Sustainable biosynthetic transparent films developed for plastic substitute

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Nowadays there is no getting away from plastics. We are producing over 300 million tons of plastic every year, over 40% of which is manufactured into films for packaging. Many of these plastic film

products, such as plastic bags and food wrappers, have a lifespan of mere minutes to hours, yet they may persist in the environment for hundreds of years.

As rapidly increasing production of disposable plastic film products overwhelms the world's ability to deal with them, plastic film pollution has become one of the most pressing environmental issues. With sunlight, wind, and wave action, only a single plastic bag can be broken into as much as 1.75 million microscopic fragments. These so-called microplastics have been found in every corner of the globe from Mount Everest, the highest peak, to the Mariana Trench, the deepest trough. Whereby they have been found in more than 100 species, including, fish, shrimp, and birds.

In a study published in *Matter*, a team lead by Prof. Yu Shuhong from the University of Science and Technology of China (USTC) of the Chinese Academy of Sciences reported an ultra-strong, ultra-tough and transparent nacre-inspired nanocomposite film, which is constructed from sustainable ingredients by living bacteria. This sustainable film is fabricated through a simple one-step fermentation so-called aerosol-assisted biosynthesis process. This novel fermentation process combined nanomaterial deposition and nanoscale assembly with bacterial secretion process to achieve advancing strength and transparency. Benefiting from the combination of clay nanosheets and bacterial cellulose, this film processes a nacre-inspired "brick and fiber" structure which provides outstanding mechanical strength. Meanwhile, the interaction between clay nanosheets and bacteria resulted in finer bacterial cellulose fibers which further improve the strength and transparency of film.

This nacre-inspired composite film possesses multiple intriguing macroscopic properties in one material, including unique optical properties and excellent mechanical properties. Benefiting from the nacre-inspired "brick and fiber" structure with finer BC fiber, the

transmittance and the haze of the nacre-inspired composite film are more than 73% and 80%, respectively, within the whole visible spectrum. The unique optical performance combining high optical transmittance and high optical haze is critical for efficient light management in optoelectronic devices, which is challenging for plastics film because of their homogeneous structure. Such nacre-inspired composite film with high transparency and haze can be utilized as a potential material for plastic substitute in light management.

Meanwhile, the obtained nacre-inspired composite possesses high strength (~482 MPa) and stiffness (~15 GPa), which are more than six and three times higher than those of PET film, respectively. Besides, good flexibility allows the nacre-inspired composite to be folded into desired shape and show no visible damage after unfolding. Moreover, the nacre-inspired composite exhibits an extremely low thermal expansion coefficient (~3 ppm K-1) and a high maximum service temperature (up to 250 oC), which means better thermal stability and dimensional stability of the nacre-inspired composite, making it safer and more reliable than plastics in daily use. Comparing to exciting bio-based polymers, our nacre-inspired composite shows much better mechanical and thermal properties with good sustainability. Furthermore, given the intrinsic feature of fermentation, large-scale production of this sustainable nacre-inspired composite for commercial use can be expected in the near future.

The nacre-inspired composite not only can replace plastic and save us from drowning in them, but also shows great potential as the next generation of substrate material for flexible electronics. In general, an ideal substrate for flexible electronics requires optically transparency for displays, flexibility and foldability, low-cost and dimensionally stability under thermal cycling. Integrates the excellent mechanical, thermal and optical properties in one material, the nacre-inspired composite will play greatly important role as a novel substrate material for flexible

electronics.

More information: Qing-Fang Guan et al. Ultra-Strong, Ultra-Tough, Transparent, and Sustainable Nanocomposite Films for Plastic Substitute, *Matter* (2020). DOI: 10.1016/j.matt.2020.07.014

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