Electronic Supplementary Information (ESI)

High Lubricity and Electrical Responsiveness of Solvent-Free Ionic SiO_2 Nanofluids

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(S1) Structure characteristic of SiO_2-DC5700-NPES and SiO_2-PMPS-M2070 NFs by FTIR spectra

Figure S1a compared the FTIR spectra of initiator SiO_2 NPs, SiO_2-DC5700 salt and SiO_2-DC5700-NPES NFs. The broad peak at 3425 cm^{-1} in the spectrum of SiO_2 NPs is assigned to the H-O-H stretching modes of the free or adsorbed water. The peak at 1105 cm^{-1} can be attributed to the Si-O-Si anti-symmetric vibrations. Another two characteristic peaks at 812 and 473 cm^{-1} correspond to the symmetric stretch and bending mode of the Si-O-Si, respectively[1]. Three absorption peaks appearing at 2850 cm^{-1}, 2925 cm^{-1} (-CH_2- stretching) and 1736 cm^{-1} (C-N stretching) in the SiO_2-DC5700 are all exact proofs that DC5700 has grown from the initiator particles. Whereas, the peaks at 1646 cm^{-1} and 1470 cm^{-1} are assigned to the stretching vibration of the benzene ring in NPES. In addition, the peaks at 2850 and 2925 cm^{-1} in the spectrum of the solvent-free SiO_2 NFs has been strengthened, which is ascribed to the stretching vibration of -CH_2- and -CH_3- from NEPS. The above described results corroborated that the SiO_2 initiator were grafted in succession with corona and canopy.

Figure S1b gives the FTIR spectra of SiO_2-PMPS salt and solvent-free SiO_2-PMPS-M2070 NFs. As for SiO_2-PMPS salt, the main absorption peaks at around 2948 and 1073 cm^{-1} correspond to stretching vibrations of C-H and P=O, respectively, owing to grafting of PMPS onto the SiO_2 surface. Strong peaks at 2928 and 2860 cm^{-1} are observed in the FTIR spectrum of SiO_2-PMPS-M2070 NFs, which are ascribed to the stretching vibrations of $-CH_2-$ and $-CH_3-$ from M2070. Additionally, the peak at 1057 cm^{-1} is assigned to the C-O stretching vibration of M2070. These results give evidence of chemical bonding between SiO_2 NPs, PMPS and M2070.

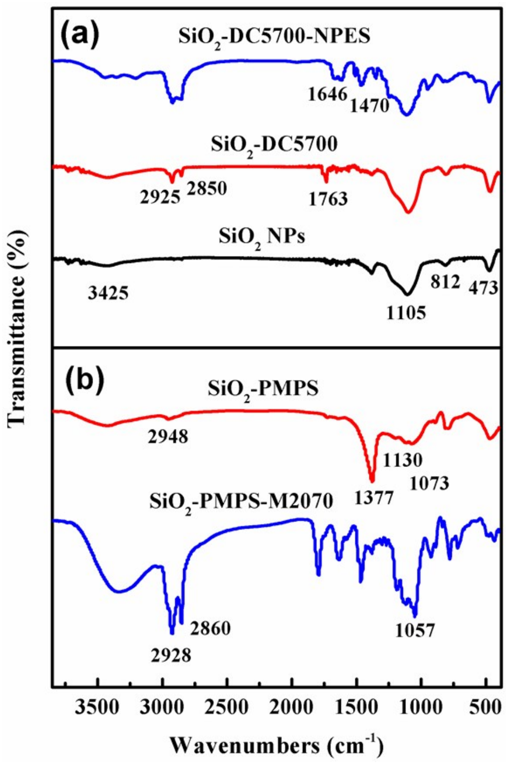

Figure S1. FTIR spectra of initiator SiO_2 NPs, SiO_2-DC5700 salt and SiO_2-DC5700-NPES NFs (a) and SiO_2-PMPS, SiO_2-PMPS-M2070 NFs (b).

(S2) TGA analysis of SiO_2-DC5700-NPES and SiO_2-PMPS-M2070 NFs

Figure S2 shows the TGA curves of the solvent-free ionic SiO_2 NFs, it is seen clearly that the solvent-free SiO_2 NFs exhibited different thermal stabilities owing to the distinct organic corona and canopy structures. At temperatures lower than 180 ^oC, obvious mass loss was not noticed for both kinds of solvent-free NFs, indicating that the NFs endowed with good thermal stabilities and did not contain any residual solvent. However, SiO_2-DC5700-NPES NFs started to degrade at temperatures higher than 200 ^oC probably due to decomposition and oxidative degradation of low-molecular-weight fragments in the canopy polymer. With respect to SiO_2-PMPS-M2070, no mass loss was noticed at temperatures lower than 300 ^oC, indicating its higher thermal stability than that of SiO_2-DC5700-NPES NFs. The rather high thermal stability SiO_2-PMPS-M2070 may allow potential applications under high temperature. Nonetheless, above 300 ^oC, both kinds of NFs started to degrade due to decomposition of the significant fraction of organic groups[2].

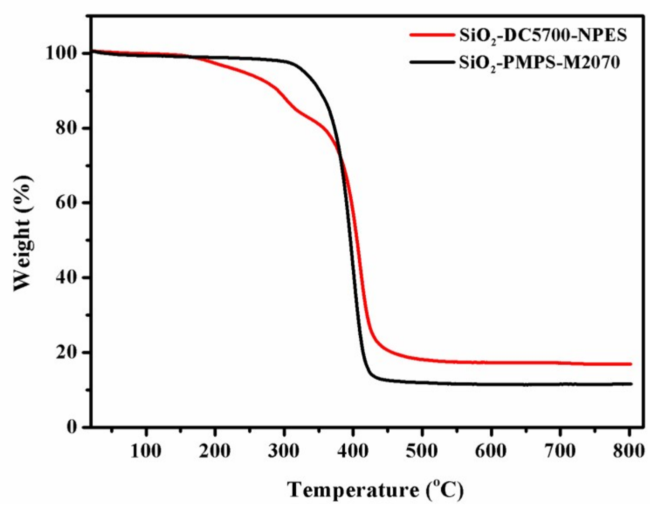

Figure S2. TGA curves of the solvent-free SiO_2 NFs

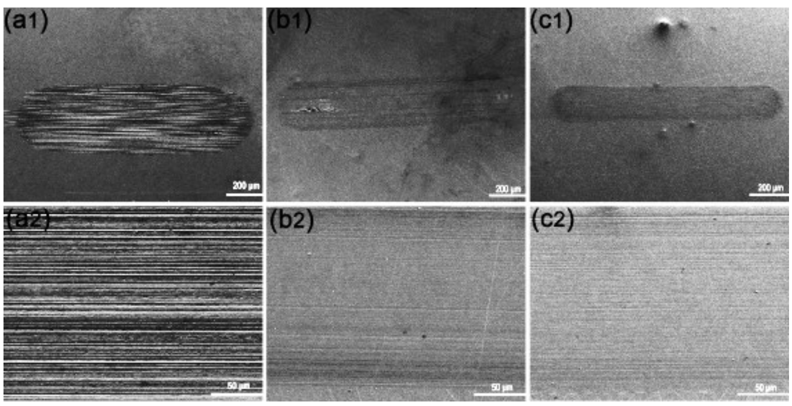

Figure S3. SEM micrographs of worn surfaces of the steel disks when lubricated with PEG (a1, a2), and PEG containing 5 wt% (b1, b2), 10 wt% (c1 and c2) solvent-free

SiO$_2$-DC5700-NPES NFs.

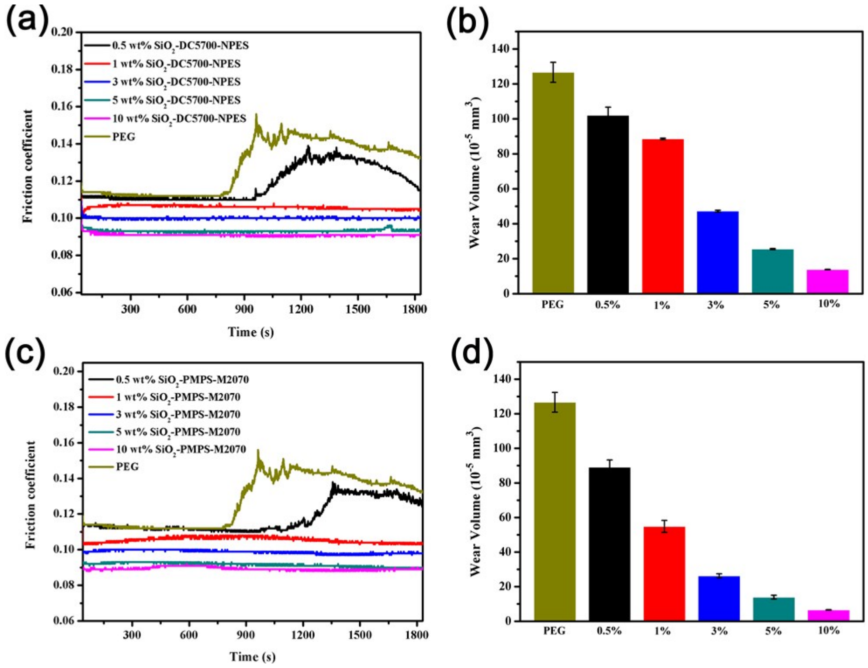

Figure S4. (a) Friction coefficients and (b) wear volumes of the steel disks lubricated with PEG and PEG containing SiO$_2$-DC5700-NPES NFs additive at 100 N; (c) friction coefficients and (d) wear volumes of the steel disks lubricated with PEG and PEG containing SiO$_2$-PMPS-M2070 NFs additive at 100 N.

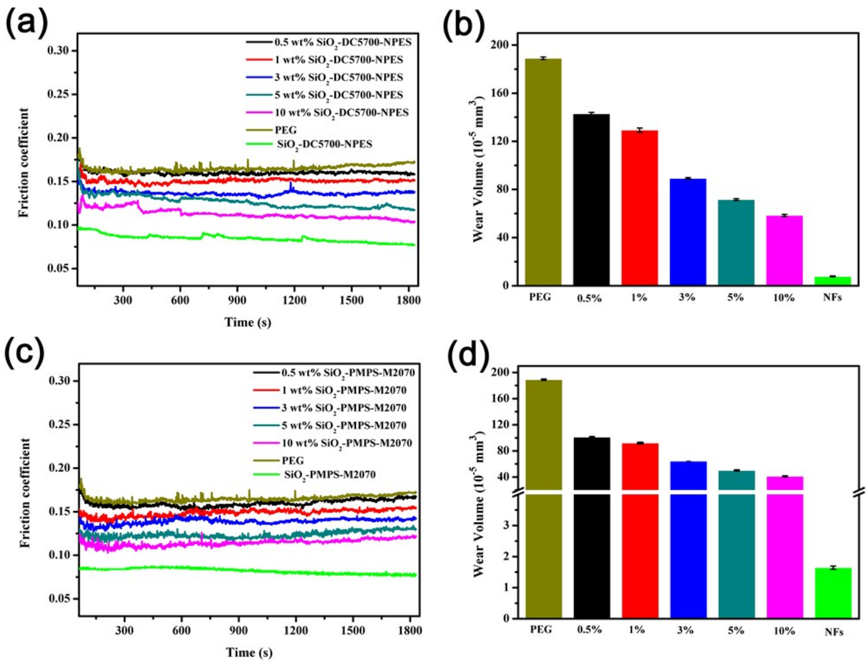

Figure S5. (a) Friction coefficients and (b) wear volumes of the steel disks lubricated with PEG and PEG containing SiO$_2$-DC5700-NPES NFs additive under 100 °C; (c) friction coefficients and (d) wear volumes of the steel disks lubricated with PEG and PEG containing SiO$_2$-PMPS-M2070 NFs additive under 100 °C.

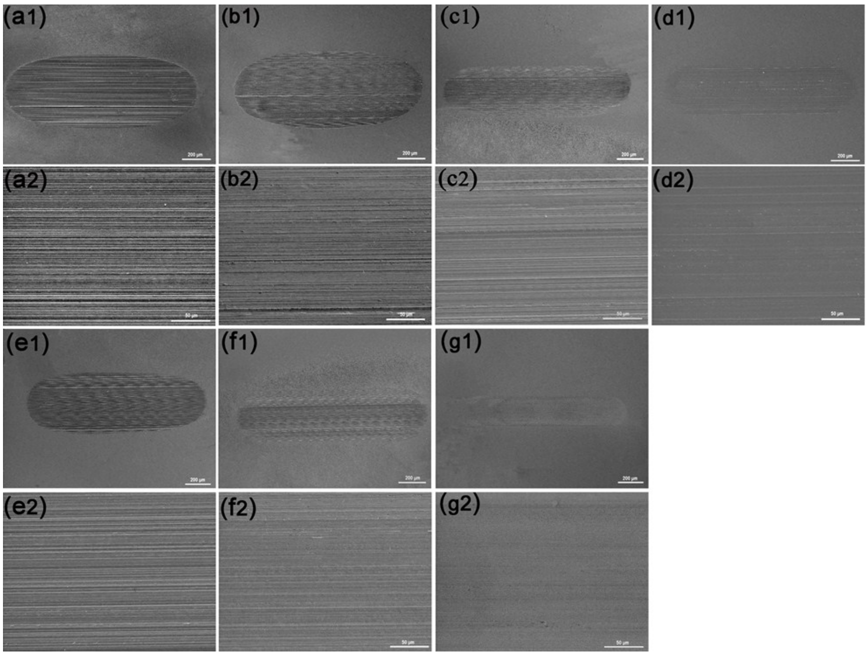

Figure S6. SEM micrographs of worn surfaces of the steel disks when lubricated with PEG (a1, a2); and PEG containing 1 wt% SiO_2-DC5700-NPES NFs (b1, b2); 5 wt% SiO_2-DC5700-NPES NFs (c1, c2); SiO_2-DC5700-NPES NFs (d1, d2); 1 wt% SiO_2-PMPS-M2070 NFs (e1, e2); 5 wt% SiO_2-PMPS-M2070 NFs (f1, f2) and neat SiO_2-PMPS-M2070 NFs (g1, g2) under 100 °C.

References

1 G. H. Du, Z. L. Liu, X. Xia, Q. Chu and S. M. Zhang, *J. Sol-Gel Sci. Technol.*, 2006, **39**, 285-291.

2 H. P. Bai, Y. P. Zheng, T. Y. Wang and N. K. Peng, *J. Mater. Chem. A*, 2016, **4**, 14392-14399.