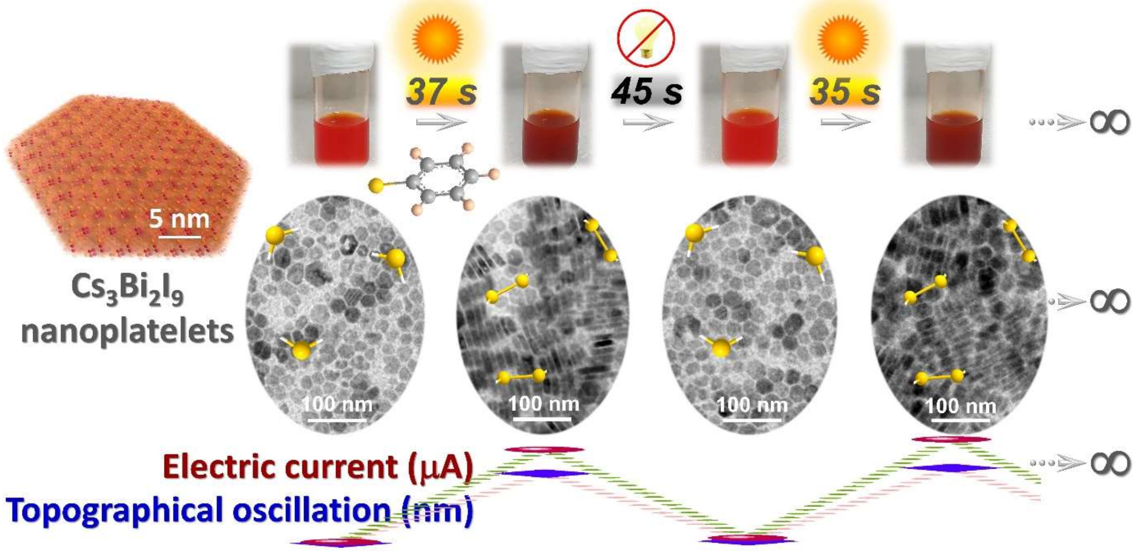
Sunlight-triggered sleep-wake cycle of nanoplatelets



Humans have traditionally aligned their sleep-wake cycles with the natural 24-hour rhythm, sleeping at night and waking with the sunrise. In this cycle, sunlight serves as a stimulus. A newly discovered phenomenon, termed Stimuli-assisted Reversible Nano-Assembly (SaRNA), demonstrates that solution-dispersed nanostructures can mimic a sunlight-triggered sleep-wake cycle, completing the transition in under a minute. These nanostructures are in the form of two-dimensional nanoplatelets, measuring approximately 25 nanometers - far too small to be seen by the human eye - can only be observed using an electron microscope. This sunlight-triggered autonomous motion of the nanoplatelets is associated with a visible color change between red and brown. A red color signifies the sleep state of the scattered nanoplatelets, while a brown color represents their stacked configuration in a sitting posture. In films, the reversible sleep-wake transition occurs over the span of a few hours. The electronic conductivity and electrical current of the nanoplatelets is 3.5 times greater in the stacked sitting posture compared to their scattered sleep state. SaRNA enables reversible mechanical responses in nanoplatelets, inducing topographical oscillations ranging from 14 to 50 nanometers. These nanoactuators hold immense potential for applications in soft robotics, nanogenerators via piezoelectric or triboelectric effects, switchable displays, valves, motors, light modulation, triggered drug delivery, chemical detection, and more. This is the first example of any hybrid or inorganic solid-state nanomaterial to demonstrate perpetual photomechanical response for harnessing onboard energy reserves.

What are these nanoplatelets?

These nanoplatelets are made of cesium bismuth iodide ($Cs_3Bi_2I_9$) which belongs to the family of hybrid perovskites. Halide perovskite is a class of materials that have a specific crystal structure, known as the perovskite structure, in which a metal cation is surrounded by halide anions. Halide perovskites have gained significant attention in recent years, particularly for their exceptional performance in solar cells and optoelectronic devices like photodetectors, light-emitting diodes and X-ray detectors. They exhibit high absorption coefficients, tunable band gaps, and ease of fabrication, making them attractive for low-cost and efficient devices. These $Cs_3Bi_2I_9$ nanoplatelets were prepared by the hot-injection method. In fact, Moungi G. Bawendi received the 2023 Nobel Prize in Chemistry for developing the hot-injection method for making high quality quantum dots that are stable and uniform.

How sunlight triggers the sleep-wake cycle in nanoplatelets?

The $Cs_3Bi_2I_9$ nanoplatelets exhibit a reversible assembly process when exposed to an aromatic thiol, which serves to cap the nanoplatelets. The redox properties of thiols, attached to the photoactive perovskite nanoplatelets facilitate the formation of sulfur-sulfur (-S-S-) bonds, driving the nanoplatelets into a stacked configuration under sunlight exposure. In the absence of light (dark conditions), these sulfur-sulfur bonds break, and the nanoplatelets revert to their scattered (sleep) state. This dynamic process can be repeated indefinitely, demonstrating the system's potential for sustained photo-switchable behavior.

What is the future of SaRNA?

The SaRNA phenomenon, with its innovative capabilities, offers immense potential for a wide range of two-dimensional nanomaterials beyond halide perovskite nanoplatelets. Through innovative strategies, SaRNA can be activated by various stimuli, including infrared and ultraviolet radiation, , electric fields, magnetic fields, temperature and more. Its applications span multiple domains, including display technologies, switchable sensing, inkless writing, security markings, optical shutters and memory storage, molecular devices, electrocatalysis, and photorechargeable batteries.

Reference: V. Hazra, S. Saha, S. K. Pati, S. Bhattacharyya, Light-Triggered Reversible Assembly of Halide Perovskite Nanoplatelets. *Advanced Materials* **2024**, DOI: 10.1002/adma.202414170.

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