Supplementary Information (SI) for Green Chemistry.

Supporting materials for:

DES-separated bamboo lignin-reinforced DES gels with high conductivity, strength, flexibility, and environmental stability

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Supplementary Notes

Supplementary Notes 1: the recyclability of DES

Extensive studies have confirmed the recyclability of DES. clear evidence. Shen et al. (2019) recycled a ChCl-based DES 4 times under optimal process conditions in their study on eucalyptus pretreatment. The results showed that the recovery rate of the DES was at least 90% per cycle, and the basic chemical structure of the recycled DES remained unchanged. After 4 cycles, the pretreatment efficiency of the DES (delignification rate and hemicellulose removal rate) was largely maintained, and the structural characteristics of the lignin remained stable. Zhai et al. (2025) achieved efficient DES recovery via a straightforward rotary evaporation process. The recovery rate of DES remained as high as 87.8% after 3 cycles, and the recycled DES exhibited stable chemical structure without significant degradation. Moreover, its fractionation efficiency, lignin yield, and furfural production efficiency did not show significant declines. The above studies fully confirmed the feasibility of recovery and reuse of these DES.

Supplementary Notes 2: Toxicity and environmental risks of gel components

Regarding environmental risks, the low toxicity and biodegradability of DES have been confirmed by multiple studies. Juneidi et al. (2015) assessed the toxicity and biodegradability of six ChCl-based DESs, indicating that ChCl-EG-DES exhibits a low toxicity with a median lethal concentration (LC_{50}) > 100 mg/L. Nejrotti et al. (2022) conducted the OECD 301D Closed Bottle Test, confirming that this DES meets the "readily biodegradable" standard. Furthermore, the toxicity of DESs primarily depends on the combination of hydrogen bond acceptor (HBA) and hydrogen bond donor (HBD) groups. As a natural quaternary ammonium salt widely present in both plants and animals, Bet generally exhibits superior biocompatibility compared to ChCl. Consequently, Bet-EG-DES is considered to possess lower toxicity and exert milder environmental impacts. In summary, both DESs selected in this study exhibit low environmental risk and fully comply with the core principles of green chemistry.

In addition, the inorganic components introduced into this system （GO and $Fe_2(SO_4)_3$）, also exhibit controllable and lower environmental risks. GO is prone to sedimentation, flocculation, and surface chemical transformation in natural environments, and its activity significantly decreases with increasing environmental ion concentration and natural organic matter content, thereby greatly weakening its potential ecological toxicity; Previous studies have also shown that low-dose GO does not exhibit significant chronic harm in most aquatic models. For iron salts such as $Fe_2(SO_4)_3$, their ecological impact is milder: iron is one of the most abundant metal elements in nature, and iron ions can form low solubility precipitates with hydroxyl or carbonate ions in water, quickly removing them from the environment. Therefore, their biological contact and toxicity are extremely low under actual exposure conditions.

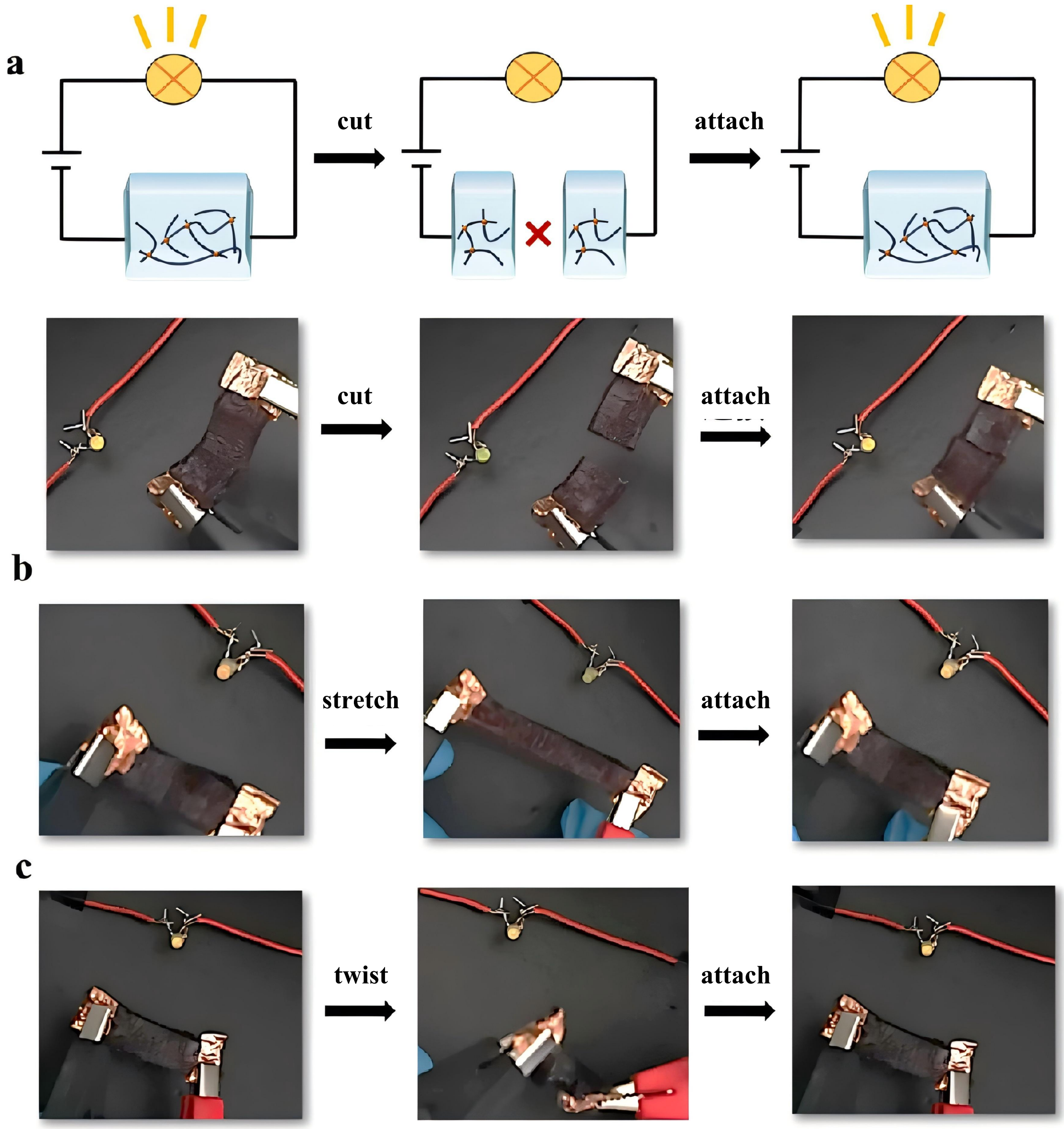

Figure S1: a) Changes of bulb brightness after Fe-L-GO-0.2/PAA cutting off and reconnection; b) changes of bulb brightness when Fe-L-GO-0.2/PAA was stretched; c) changes of bulb brightness when Fe-L-GO-0.2/PAA was twisted

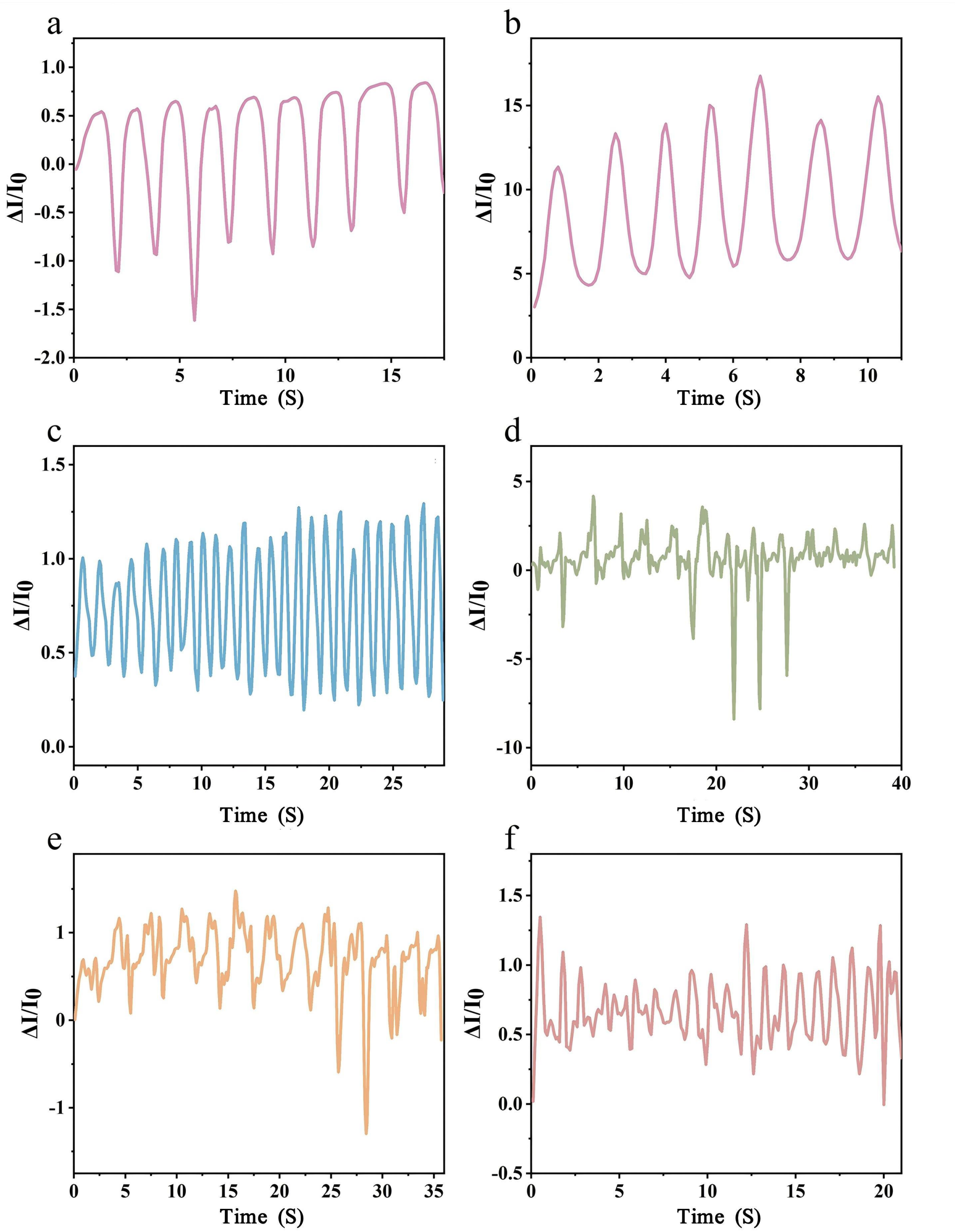

Figure S2 Relative current-time curves of Fe-L-GO/PAA under different deformations: a) slow stretching cycle, b) rapid stretching cycle, c) compression cycle, d) torsion cycle, e) wrist circulation at different bending angles, f) finger circulation at different bending angles

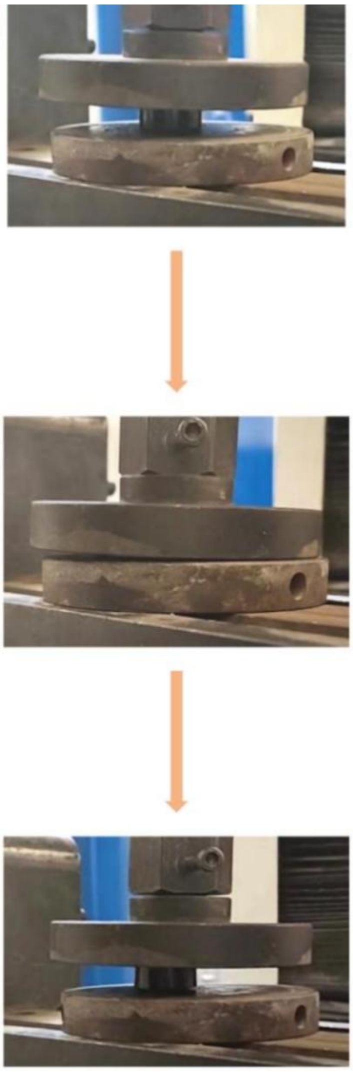

Figure S3 Photos of L/PAA before and after compression

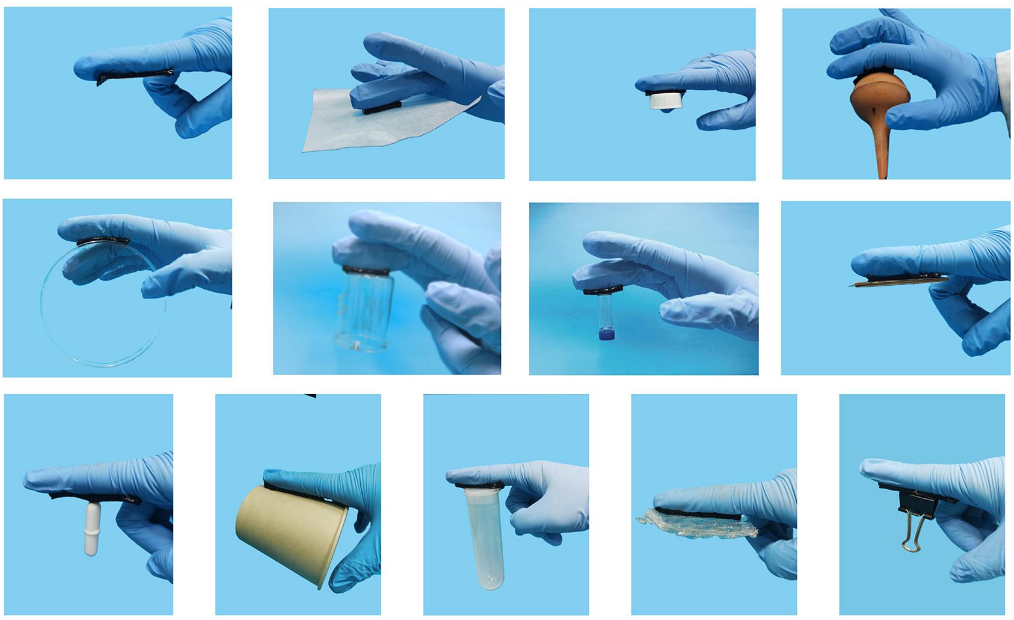

Figure S4 Adhesion effect of L/PAA on different items