Enhanced triboelectric nanogenerators of polymeric sulfur blends with toxin-free synthesis

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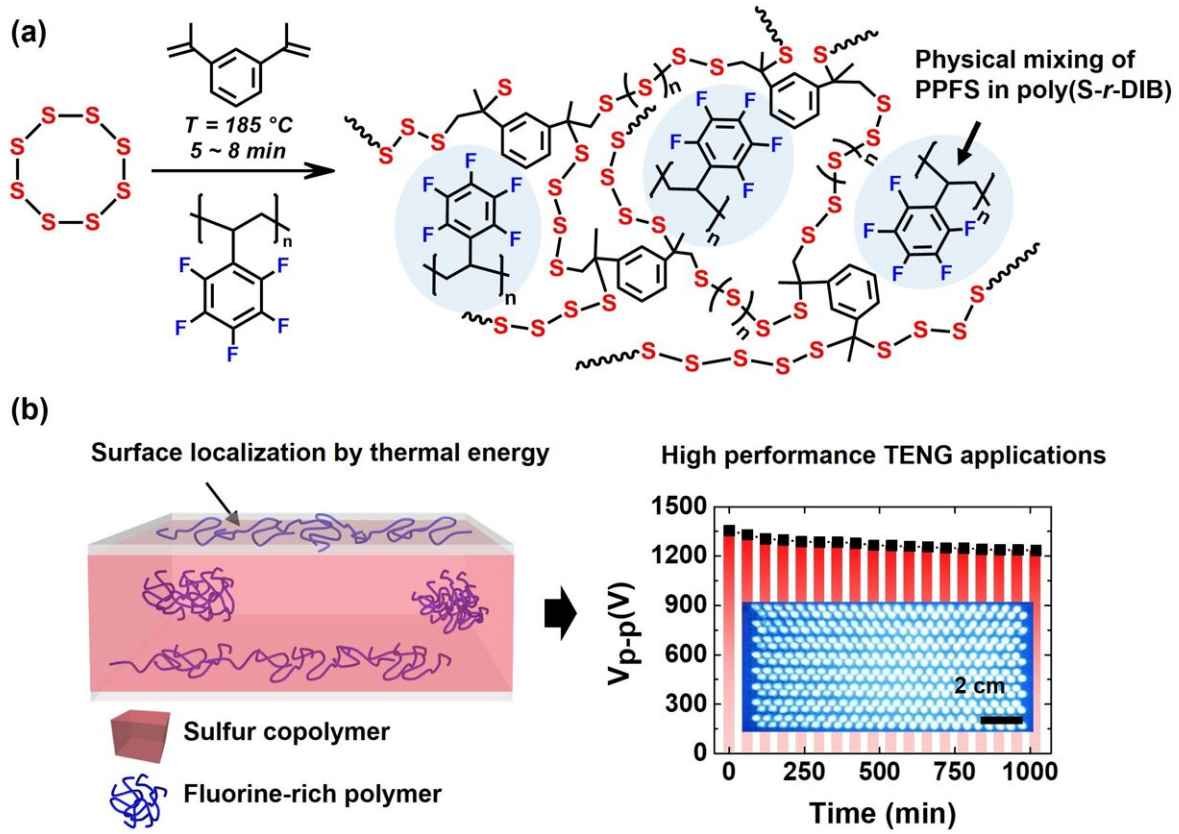

Toxic gas-free synthesis of sulfur copolymer and fluorine-rich polymer blends. (a) schematic of synthesis of the polymer blend through inverse vulcanization. (b) Migrated fluorine-rich polymer to the surface of polymer blend film by thermal energy, achieving high triboelectric performance. Credit: Inha University

A triboelectric nanogenerator (TENG) is an energy-harvesting device that converts mechanical energy into electricity through contact separation or relative sliding movements of two opposite tribo-polar materials. Researchers from Inha University previously reported the first example of sulfur backbone polymer-based TENG. The surface of the sulfur copolymer film was directly fluorinated using toxic fluorine gas to enhance TENG performance.

Sulfur and fluorine have higher electron affinity (EA) of –200 kJ/mol and –322 kJ/mol, respectively when compared to the EA of carbon (–122 kJ/mol). The fluorinated sulfur copolymer film can achieve a six-fold and three-fold increase in voltage and current in comparison with polytetrafluoroethylene (PTFE), the current conventional negative material. Moreover, elemental sulfur is a by-product of petroleum refining; therefore, high-purity sulfur is commercially available at low cost. However, to ensure operational safety for this technique in practical industrial applications, it is necessary to design waste-treatment systems as well as methods for recovery of the toxic fluorine gas.

In order to overcome these limitations, researchers have recently reported a facile and toxic-fluorine-gas-free route for the synthesis of extremely negative triboelectric polymer blends comprising a fluorine-rich polymer (poly(pentafluoro styrene), PPFS) and a sulfur backbone-based polymer. In this method, PPFS molecules were phase-separated onto the air interface via hot pressing, which resulted in highly efficient triboelectric energy harvesting. Despite the low loading value (7.5 wt.%) of PPFS, its surface coverage exceeded 90% owing to the phase separation in the blend film induced by high differentiation of surface energies between the sulfur copolymer and PPFS.

The localization of substantial quantities of fluorine on the film surfaces provided the polymer blends with extremely negative triboelectric properties. The triboelectric performances of the polymer blend films in

the study were significantly superior to those of the conventional carbon-backbone-based polymers. The polymer blend-based TENG presented long-term stable performance of ~ 26 h and enhanced voltage and current outputs that were 8-fold and 9-fold higher, respectively, than those of a PTFE-based TENG. Finally, the researchers demonstrated the ability of a 4-inch film-based TENG to power up 400 series-connected blue LEDs of 3.3 V by the polymer blend film with a triboelectric open-circuit voltage of ~1360 V.

Through this work, the phase-separation strategy of fluorine-rich polymers from sulfur polymers will provide insights for research in both academia and the industry to achieve scalable, low-cost, eco-friendly, and high-performance triboelectric energy harvesting.

The research was published in *Nano Energy*.

More information: Jinhyeok Choi et al, Toxic Gas-Free Synthesis of Extremely Negative Triboelectric Sulfur Copolymer Blends Via Phase Separation of Fluorine-Rich Polymers, *Nano Energy* (2021). DOI: 10.1016/j.nanoen.2021.106761

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