Supplementary Material

Real-time and Self-powered Lubricating Monitoring Enabled by the Triboluminescence of ZnS:Cu/GF/PTFE Composites

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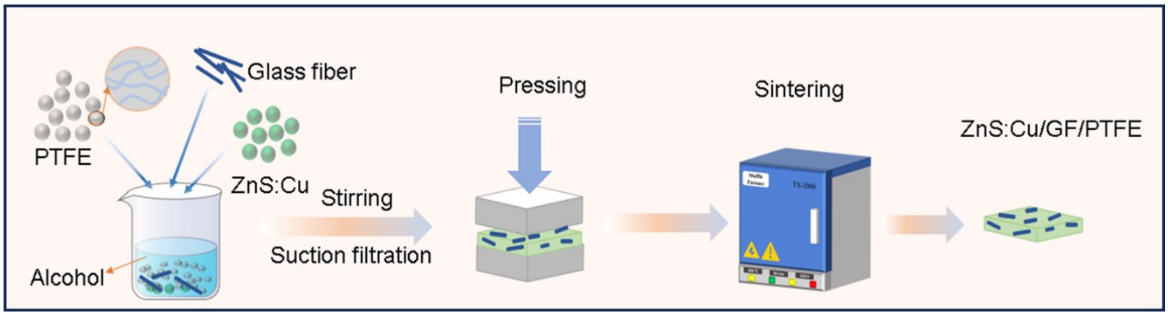

Figure S1. Preparation processes of ZnS:Cu/GF/PTFE composites.

The schematic diagram of the preparation procedure for ZnS:Cu/GF/PTFE is illustrated in Fig. S1. First, ZnS:Cu, glass fiber (GF) and polytetrafluoroethylene (PTFE) are mixed by mechanical stirring in a beaker filled with ethanol. Then, the suspension is pumped and filtered to obtain the mixture. Finally, the as-fabricated ZnS:Cu/GF/PTFE composites were obtained by cold pressing and hot firing.

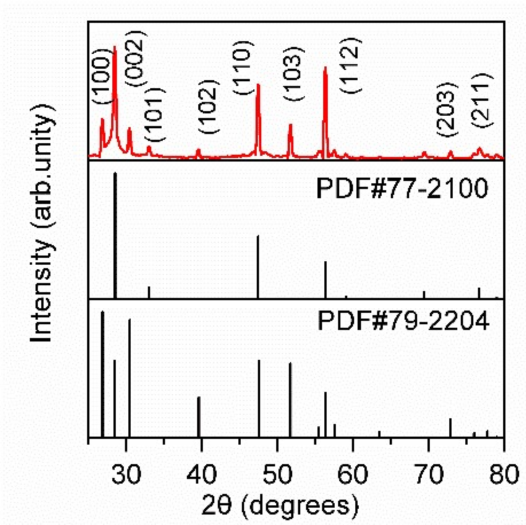

Figure S2. The XRD patterns of ZnS:Cu.

As shown in Fig. S2, the X-ray diffraction (XRD) patterns of ZnS:Cu involves two phases [1]. The lattice planes (002), (101), (110), and (112) represnt the sphalerite structure (PDF#77-2100), and the lattice planes (100), (102), and (103) closely match the wurtzite structure (PDF#79-2204).

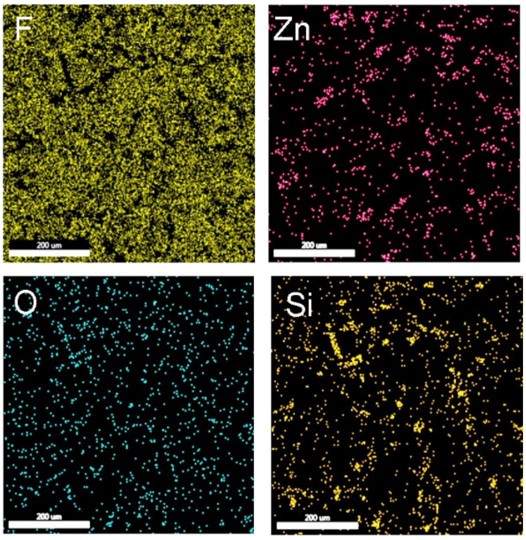

Figure S3. The EDS images of ZnS:Cu/GF/PTFE.

Fig. S3 shows the element distribution diagram (EDS) images of F, Zn, O, Si in ZnS:Cu/GF/PTFE. Zn belonges to ZnS:Cu, and glass fiber is a kind of silicate involving O and Si. The EDS images indicate ZnS:Cu and GF are well distributed in PTFE.

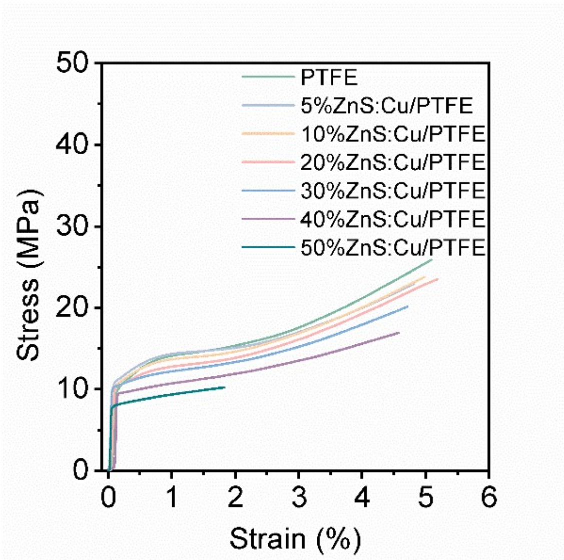

Figure S4. The tensile curves of ZnS:Cu/PTFE composite.

Room-temperature mechanical properties of ZnS:Cu/PTFE were determined by DY35 universal testing machine at a tensile rate of 50 mm min^{-1} according to GB/T 1040.2-2006. As shown in Fig. S4, the tensile strength of ZnS:Cu/PTFE composites gradually decreases with the increase of ZnS:Cu concentration.

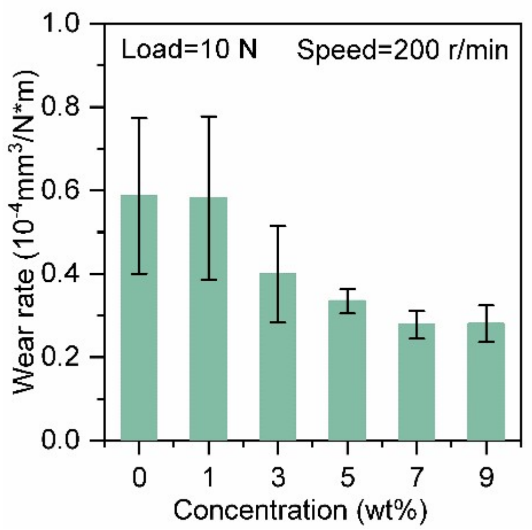

Figure S5. The wear rate of ZnS:Cu/ GF/PTFE composite with various contents of GF.

Fig. S5 shows that the wear rate of ZnS:Cu/GF/PTFE decreases with the increase of the concentration of GF. When the concentration of GF is 7%, the wear rate is reduced by 50%, and no longer decreases with the increase of GF concentration.

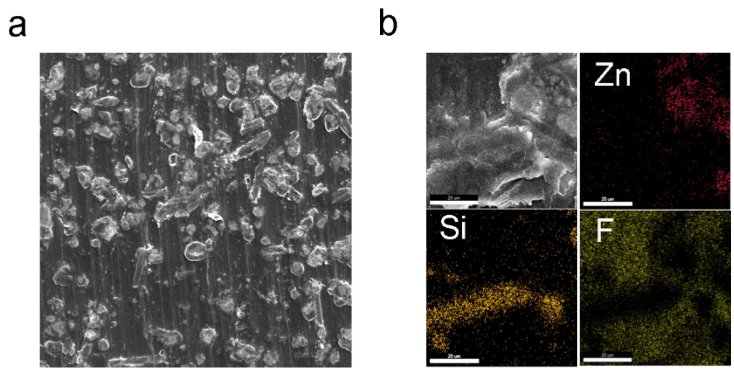

Figure S6. The SEM and EDS images of grinding crack of ZnS:Cu/GF/PTFE.

Fig. S6a presents the SEM image of ZnS:Cu/GF/PTFE grinding crack. Particles and rods are distributed on the surface. As shown in Fig. S6b, Zn and Si are distributed in EDS images respectively, indicating ZnS:Cu and GF expose on the surface of grinding crack, which could support the load during friction to reduce wear of PTFE.

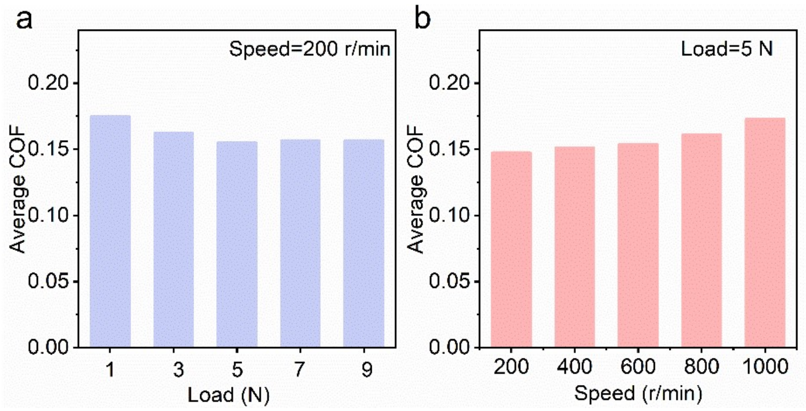

Figure S7. (a-b) Average COF of the ZnS:Cu/GF/PTFE under different loads and speeds.

As illustrated in Fig. S7a, the average COF of ZnS:Cu/GF/PTFE decreases with the increase of applied load. According to the equation [2-4]: $\mu = kN^{n-1}$, (μ, COF; N, load; k and n ($2/3<n<1$), constants), the coefficient of friction is inversely proportional to the load, which is consistent with above result. Figure S7b shows the average COF increases with the increase of speed. Due to the higher interfacial temperature caused by increasing speed, the shear strength of the composite decreases, which leads to the increase of the friction coefficient [5].

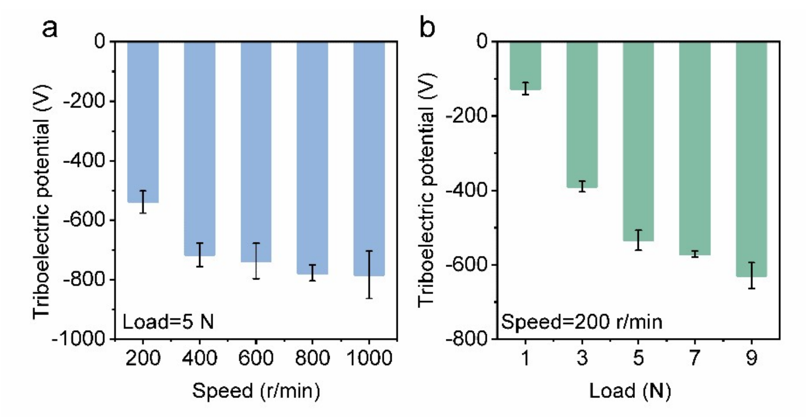

Figure S8. (a-b) Surface triboelectric potential of the ZnS:Cu/GF/PTFE under different loads and speeds.

Fig. S8 shows the tirboelectric potential variations with the increase of the applied speed and load. The TL of ZnS:Cu in ZGPC is mainly derived from triboelectricity under mechanical stimulus. Thus, the TL intensity increases with the increase of the speed and load.

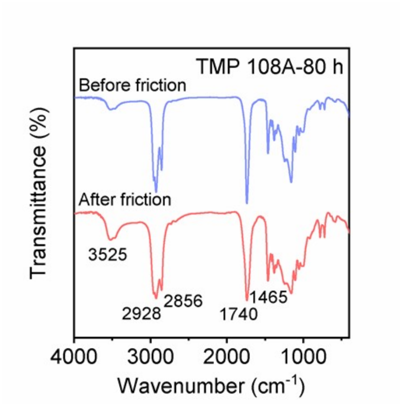

Figure S9. The Fourier infrared spectra of TMP 108A oxidized at 200 °C for 80 h before and after rubbing.

As shown in Fig. S9, the absorption peaks at 3525 cm^{-1} and 1740 cm^{-1} belong to the vibration absorption peaks of carboxyl group and carbonyl group, respectively. Compared to the absorption before friction, the absorption at 3525 cm^{-1} was enhanced and the absorption strength at 1740 cm^{-1} was decreased, which should be caused by the oxidation of carbonyl to carboxyl groups during friction. These results suggest that the TMP 108A is oxidized.

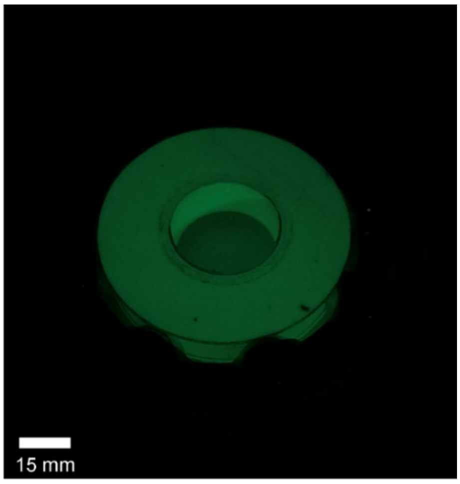

Figure S10. The optical photo of TL rolling bearing under ultraviolet light.

The constructed bearing consists of ZnS:Cu/GF/PTFE inner ring, iron-plated chrome ball and cage, and PVC outer ring. Because of the fluorescence property of ZGPC, the inner ring of the bearing shows a bright green luminescence under UV lamp.

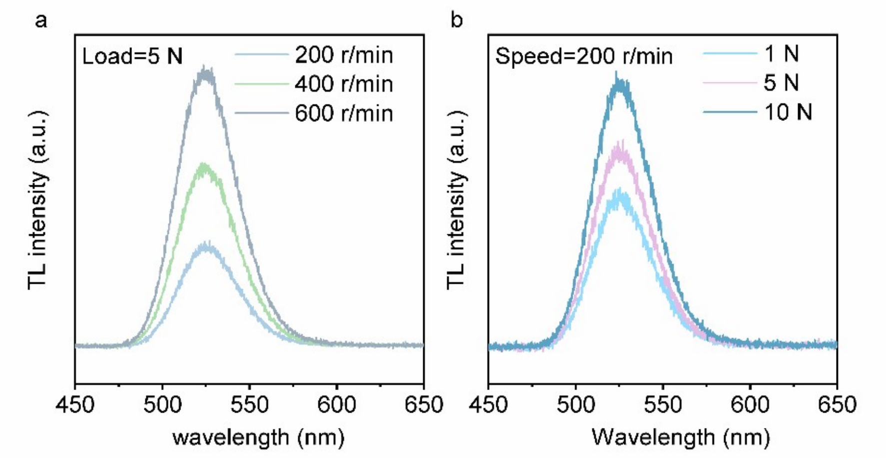

Figure S11. (a-b) TL intensity of ZGPC under different speeds and loads by ball-on-disk method.

Fig. S11 illustrates that TL intensity of ZGPC increases with the increase of the speed and applied load. It could be utilized to monitor the abnormal operation conditions.

Movie S1. The wireless transmission of triboluminescent signals at varied speeds.

References

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