Polydopamine Coatings with Nanopores for Versatile Molecular Separation

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Abstract: There are increasing demands for highly efficient and multi-functional membranes in various separation processes. Mussel-inspired polydopamine (PDA) has provided a promising way to meet these requirements due to both of the surface-adhesive property and film-forming ability. Herein, uniform, compact and robust PDA coatings were fabricated on an ultrafiltration substrate via tailoring the oxidized self-polymerization of dopamine. The as-prepared PDA coatings are nanoporous (0.56-0.04 nm and 0.93-0.04 nm) with a thickness of ~75 nm, endowing the composite membranes with high solute rejection and solvent permeability during molecular separation. They are useful in organic solvent nanofiltration due to their superior structural stability. Moreover, the composite membranes can be applied for nanometer catalyst recycle from organic solvents for the first time, which has much broadened the potential applications of these mussel-inspired coatings for versatile separation processes.

Introduction:

Molecular-level separation plays crucial role in chemistry, energy and environment fields. Membrane technology has been regarded as a most promising alternative to conventional separation process due to its efficient and energy-saving features. Herein, a compact and robust PDA coatings were fabricated on ultrafiltration membranes triggered by $CuSO_4/H_2O_2$ as the selective layers applied in aqueous and organic nanofiltration.

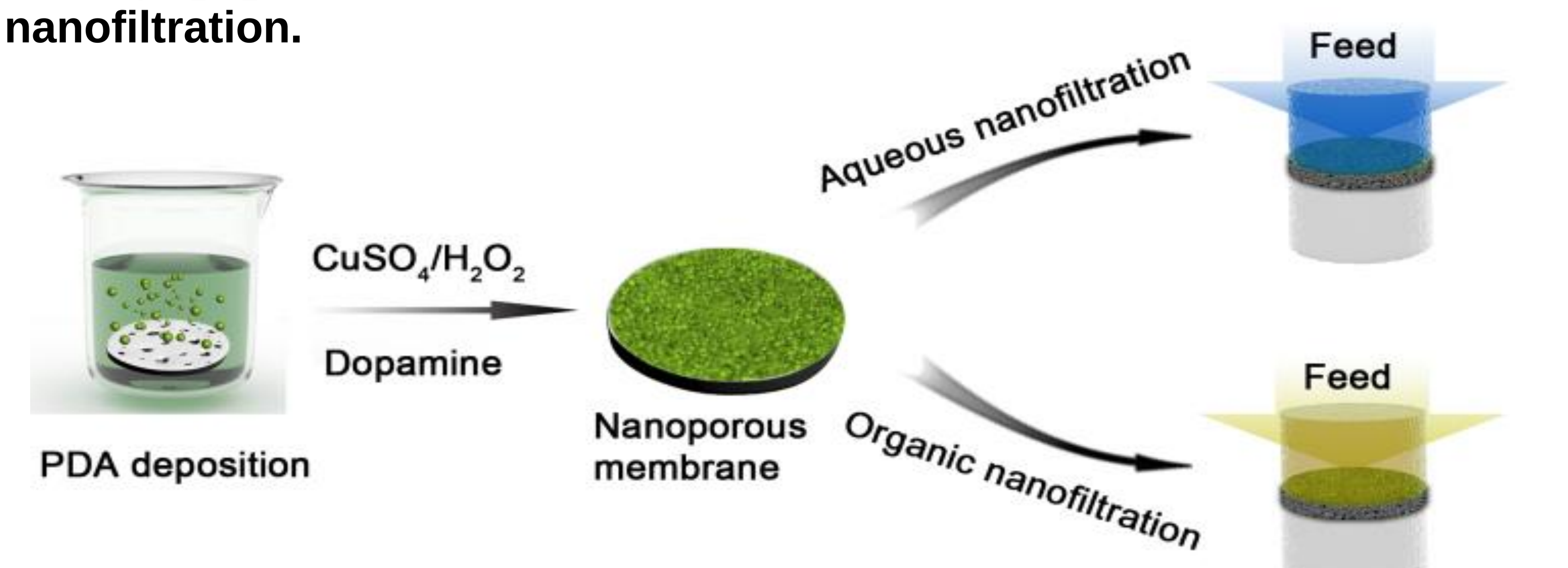

Fig. 1 Schematic diagram of PDA deposition processes and application of composite membranes for versatile nanofiltration.

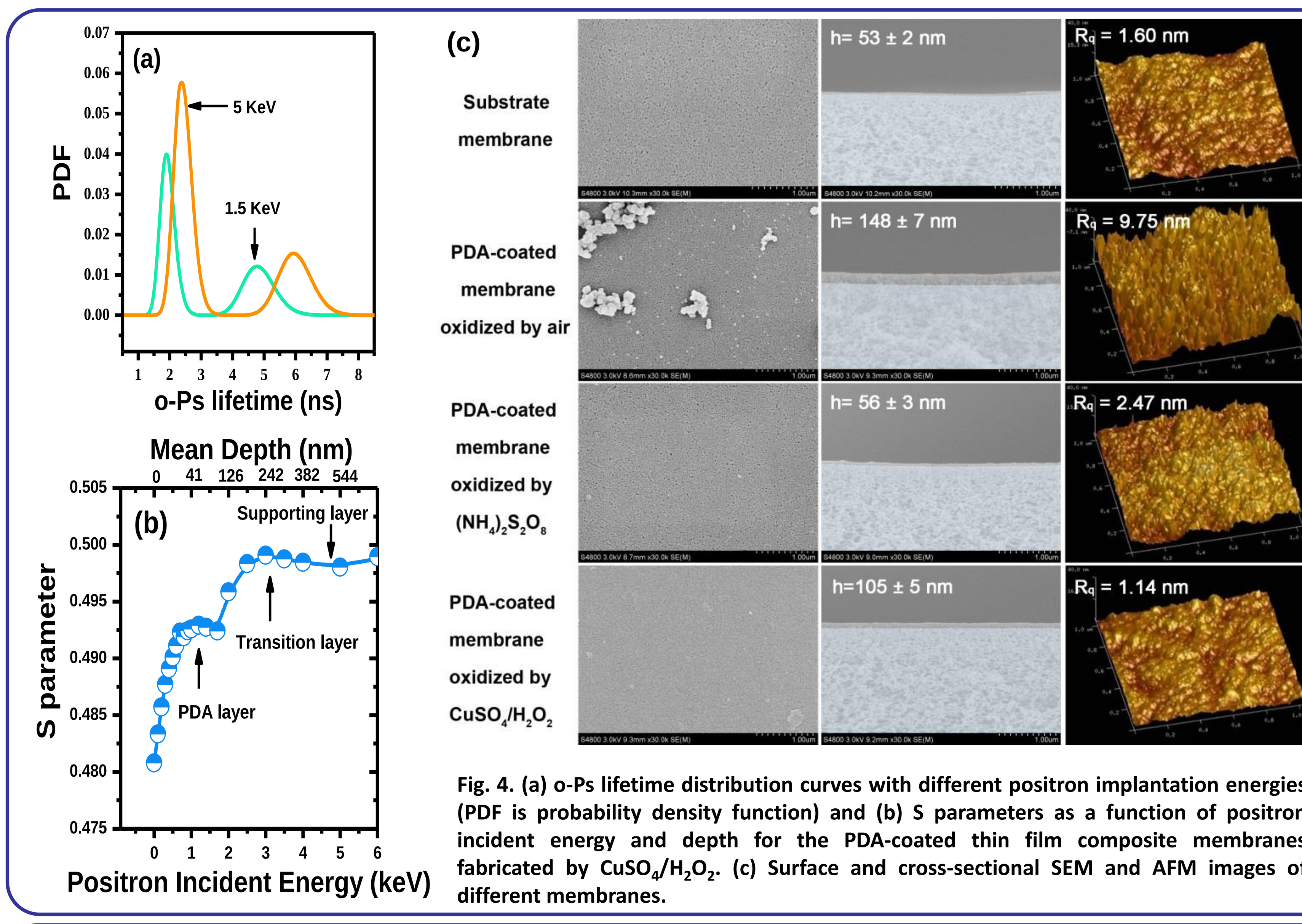

Fig. 4. (a) o-Ps lifetime distribution curves with different positron implantation energies (PDF is probability density function) and (b) S parameters as a function of positron incident energy and depth for the PDA-coated thin film composite membranes fabricated by $CuSO_4/H_2O_2$. (c) Surface and cross-sectional SEM and AFM images of different membranes.

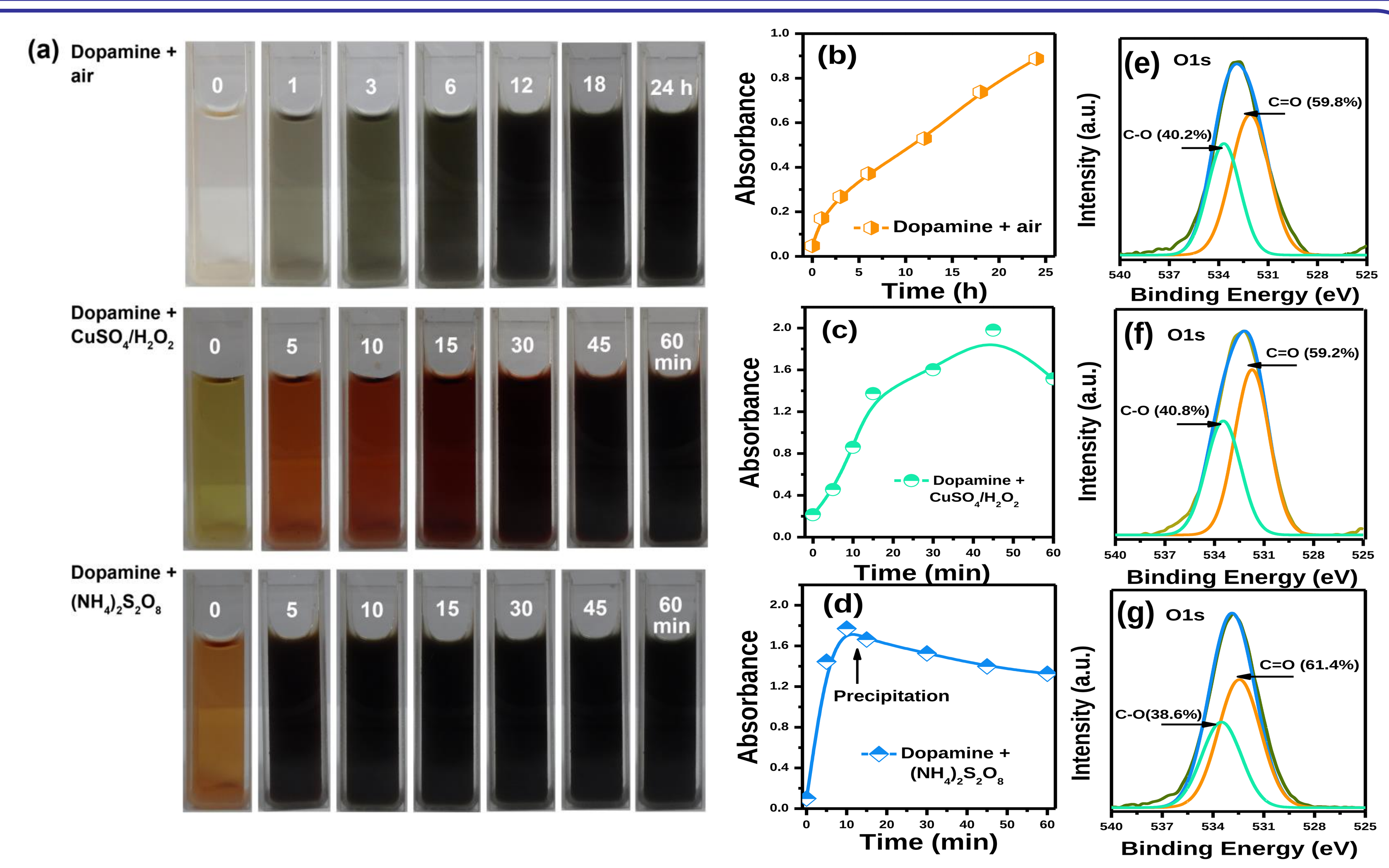

Fig.2 (a) Photographs and (b-d) time-dependence of UV-vis absorbance at 420 nm for various diluted dopamine solutions with different oxidants. (e-g) High-resolution XPS spectra of O1s in PDA powders oxidized by different oxidants.

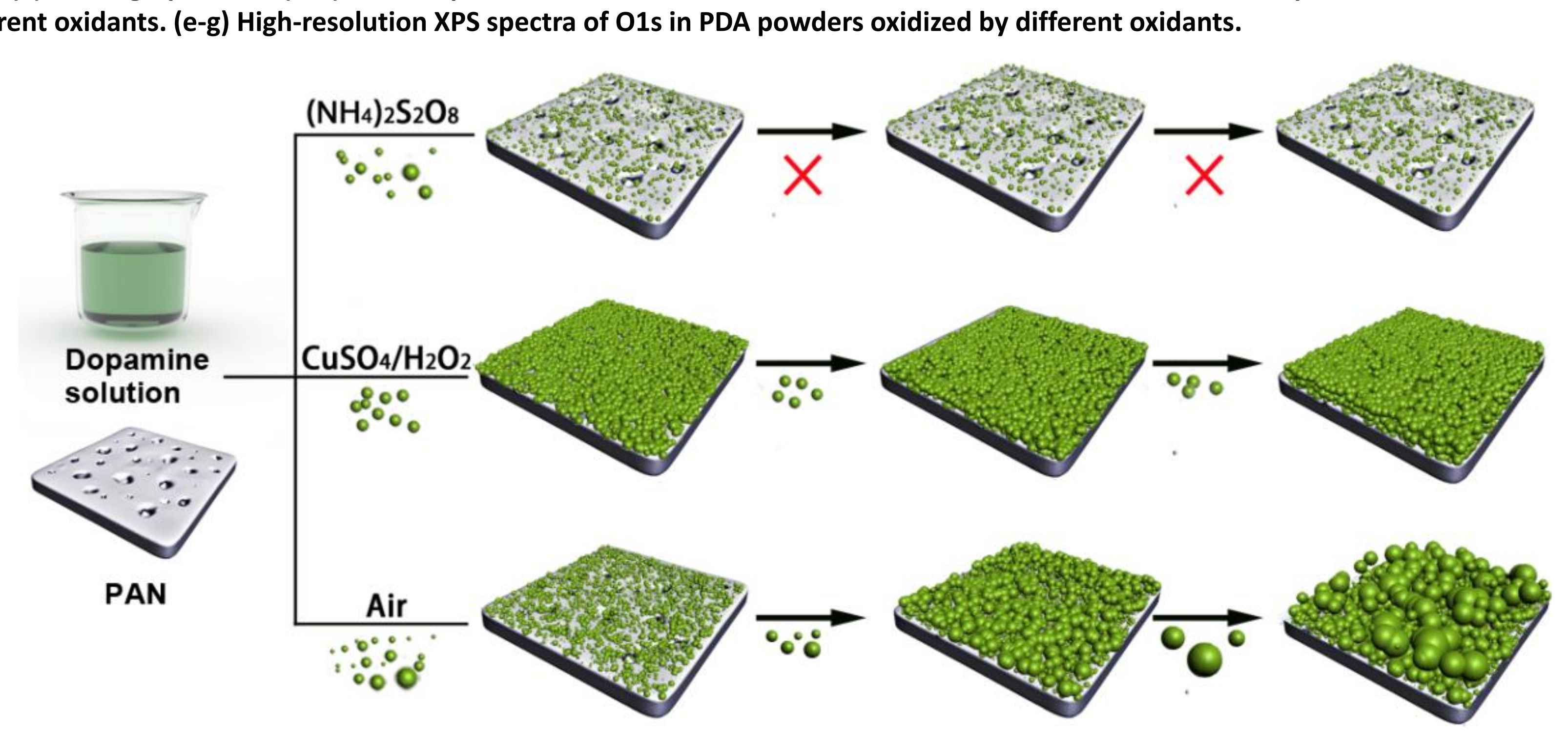

Fig.3 Schematic diagram of PDA deposition processes on the substrate surface oxidized by three different oxidants. "×" represents the PDA particles are not able to deposit onto the substrate surface.

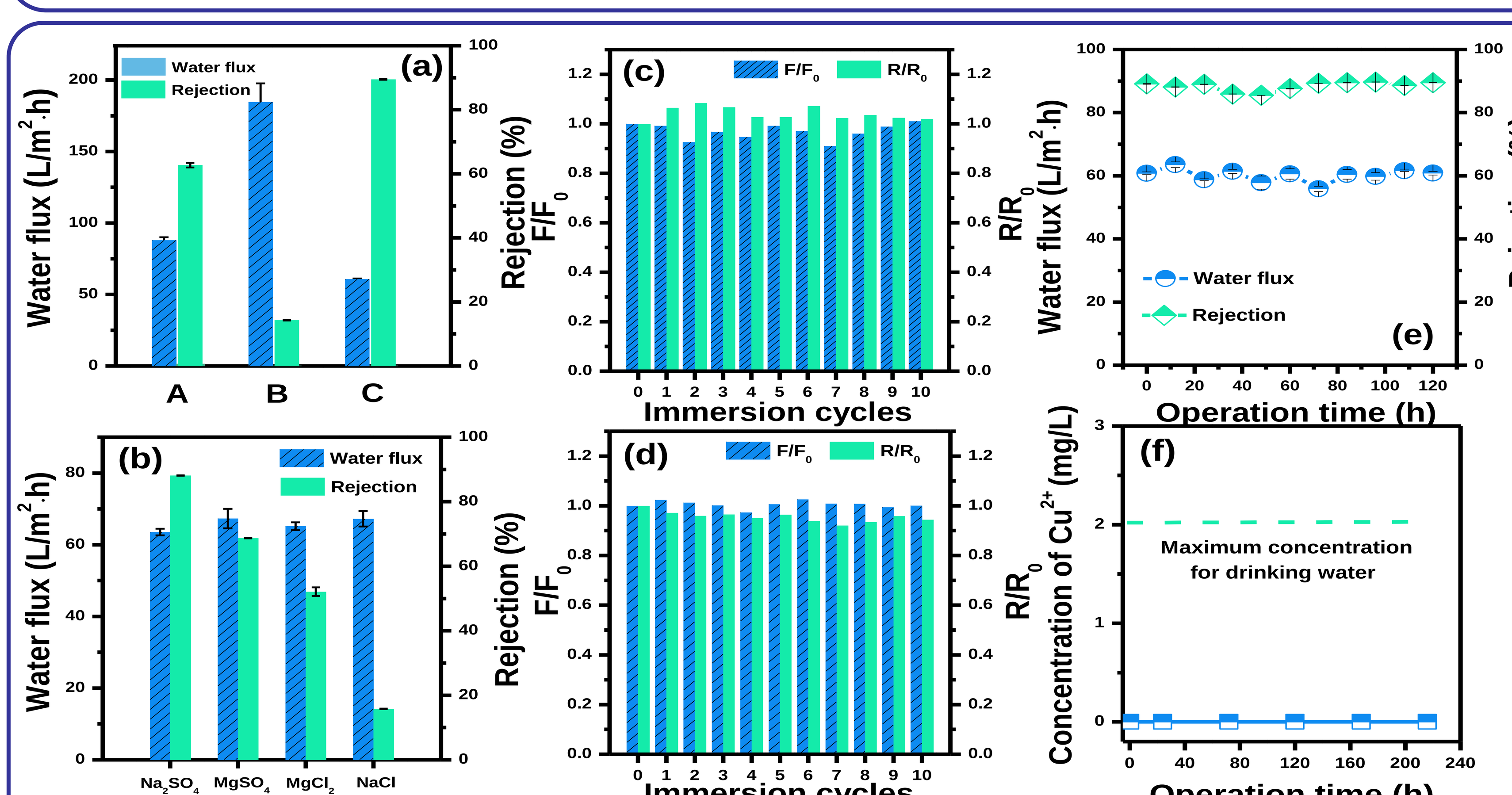

Fig. 5(a) Nanofiltration performances of the PDA-coated membranes oxidized by different oxidants: (A) air, (B) $(NH_4)_2S_2O_8$ and (C) $CuSO_4/H_2O_2$. (b) Effects of inorganic salts on the nanofiltration performance of the PDA-coated membranes oxidized by $CuSO_4/H_2O_2$. (c) Nanofiltration performance of the PDA-coated membranes treated by aqueous solution under pH = 3 and (d) pH = 11 with different immersion cycles. (e) Structure stability of the PDA-coated membranes with different operation times (Na_2SO_4 solution as feed). (f) Concentration of Cu^{2+} in the filtrate with different operation times. All solute concentrations are 1000 mg/L.

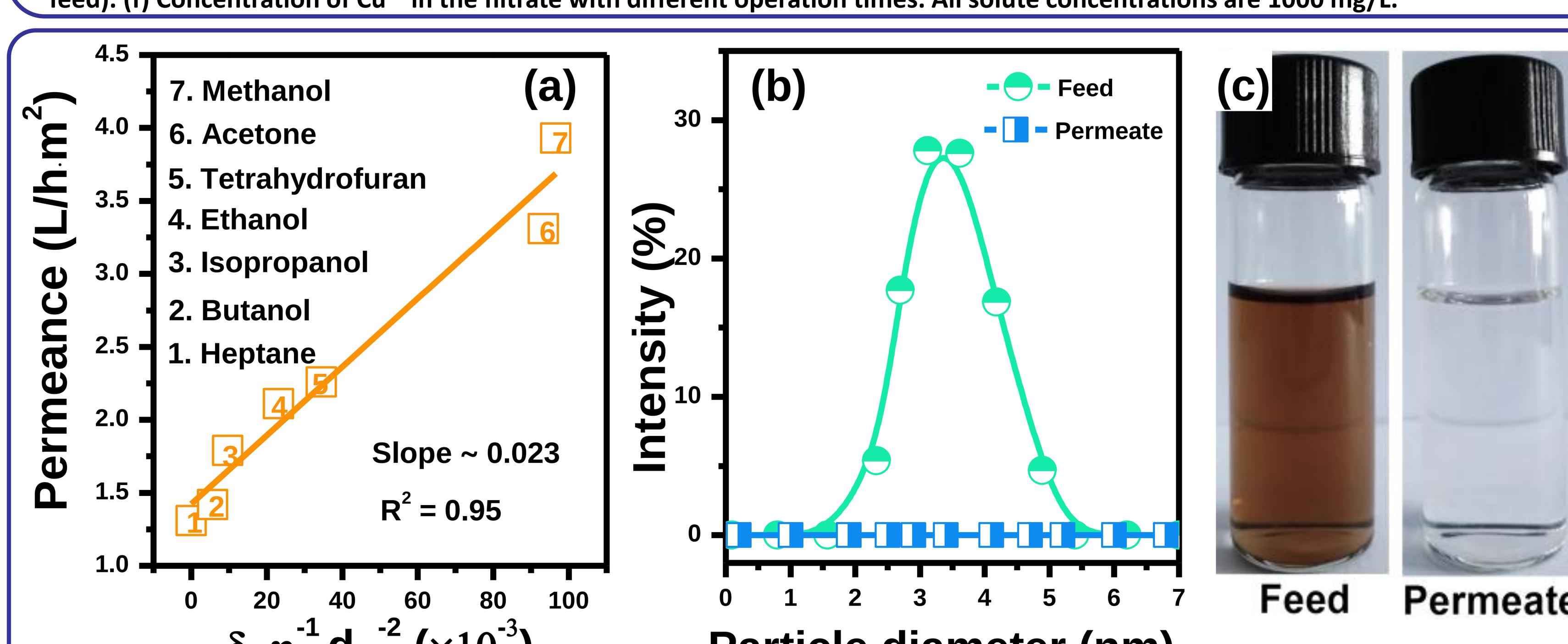

Fig. 6. (a) Plot of solvent permeance against the combined solvent property (viscosity, molar diameter, and solubility parameter) for PDA-coated membranes oxidized by $CuSO_4/H_2O_2$. (b) Size distribution and (c) photographs of Au nanoparticles in the feed and the permeate methanol solutions.

Conclusions

In summary, we provide a facile and efficient strategy to fabricate compact and robust PDA coatings via accurately regulating oxidants to tailor the oxidized self-polymerization of dopamine. The $CuSO_4/H_2O_2$-triggered PDA coatings possess nanopores with a thickness of ~75 nm, resulting a rejection of over 90% for $NaSO_4$ and PEG 1000 accompanied with water permeation flux as high as 60 L/m²h, which is much better than that of conventional PDA-based nanofiltration membranes. In addition, the PDA-coated composite membranes exhibit robust stability in organic solvents and were firstly applied for nanometer catalyst recycle from organic solvents. These mussel-inspired coatings employed in versatile molecular separation processes have opened a new door for practical applications.

Acknowledgement

Financial support is acknowledged to the National Natural Science Foundation of China (Grant no. 21534009), and the Zhejiang Provincial Natural Science Foundation of China (Grant no. LZ15E030001). The authors thank Prof. Kueir-Rarn Lee from Chung Yuan University (Taiwan) for the analysis of positron annihilation spectroscopy.

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