A light touch for membrane selectivity

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Credit: AI-generated image (disclaimer)

Membranes that change their pore size in response to external stimuli, such as pH, heat and light, are set to transform separation science and technology. Such smart membranes developed by KAUST researchers display tunable pore size, which means they can selectively separate compounds according to their size when exposed to different light wavelengths.

Covalent organic networks (CONs) have recently emerged as metal-free potential alternatives to conventional membrane materials, such as metal-organic and zeolitic frameworks. These lightweight crystalline porous nanomaterials, which result from organic molecular building blocks held together by strong covalent bonds, are stable in aqueous and organic solvents. They also present a well-defined topology and pore size, which makes them attractive for applications in many fields, including gas adsorption and separation, energy storage and conversion, optoelectronics, chemical sensing and drug delivery. However, these structural features cannot be altered, which restricts the membranes' applicability.

A KAUST team has now generated a light-responsive membrane by incorporating light-switchable azobenzene units into a CON. These light-switchable units adopt two different configurations depending on the irradiation wavelength: atranslinear geometry when exposed to UV light and acisbent geometry when exposed to visible light. This approach was "inspired by cell membranes with stimuli-responsive channels for self-regulating permeability and selectivity in response to environmental signals," says postdoc Jiangtao Liu, who led the study under Suzana Nuñes's mentorship.

The researchers used azobenzene derivatives bearing one reactive group at each extremity as linkers to bridge large flexible cyclic molecules, called cyclens, and to form a continuous network. They dissolved azobenzene derivatives in a dichloromethane–hexane mixture and cyclen in water and allowed these precursors to react at the aqueous–organic interface to produce a free-standing membrane. The membrane displayed a "unique origami-like structure that can be folded and unfolded under UV and visible light," Liu says.

By controlling the trans-to-cistransformation of azobenzene using light, the team remotely manipulated the membrane pore size at the molecular

level and, consequently, dynamically tuned the permeability and selectivity of the membrane toward various solvent and dye molecules. Liu explains that exposure to UV light "closes" the gates and reduces the pore size, which can enhance membrane selectivity. Conversely, the initial pore size corresponding to the "open" state can be retrieved using visible light.

The team plans to expand their work by designing new smart membranes for DNA, RNA or virus recognition using unique host-guest interactions.

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