Support Information for:

Dependence of the Friction Strengthening of Graphene on Velocity

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A. Calculation of the contact area between the tip and graphene

The contact area between the tip and graphene can be calculated directly based on a simplified mathematic mode, as shown in Figure S1(a). Assuming the tip apex is spherical with a radius of R, and the indentation depth of the tip into the surface is H. The contact area between the tip and the surface as the red curve shown can be calculated as: $S = 2\pi RH$. The radius of the tip can be measured through SEM images (see Figure S2), and the indentation depth can be obtained from the force-distance curves based on the approaching contact line in contact zone[1] (see Figure S1(b)). Note that the indentation depth needs to be carefully measured due to the hard SiO_2 substrate resulting in the tip press into the surface only a little. When the tip reaches the lowest point, the separation between the tip and the surface will somewhat increase due to the tip can not press into the surface any longer. The measured average indentation depths on graphene with thickness of 0.5 nm and 1.2 nm are about 0.40±0.06 nm and 0.38±0.09 nm respectively. Combining the measured radius of the tip (about 7.5

nm), the calculated contact areas between the tip and graphene with thickness of 0.5 nm and 1.2 nm are about 21.35 nm^2 and 20.48 nm^2, respectively.

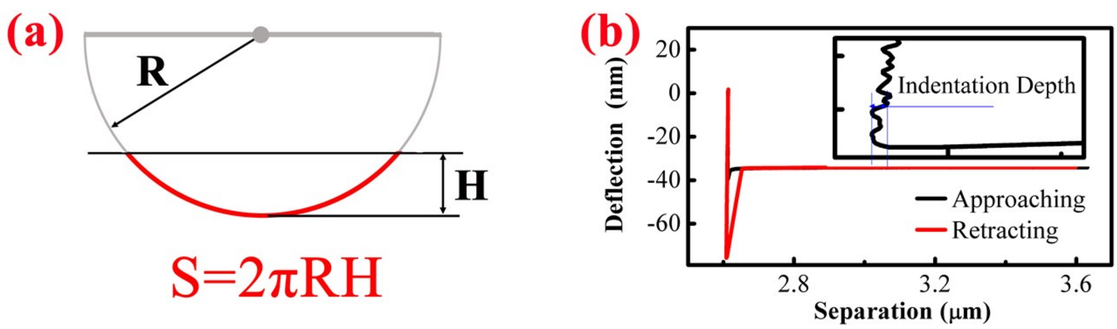

Figure S1. (a) The simplified mathematic mode for calculating the contact area between the tip and graphene, (b) an example of the measured force-distance curve measured on graphene surface. The inset in (b) demonstrates the indentation depth measured from the approaching line. The applied load and the load rate are 5 nN and 1 Hz, respectively.

B. SEM characterization of the AFM tip

AFM tip (PPP-LFMR) used for friction tests was characterized using SEM (HITACHI S-4800) to measure the tip radius. Figure S2 shows the SEM images of the Si tip with different magnifications before friction tests. A circle was adopted to fit the sides of the tip through the drawing software, and the radius of the circle was considered as the radius of the tip, as shown in Figure S2(b). In order to ensure the accuracy, more than five fittings were performed. The measured tip radius was about 7.5±0.8 nm.

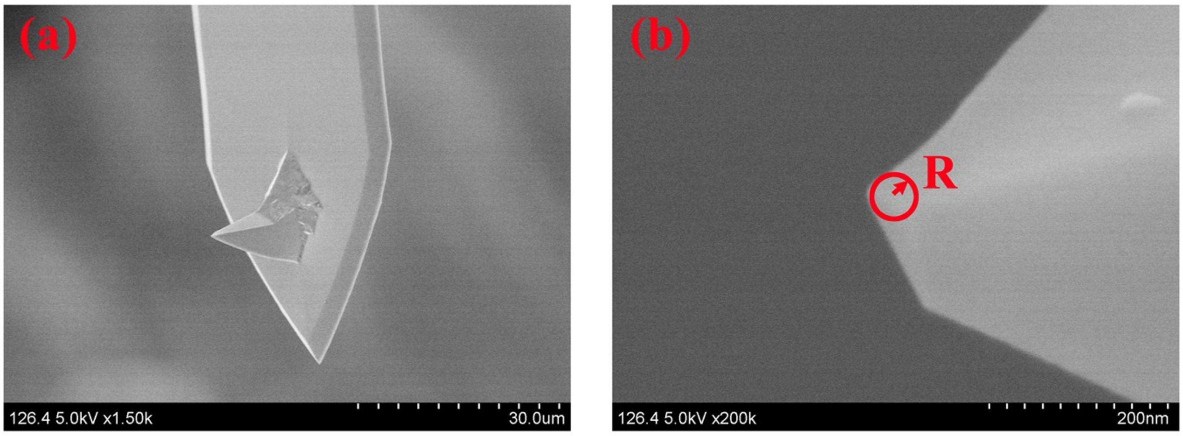

Figure S2. SEM images of the Si AFM tip (PPP-LFMR) measured before friction tests with different magnifications: (a) 1.5 K and (b) 200 K.

C. Friction versus velocity

The friction versus load has been measured on the graphene with the thickness of 0.5 nm, which is concluded in Figure S3. The measuring region is 5 nm x 5 nm, which is equal to the size of the region used for the atomic-scale stick-slip measurement. It can clearly seen that in the range of velocity from 8 nm/s to 65 nm/s, the friction is nearly in the same range due to the relative large error which is caused by the relatively small measuring region.

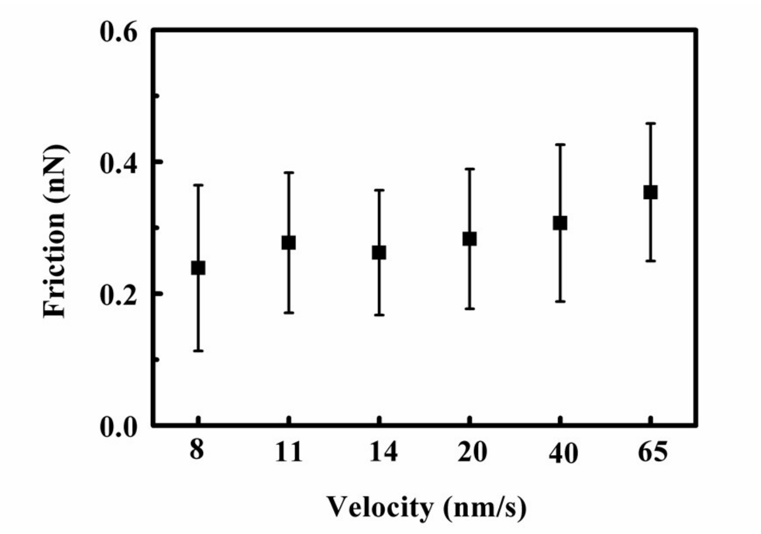

Figure S3. Friction versus tip velocity measured on the graphene with the thickness of 0.5 nm. The graphene region is 5 nm x 5 nm, and the applied load is 10 nN.

Reference

1. H. J. Butt, B. Cappella and M. Kappl, Surf. Sci. Rep., 2005, **59**, 1-152.