All that powerful materials is not forever

Transient technology is foreseeable as a key ingredient for the development of emerging devices, especially for the sake of a sustainable human society. Scientists explore materials, devices and systems that are completely dissolved or selectively disintegrated at a particular time. Since no toxic products are released, they can be used to replace some existing devices with environmentally friendly alternatives which disintegrates when exposed to water. Consumer optoelectronics, including portable electronics (*e.g.*, smartphones, tablets and laptops) and environmental sensors (*e.g.*, photo/gas/thermal/pressure detectors) together with their network for Internet of Things, have greatly promoted qualities of life. However, rapid technological advances have led to a significant decrease in the lifetime of non-degradable consumer electronics that approaching an average of several months to few years. The hope of sustainable society therefore goes on transient technology.

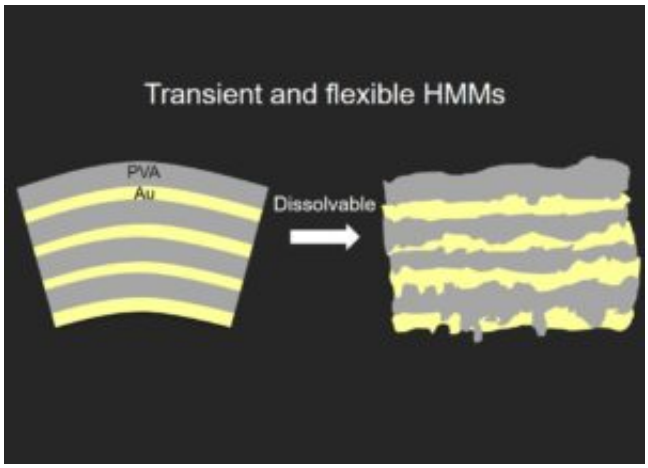

Fig. 1. Proof of concept design of transient and flexible HMMs.

On the other hand, another research highlight is metamaterials, which controls the electromagnetic waves. One of them is hyperbolic metamaterials (HMMs), defined by the iso-frequency curve in momentum-space is hyperbolic shape. Generally, HMMs are composed of metal-dielectric alternative multilayers resulting in the increased photonic density of states. For the biology, photonics, optoelectronics and chemistry applications, HMMs have been proved to increase both of the charge separation and recombination rates. Nano-patterned HMM structures can achieve an 80-fold enhancement of the spontaneous emission. HMMs also enhances the transition rate of the optical gain media to achieve the laser action easily and reduce the threshold. Moreover, it is theoretically suggested that HMMs can serve as the invisible cloak material in the visible wavelength.

As a proof of concept, we demonstrate the polymer-based transient HMMs composed of gold

(Au)/poly(vinyl alcohol) (PVA) with thickness of 25/42 nm for four alternative multilayers (Fig. 1). These transient HMMs devices can be easily washed away and then disappear just by some drops of water. Within 5 min, the dissolving process can destroy the properties of hyperbolic dispersion, and then after 1.5 h, the whole device is almost disintegrated (Fig. 2a). We fabricate the transient HMMs on a polyethylene terephthalate (PET) substrate as future flexible and wearable optoelectronic devices as shown in Fig. 2b. The transient HMMs still remain their original functionalities rather than being damaged during the bending process. Figure 2c presents the integration of the transient HMMs onto a human finger as a wearable device. Owning to the lightweight and flexible characteristics, the angle between releasing state and bending state can reach ~90°, showing the outstanding mechanical tolerance property of the transient HMMs. Moreover, the device exhibits an excellent mechanical stability without any particular photo-degradation for more than 3000 bending cycles on a flexible substrate. Besides, the recent development in metalens has attracted tremendous attention, since it can be operated to focus visible light with only few hundred nanometers thick to replace the normal lens including display, cameras and smartphone. Therefore, we combine the transient HMMs with a smartphone (Fig. 2d) as a degradable portable device to minimize the waste for environmentally friendly purpose.

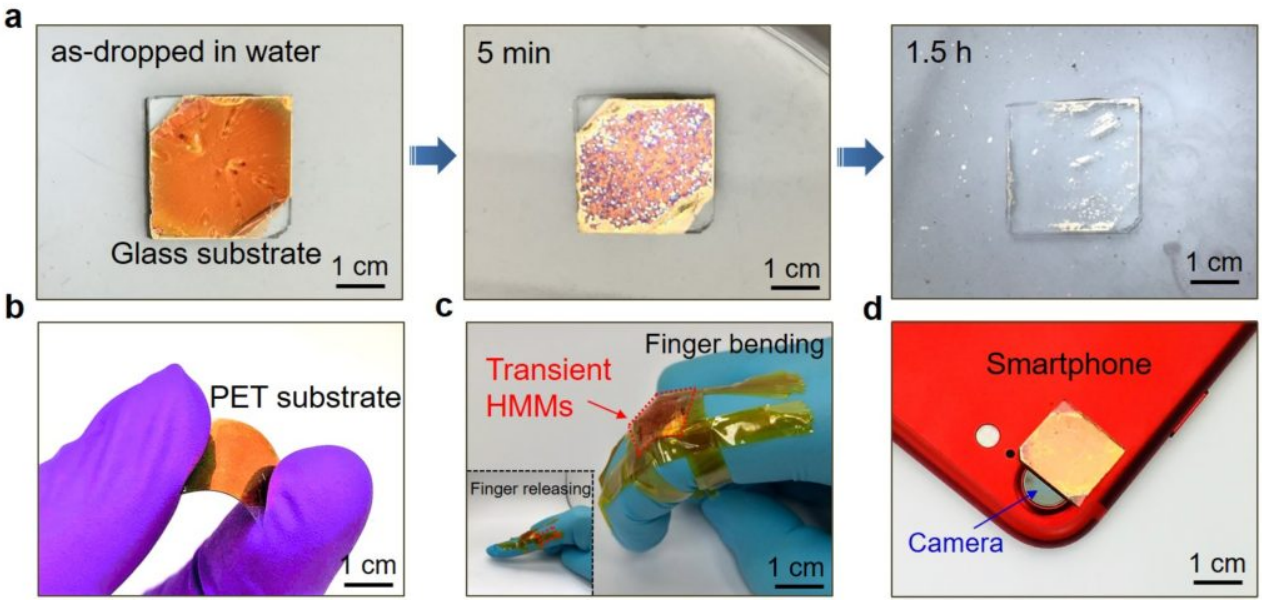

Fig. 2. Demonstration of the dissolvability and the flexibility of the transient HMMs. (a) The dissolving processes in water for the transient HMMs device on a glass substrate at room temperature. (b) Transient HMMs on a PET substrate in a bending configuration. (c) A piece of a transient HMMs device was attached to a human finger in a bending gesture. Inset image is the finger in the releasing configuration. (d) Integration of the transient HMMs with a camera of smartphone.

Interestingly, when introducing the concept of transient, a wide variety applications and unexplored functions can be imagined, such as being an invisible cloak for a while but dissolved away in the next minute; implantable medical media as a short-lived bio-sensor or nanorobotics in the human body that prevents the long-term side effects; and as consumer electronics for enhancing light emission that disappears after use to minimize the environmental damage. The transient HMMs are promised to be the high-speed optical modulator temporarily, but disappear after the transmission of confidential files. Consequently, this demonstration presents a platform for expanding both the research interests of transient technology and metamaterials.

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Publication

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