An Insight into the Next-Generation Smart Membranes

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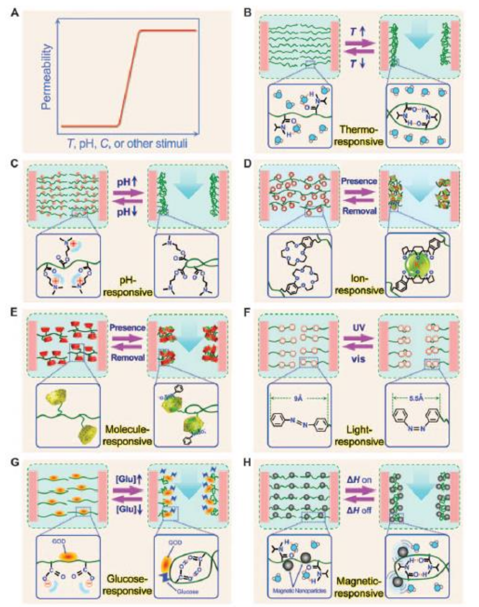
INTRODUCTION

Membranes are used in desalination or water treatment to separate pollutants from water based on characteristics such as size or charge. Nanofiltration (NF), ultrafiltration (UF), microfiltration (MF), and reverse osmosis (RO) are typical membrane techniques. However, traditional membranes have a number of disadvantages, including fouling both on surfaces and in internal structure, uncontrollable pore size, and membrane features.

Smart membranes, also known as stimuli-responsive membranes, have recently attracted attention due to their selectivity, tunable permeability, and tunable and/or reversible attributes. This new generation of smart membranes is created by integrating various stimuli-responsive materials into membrane substrates. These multi-functional smart membranes can self-adjust their physical and chemical features in response to environmental signals such as temperature, pH, light, and other stimuli.[1]

Thermo-responsive membranes, pH-responsive membranes, ion-responsive membranes, molecule-responsive membranes, UV-light-responsive membranes, glucose-responsive membranes, magnetic-responsive membranes, and redox-responsive membranes are the current kinds of smart membranes. Because of their smart structures, they have the potential to improve performance by providing high selectivity without reducing permeability, high mechanical stability, and high resistance against fouling, and can meet requirements such as molecular weight cut-off (MWCO), removal efficiencies, and wastewater quality. The responsive gating function is divided into two models: positively and negatively responsive gating membranes.

Figure 1 (left) shows smart membranes with a positively-responsive gating model. Figure 2 (right) shows smart membranes with a negatively-responsive gating model.[2]



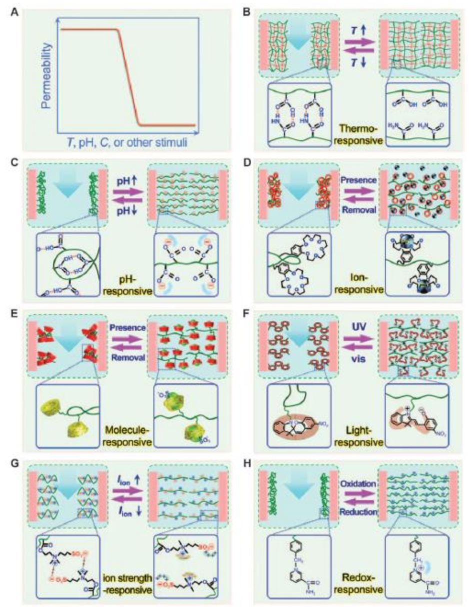


Figure 1 (left). Smart membranes with a positively-responsive gating model.

Figure 2 (right). Smart membranes with a negatively-responsive gating model.

KINDS OF SMART MEMBRANES

Thermo-responsive Smart Membranes

Thermo-responsive polymers, such as N-substituted polyamides and poly(2-oxazolines), polyethers, poly(vinyl caprolactone), and poly(methyl vinyl ether), typically exist at a low critical solution temperature (LCST), which is important in the positively-responsive gating function.

pH-responsive Smart Membranes

Polymers with weak alkaline groups are used to fabricate smart or intelligent membranes with a positively-pH-responsive gating function by protonation or deprotonation for configuration changes.[2]

Ion-responsive Smart Membranes

Copolymers can be used to produce PNIPAM and crown ether-based ion-responsive smart membranes that use the PNIPAM units as actuators and the crown ethers as ion receptors.[2]

Molecule-responsive Smart Membranes

The ability of beta-cyclodextrin (b-CD) to identify molecules and the thermoresponsiveness of PNIPAM could be used to create smart membranes with a positively molecule-responsive gating function that can perform the separation or detection of certain molecules.[2]

UV-light-responsive Smart Membranes

By using substances based on azobenzene, which undergoes a trans-cis isomerization conversion in response to UV light, smart membranes with a positively-UV light-responsive gating function can be produced.[2]

Glucose-responsive Smart Membranes

By combining glucose oxidase with pH-responsive polymers with weak acid groups, such as carboxylic acid groups, smart membranes with a positively glucose-responsive gating function can be produced (GOD).[2]

Magnetic-responsive Smart Membranes

Magnetic nanoparticles, such as iron oxides, are doped with thermo-responsive polymers to include a magnetic-responsive property into smart membranes.[2]

KINDS OF SMART MEMBRANES

Ion-strength-responsive Smart Membranes

Because of the simultaneous presence of positive and negative charges, smart membranes with a negatively-ion-strength-responsive gating function can be prepared using zwitterionic polymers such as poly(N,N0-dimethyl(methylmethacryloyl) ethyl) ammonium propane sulfonate) (PDMAPS).[2]

Redox-responsive Smart Membranes

Smart membranes with negatively oxidation-responsive gating functionalities can be produced by using oxidizable polymers such as poly(3-carbamoyl-1-(p-vinylbenzyl)pyridinium chloride) (PCVPC).[2]

CONCLUSIONS

Smart membranes can show tuneable features based on the condition of the stimulus or stimuli present internally or externally, resulting in improved and desirable controllability over the process of pollutant removal from water. Because of their physicochemical stability, repeatability, and long life, stimuli-responsive smart materials (mainly adsorbents and filtration membranes) have the potential to be key materials for membrane production, particularly in the field of water treatment.

Smart membranes have a bright future, and it is important to investigate and encourage their use and advancement.

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