Electronic Supplementary Information

Investigating the tribological performance of nanosized MoS_2 on graphene dispersion in perfluoropolyether under high vacuum

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Experiment Section

Synthesis of Nanosized MoS_2 on graphene (MoS_2/Gr). The MoS_2/Gr nanocomposites were synthesized according to the procedures described by Koroteev et al.[1] with some modifications. Briefly, 100 mg of graphene (XF001H, XFNANO®, China) was dispersed and stirred in 20 mL of a water-ethanol (1:1) solution with 100 mg ammonium thiomolybdate $(NH_4)_2MoS_4$ (99.97%, Aldrich, USA) at room temperature until a black homogeneous slurry was achieved. Next, 0.5 mL of concentrated HCl was added in the slurry. After further stirring for 10 min, the solution was filtered through a microporous membrane and the sediment was washed with distilled water for many times to remove HCl. Then the powders were dry to air, and finally calcined at 800 ^oC for 1 h in flowing Ar.

Preparation of PFPE with additives. Considering the result demonstrated by Zhao et al.,[2] 1.0 wt% of MoS_2/Gr was added to PFPE (Fomblin YL VAC 25/6, Solvay Solexis, Italy) and thoroughly mixed by a magnetic stirrer for half an hour and then ultrasonic mixing for one hour. For comparison a similar mixtures with 1.0 wt% G, 1.0 wt%MoS_2 (a commercial MoS_2, with particle size of 0.5 μm, Shanghai Shen Yu Industry & Trade Co., Ltd. China) and 0.5 wt%Gr+0.5wt% MoS_2 were prepared as well.

Characterizations. The microstructures of MoS_2/Gr nanocomposites were characterized using a JSM-6701F field emission scanning electron microscope (FE-SEM) at an accelerating voltage of

5 kV. Transmission electron microscopy (TEM) observations were conducted on a JEOL JEM-1200EX operating with 100 kV accelerating voltage equipped with energy dispersive spectroscopy (EDS) detector. X-ray diffraction (XRD) was carried out on a Bruker D8 DISCOVER high resolution X-ray diffractometer with Cu Kα radiation (λ = 1.54 Å). Raman spectra of the samples were recorded on a Labram HR Evolution Raman spectrometer with a laser excitation wavelength of 532 nm. X-ray photoelectron spectroscopy (XPS) data were collected by a PHI-5702 X-ray photoelectron spectrometer using a monochromatized aluminum Kα anode.

Tribology Test. Taking into account the dispersions of different additives in PFPE, the samples that PFPE plus different additives obtained for one day after preparation are used for the tests. The friction and wear tests were carried out by a ball-on-disk tribometer in a vacuum (lower than 5.0×10^{-3} Pa) at room temperature (20 ± 5 ^{o}C). The fixed upper specimens were the cleaned AISI 440C steel balls (HRC = 60, Ra = 0.10 mm) of 8 mm in diameter, loaded against rotating discs (AISI 52100 steel, ø 24.00 × 7.88 mm, hardness 650HV) with a normal load of 5 N. The rotational speed was 1000 r/min for all tests, corresponding to a linear speed of 0.52 m s^{-1}. Each friction test was repeated three times under the same conditions. After the friction tests, the wear track profiles were analyzed by a noncontact 3D surface profiler (AD Corporation, Massachusetts, USA), and then the wear rates (W) were calculated by the formula:

$$W = \frac{V}{FL}$$

where V is the wear volume, F is the normal load, and L is the total friction distance.

References

1. V. O. Koroteev, D. A. Bulushev, A. L. Chuvilin, A. V. Okotrub, L. G. Bulusheva, *ACS Catal.*, 2014, **4**, 3950−3956.
2. J. Zhao, Y. Y. He, Y. F. Wang, W. Wang, L. Yan, J. B. Luo, *Tribol. Int.*, 2016, **97**, 14–20.