Light-Activated Gel: Paving the Way for Smarter Electronics

A novel light-responsive gel combining MXene nanosheets with supramolecular complexes was investigated, showcasing reversible phase transitions and enhanced conductivity.

MXenes are a rapidly emerging class of two-dimensional (2D) materials that have garnered significant attention in materials science due to their unique properties and broad applications. First discovered in 2011, MXenes are synthesized by selectively etching out elements from layered transition metal carbides, nitrides, or carbonitrides. MXenes exhibit a unique combination of metallic conductivity, excellent mechanical flexibility, high surface area, and tunable surface chemistry. These attributes make them highly promising for various applications, including energy storage, electromagnetic interference, water purification, and catalysis. The research team led by Jiun-Tai Chen from National Yang Ming Chiao Tung University explored conductive composite gels with multifunctional capabilities. By incorporating inorganic dopants into an organic matrix, the gel's conductivity can be significantly improved while introducing new properties such as thermal responsiveness, light responsiveness, and self-healing abilities.

The research team studied a light-responsive MXene-based composite gel, termed MXenegel, which integrates azobenzene-containing supramolecular complexes with MXene nanosheets (**Fig. 1**).[1] This innovative material exhibits reversible photo-modulated phase behavior, transitioning between liquid and solid states under UV and visible light, respectively, while maintaining its electrical conductivity, making it suitable for traditional solid-state electronics. The motivation behind this research stems from the need for intelligent and eco-friendly electronic components that can adapt to environmental changes and promote sustainability. Traditional solid-state materials often lack compatibility with dynamic substrates, such as human skin, and do not respond to environmental stimuli. The MXenegel addresses these challenges by providing a new charge transport pathway that can sense environmental changes and be reprogrammed or recycled.

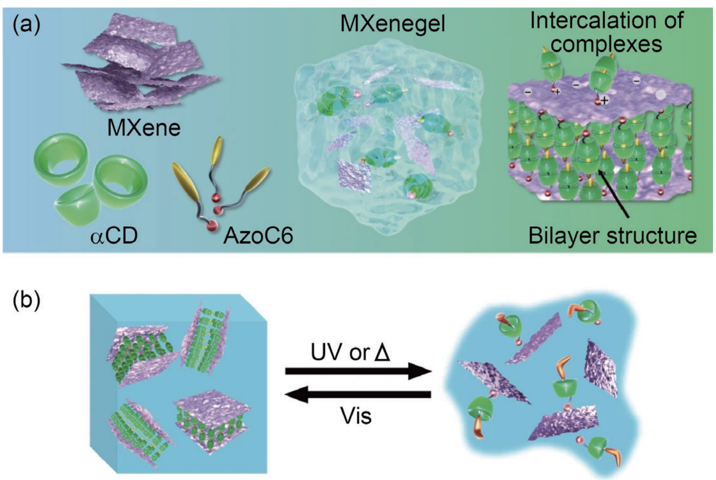

Fig. 1: Schematic illustration of the light-responsive MXenegel. (a) αCD and AzoC6 form a bilayer structure of AzoC6@2αCD supramolecular complexes in MXenes. The positive head ends of the complexes are electrostatically attached to the negatively charged MXene surfaces. (b) Light-responsive sol–gel transition behavior of the MXenegel. [Reproduced from Ref. 1]

Multiple instruments were used in this work, providing spectroscopical and electronic evidence to support the unique behavior of MXenegel. The MXenegel was shown to undergo a gel-to-sol transition upon UV light irradiation, which is attributed to the disassembly of the AzoC6@2αCD inclusions intercalated between the MXene layers. This phase transition is reversible, as the sol-state MXenegel can be converted back to a gel-like structure under visible light irradiation or by keeping it in a dark room at room temperature. Additionally, the X-ray diffraction spectra performed at **TLS 23A1** of the NSRRC played an important role in this research. The small-angle X-ray scattering (SAXS) spectra revealed the microstructural details of MXenegel, confirming the successful formation of the AzoC6@2αCD inclusion complexes and their intercalation between MXene layers (**Fig. 2**).

In summary, this work shows a light-modulated MXenegel with reversible phase transition based on photoresponsive host–guest chemistry. Detailed NMR, 2D-ROESY, XPS, and X-ray scattering analyses obtained from synchrotron facilities revealed the microstructure of the MXenegel. The potential applications of MXenegel in electronic circuitry are diverse and promising. The material could serve as a light-responsive wire in electronic circuits, enabling its integration into solid-state electronics

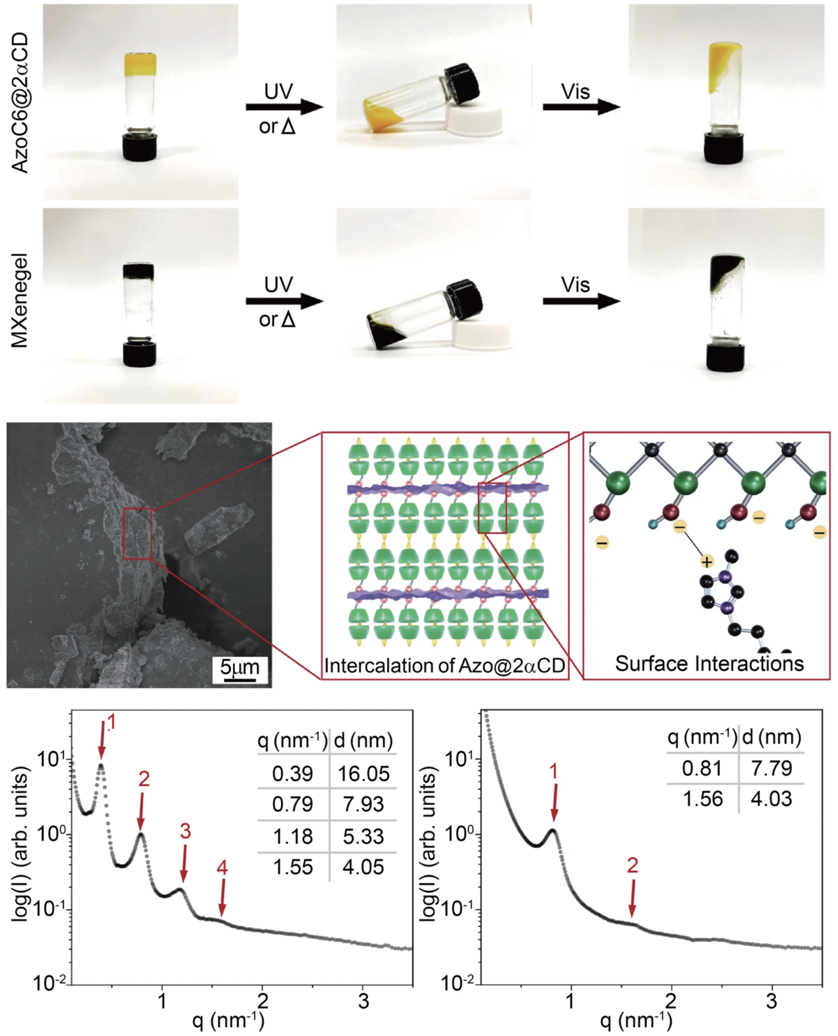

Fig. 2: Light-responsive phase behavior of AzoC6@2αCD and 30 wt% MXenegel under different light irradiations. SEM images of the vacuum-dried MXenegel, in which a cross-sectional view of the MXenegel layers is displayed. The maxima are indicated in the SAXS spectra of AzoC6@2αCD hydrogel and MXenegel. [Reproduced from Ref. 1]

as conductive wires or switches. This material demonstrates a reversible photo-modulated phase behavior, allowing it to function as a photo-controllable switch, which can be utilized to control devices like LEDs. Additionally, MXenegel can be used as a writable and reconfigurable conductive ink, making it suitable for brush printing on various substrates, thus expanding its application in flexible and eco-friendly electronics. (Reported by Yu-Liang Lin, National Yang Ming Chiao Tung University)

This report features the work of Jiun-Tai Chen and his collaborators published in Nat. Commun. ***15****, 916 (2024).*

TLS 23A1 Small/Wide Angle X-ray Scattering

- Supramolecular Complex Scattering
- Materials Science, Chemistry, Surface, Thin-film Technology, Chemical Kinetics

Reference

1. Y.-L. Lin, S. Zheng, C.-C. Chang, L.-R. Lee, J.-T. Chen, Nat. Commun. **15**, 916 (2024).

Versatile Roles of Cesium

Cs-promoted Ru catalysts play a key role in enhancing efficient ammonia synthesis.

Ammonia synthesis is a cornerstone of the global chemical industry as it is essential for fertilizer production and is increasingly recognized as a potential hydrogen carrier for renewable energy applications.[1] However, the conventional Haber–Bosch (HB) process requires high temperatures and pressures, leading to substantial carbon emissions and energy consumption.[2] In the pursuit of more sustainable and energy-efficient catalytic systems, research teams led by Shih-Yuan Chen (National Institute of Advanced Industrial Science and Technology, Japan), Hsin-Yi Tiffany Chen (National Tsing Hua University), Ho-Hsiu Chou (National Tsing Hua University), and Chia-Min Yang (National Tsing Hua University) investigate the impact of carbon support graphitization on the activity and stability of cesium (Cs)-promoted ruthenium (Ru) catalysts for ammonia synthesis. By systematically tuning the graphitization degree of mesoporous carbon plates (MCPs), this study provides fundamental insights into the relationship between carbon support structure, Ru dispersion, and catalytic performance.