

Supporting Information

Covalent Functionalization of Fluorinated Graphene and Subsequent Application as Water-based Lubricant Additive

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S1. High resolution TEM images of the FG and the UFG

In order to demonstrate the prepared FG and UFG possess multiple layered microstructures, the high resolution TEM (HRTEM) images of the FG and the UFG are given. As shown in Figure S1, the prepared FG and UFG are multiple layers rather than single layer.

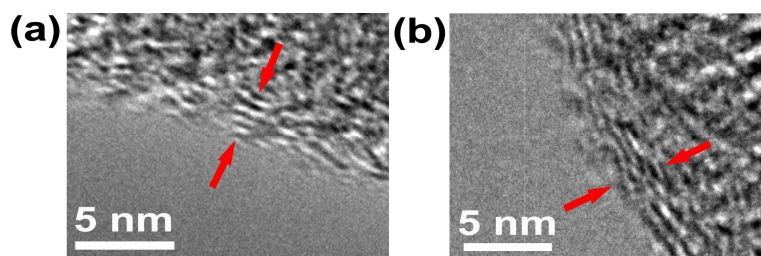


Figure S1. HRTEM images of the FG (a) and the UFG (b).

S2. The Energy-Dispersive Spectrums of the FG and the UFG

In order to further illustrate the samples are pure, the Energy-Dispersive Spectrums (EDS) of the FG and the UFG are given. As shown in Figure S2, the FG sample only contains the elements of C, O and F, the UFG sample contains the elements of C, N, O and F. Because the N and the majority of O come from the urea, thus, it can be convinced that the samples are pure.

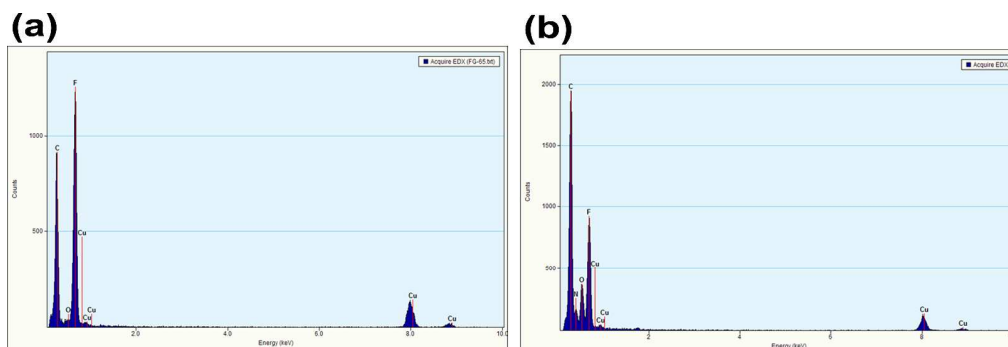


Figure S2. The Energy-Dispersive Spectrum (EDS) of the FG (a) and the UFG (b).

S3. The XPS N1s spectra of the urea and the UFG and the XPS C1s spectra of the FG and the UFG

As shown in Figure S3a, the binding energy of N1s peak of the UFG is obviously higher than that of the urea, indicating different N bonding configurations existed in the UFG¹. As shown in Figure S3b, two peaks at 284 eV and 290 eV correspond to C–C (C=C) bound and C–F (CF₂) bound carbons. The peak of C–F (CF₂) bound of the UFG loses intensity compared with that of the FG, which means the departure of fluorine. Namely, the urea has successfully modified the FG.

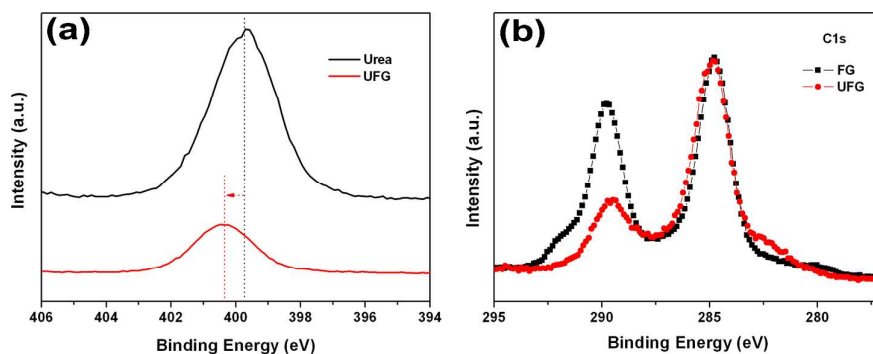


Figure S3. (a) The XPS N1s spectra of the urea and the UFG, (b) The XPS C1s spectra of the FG and the UFG.

S4. The friction coefficients of steel ball-steel block contacts in dry sliding, UFG-1 and GO-1 conditions

As clearly shown in Figure S4, in dry sliding condition, the friction coefficient of steel ball-steel block contact is 0.5, which is obviously higher than that (0.40) of the UFG-1. As an effective water-based lubricant additive, graphene oxide (GO) aqueous solution with the concentration of 1mg/mL (GO-1) shows the similar change trend with that of UFG-1 (1mg/mL), and the initial friction coefficient of GO-1 is 0.32, which is close to the value of 0.40 for the UFG-1.

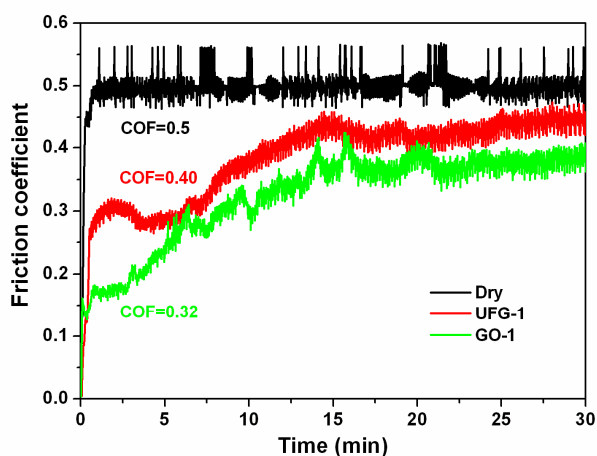


Figure S4. The friction coefficients of steel ball-steel block contacts in dry sliding, UFG-1 and GO-1 conditions.

S5. Tribological properties of the urea solutions

The tribological property of urea solution is tested at a normal load of 50 N and a given oscillation frequency of 15 Hz with an amplitude of 1 mm. 5 mg and 10 mg of urea are respectively dispersed in 5 mL ultrapure water by ultrasonic for 8 h to form urea aqueous dispersions (1 mg/mL, U-1; 2 mg/mL, U-2). As shown in Figure S5, the friction coefficient and wear rate of the U-1 and U-2 are almost equal that of the UFG-0, illustrating that the tribological properties of the U-1 and U-2 are similar to that of pure water (UFG-0), demonstrating small amount of urea can not change the tribological properties of water.

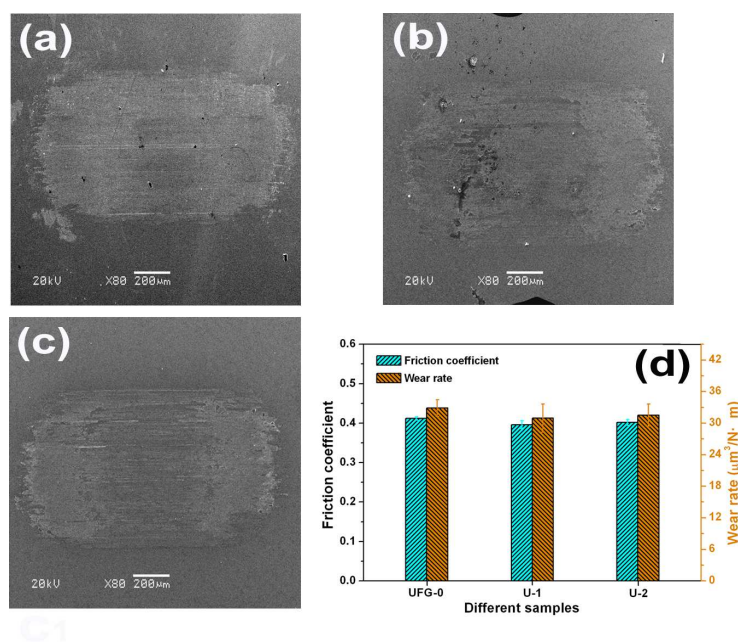


Figure S5. SEM micrographs of the wear tracks for UFG-0 (a), U-1 (b) and U-2 (c); (d) the histogram of friction coefficient and wear rate of the UFG-0, U-1 and U-2.

S6. Element mapping in a section of the worn surfaces

The characteristic distribution of elements in a section of the worn surface for the samples of UFG-0 (Figure S6) and UFG-1 (Figure S7) further confirm the fact that the UFG tribofilm effectively enhances the tribological properties of the water.

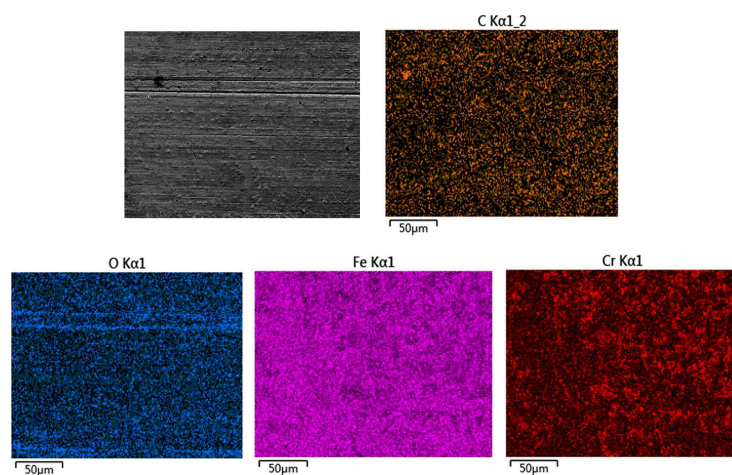


Figure S6. Element mapping of the worn surface for the sample of UFG-0.

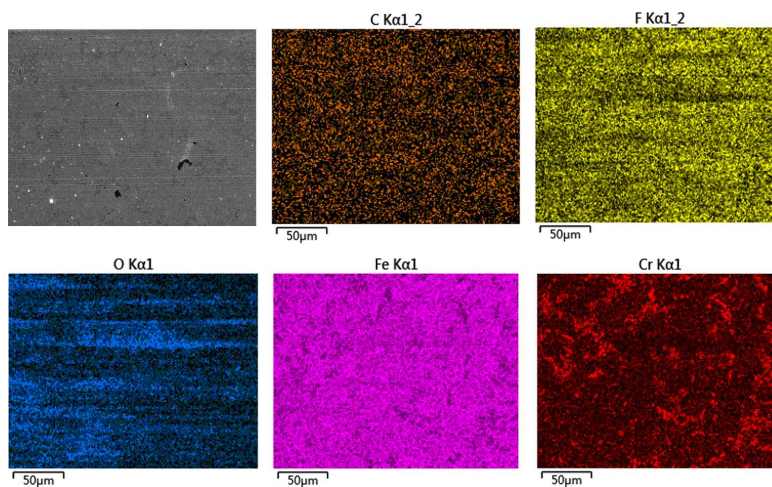


Figure S7. Element mapping of the worn surface for the sample of UFG-1.

References

- (1) Li X,; Wang H,; Robinson J. T,; Sanchez H,; Diankov G,; Dai H. Simultaneous Nitrogen Doping and Reduction of Graphene Oxide. *J. Am. Chem. Soc.* **2009**, *131*, 15939-15944.