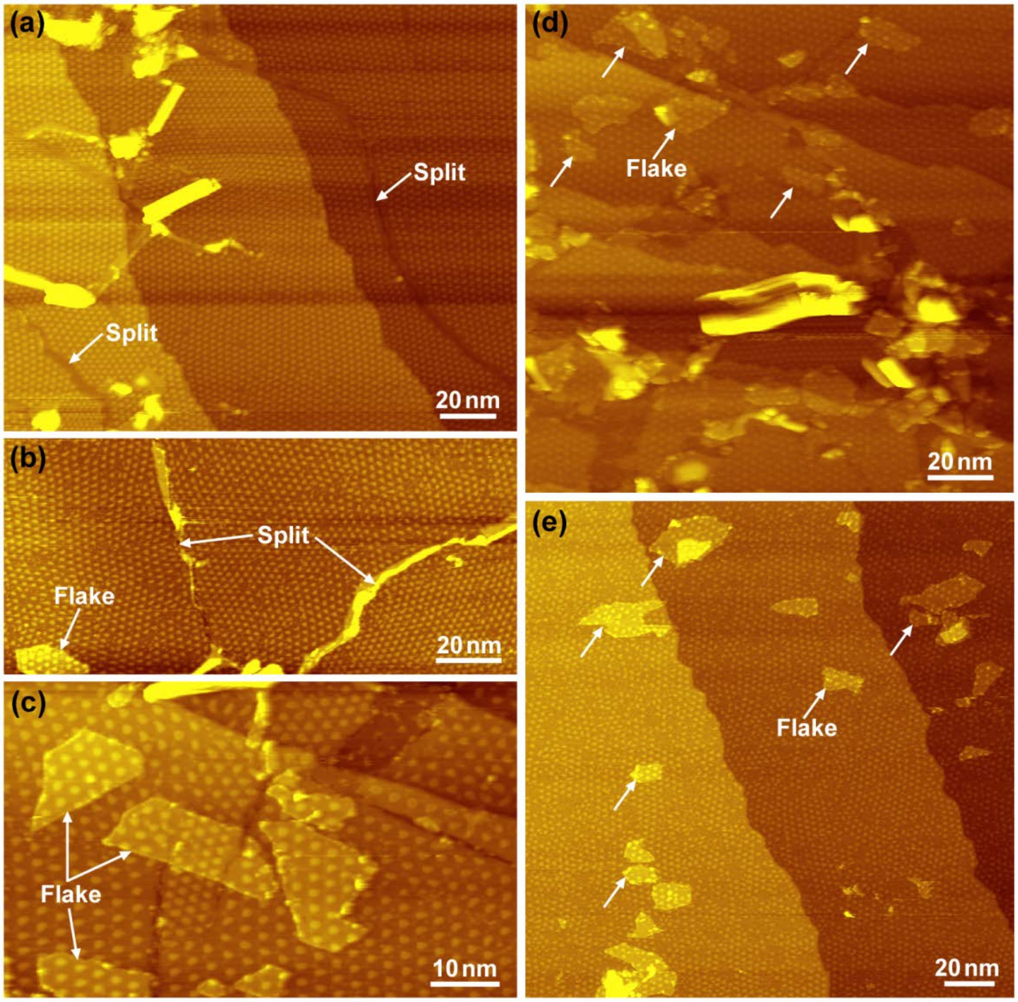


**Figure S2.** STM images showing the graphene being split and the resulting graphene nanoflakes (GNFs) sitting on top of the first graphene layer on Ru(0001). (a,b) After water exposure at 110 K, the graphene film was split along line defects, as pointed out by the arrows. Those bright protrusions are attributed to water clusters attached to defects. (c–e) GNFs sitting on the first graphene layer, as indicated by arrows, which were displaced here from other areas. The flakes show all the Moiré features from the underlying graphene layer, as shown in the close-up view in (c). Imaging parameters: (a,b) $V_s = -1$ V, $I_t = 8$ pA; (c–e) $V_s = -2.5$ V, $I_t = 5$ pA.

## Figure S3:

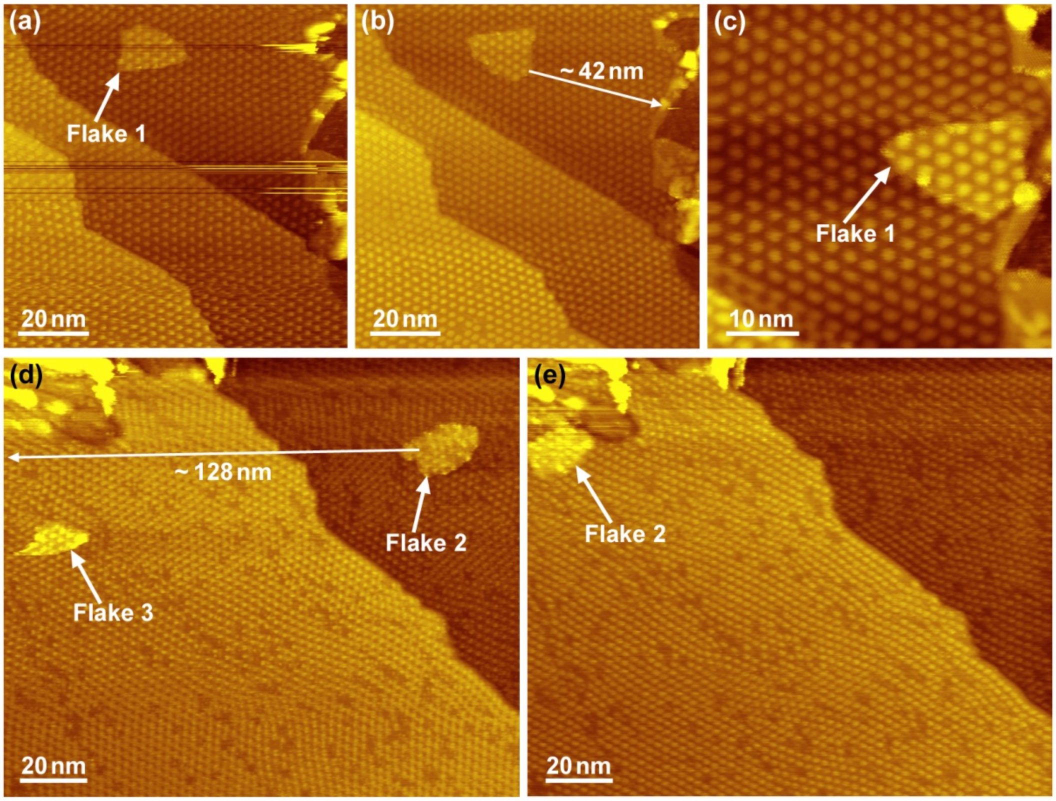


**Figure S3.** STM images showing the sliding behavior of GNFs on graphene at 5 K. (a–c) Three images, obtained with $V_s = -37$ mV and $I_t = 15$ pA, showing that Flake 1 first rotated by 180°, and then displaced to the right side by about 42 nm. (d,e) Two successive scans of an area, obtained with $V_s = -2$ V and $I_t = 18$ pA, showing that Flake 2 slid to the left side over a distance of ~128 nm, while Flake 3 moved out of the scanning area. Similar to the case at 77 K, the flakes show facile translational and rotational motions between commensurate initial and final states.

## Figure S4:

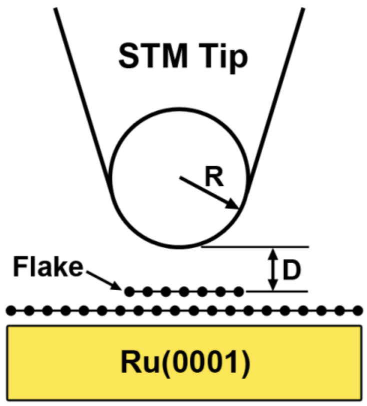


**Figure S4.** Geometry used to estimate the contribution from van der Waals forces, where *R* is the radius of a spherical tip and *D* is the tip-sample distance.

**Discussion:** To estimate the value of the van der Waals interaction between the tip and graphene flakes, we use the simple geometry in Figure S4 with *R* being the STM tip radius and *D* the tip-sample distance. The van der Waals force is calculated by $F_{vdW} = AR/6D^2$ , where *A* is the Hamaker constant, assumed to be $1\times10^{-19}$ J.[S1] With $R = 30$ nm and $D = 1$nm, we obtained a value for $F_{\mathrm{vdW}}$ of about 500 pN. As the tip moves past a flake, the projection of van der Waals force can pull the flake and cause a small rotation or a displacement of 2 Å (~graphene unit cell dimension), corresponding to an energy of the order of 1 eV, which is sufficient to overcome the activation barrier (~0.52 eV for a flake containing 4000 atoms).

## References:

**(S1)** Woodward, J. T.; Zasadzinski, J. A. Height Amplifications of Scanning Tunneling Microscopy Images in Air. *Langmuir* **1994**, *10*, 1340–1344.