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Purification of water with ultrathin graphene oxide membranes

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Abstract: *Due to fast population increase, frequent droughts, and environmental contamination, the scarcity of clean and safe drinking water has recently become a major issue. Two-dimensional graphene oxide (GO) membranes are emerging as a potential choice for water filtration due to its rapid permanence, remarkable mechanical capabilities, and good chemical stability. However, GO-based water filtration technique needs more research and development. We used the vacuum filtering approach to create ultrathin graphene oxide membranes, which we successfully used for water purification. GO membranes with thicknesses of many tenths of a nanometer reveal a well-stacked layer structure, as determined by scanning electron microscopy and atomic force microscopy. We used pressure-driven filtration to test the GO membranes' water flow, retention, and rejection abilities in the water purification process. For charged dyes, the ultrathin graphene oxide membrane demonstrated significant retention and rejection rates, but for noncharged organic dyes, the findings were mixed.*

Key Words: *Water purification; Pressure- driven filtration, Graphene oxide.*

1. INTRODUCTION:

Water is the most necessary and critical resource for human life, and owing to urbanization and global climate change, delivering clean and drinking water has become a worldwide concern. This situation has compelled us to develop innovative water purification technologies to meet human demands. Although new water purification technologies have emerged as potential answers, low-cost, high-performance nano filtering is still required.
No gas molecules can pass through graphene's one atom thick barrier because the carbon atoms are so closely linked [1][2]. If atomic flaws are created in the membrane using oxidation or chemical reaction processes, depending on the sizes of the defects and the molecules, certain gas or liquid molecules can flow through it, implying that graphene membranes can be utilized as molecular filters [3][4][5][6].

The newly discovered 2D graphene oxide nanosheet - oxygenated graphene containing hydroxyl, carboxyl, and epoxide functional groups - possesses excellent chemical and thermal stability, as well as excellent flexibility and permeability [7][8].

Furthermore, between two GO laminates, 2D nanochannels may be formed [7]. Depending on the size of the 2D nanochannels or the functional groups in the GO sheets, 2D nanochannels in GO structures can behave as nanopores for molecular transport. These 2D nanochannels can allow gas or liquid molecules to pass through the pores selectively [9][10][11].

The low friction on the non-oxidized portions of GO and the 2D nanochannel networks in the GO membrane produced by spaced GO nanosheets were ascribed to the quick flow of ions or molecules in this 2D nanochannel [9]. This phenomenon has a lot of promise for making low-cost, high-efficiency water filtration membranes [7][9][12].

Physical sieving and electrostatic contact have been found to have a role in the rejection of graphene oxide in recent research [9][12][14][15]. When a GO membrane is drenched in water, the hydration effect increases the size of the hole to 0.9 nm [12], despite the fact that it is not permeable to even tiny gases like Helium [9]. Larger ions or molecules are filtered out.

Additionally, because GO is negatively charged, electrostatic forces may play a significant role in interacting with charged molecules [14][15]. Negatively charged dye molecules are retained efficiently by ultrathin graphene nanofiltration membranes [14].

Without employing any chemical reactions, pure GO membranes may be self-assembled via vacuum filtration [7][16], spin coating [4], and a pressured ultrafiltration technique [17]. Using the vacuum filtering approach, we created a graphene oxide membrane with several tenth nanometers on an anodized aluminum oxide (AAO) disc. The sheets are piled layer by layer during vacuum filtration to create a paper-like membrane with good mechanical qualities, which has piqued curiosity [7][12][18][19]. Scanning electron microscopy, X-ray diffraction, and atomic force microscopy are used to investigate the GO membrane. For diverse organic dyes, we used pressure-driven filtration to quantify water flow and GO membrane retention.

2. EXPERIMENTAL:

Characterization: SEM pictures were acquired using the FEI field-emission SEM equipment (FE-SEM). An X-ray diffractometer with a Cu target was used to create the XRD pattern. Under tapping mode, AFM pictures were collected on a PSI Auto probe CP.

Materials: The high concentrated graphene oxide dispersion in water (5g/L) was used to make GO solutions from Graphene Supermarket Co. Sigma Aldrich was used to obtain Methyl Blue and Rhodamine B dyes.

Fabrication of GO membranes, Vacuum filtration of graphene oxide solutions over porous anodized aluminum oxide (AAO) filter discs (47 mm in diameter, 0.2 m pore size, Whatman) produced GO membranes with an effective area of 11.34 cm2. During filtering of the acidic GO dispersion, a porous anodized aluminum oxide (AAO) filter disc can corrode and release a considerable quantity of Al3+, thereby crosslinking the GO sheets and greatly strengthening the resultant membrane [20]. Before the flux and purification experiments, the GO membrane system, which consisted of a graphene oxide layer and an AAO filter disc, was dried for 24 hours at 60°C in the oven.

Measurement of water flux and purification: Pressure-driven filtration [12][21][22][23] and forward osmosis filtration [24] have recently been tested with nanometer-thick GO membranes, with encouraging results. To investigate water flow and purification testing of the GO membrane in the water purification process, we used pressure-driven filtration.

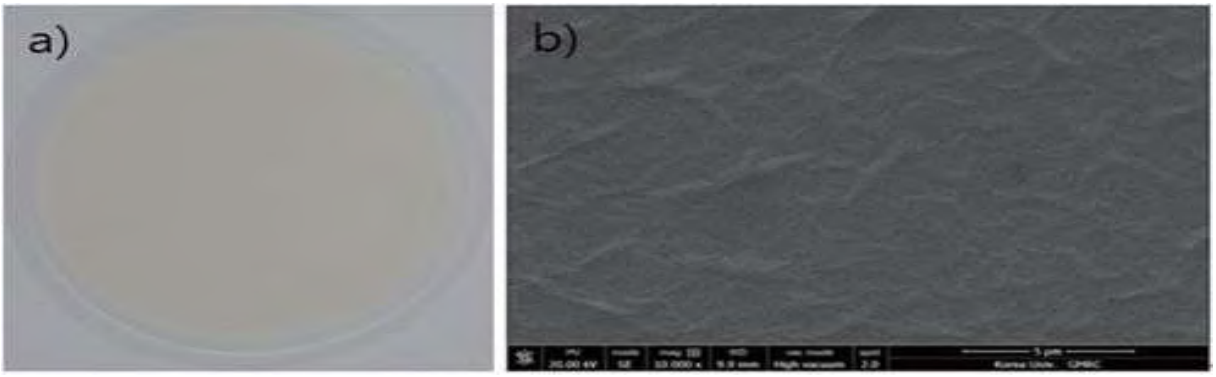

Fig.1 a) Digital image of the GO membranes on AAO filter diss. b) FESEM image (top view) of the GO membrane on an AAO filter disc.

3. RESULTS AND DISCUSSION.

Fig. 1a On the AAO filter disc, a well-stacked graphene oxide membrane with a 40 nm thickness is shown. Figure 1b shows a FE-SEM picture of uniformly coated GO membranes produced by vacuum filtering, as well as the membranes' stacked wrinkling structure. X-ray diffraction was used to determine the interlayer gap between the GO flakes (XRD). In the XRD pattern of GO membrane (Fig. 2), the (002) plane peak at 2-theta =10.24 corresponds to interlayer spacing of 0.86 nm. The amount of intercalating atomic layers of water determines interlayer spacing, and ions travel inside this water layer [12]. As a result, the XRD data show how water molecules penetrate 2D nanochannels.

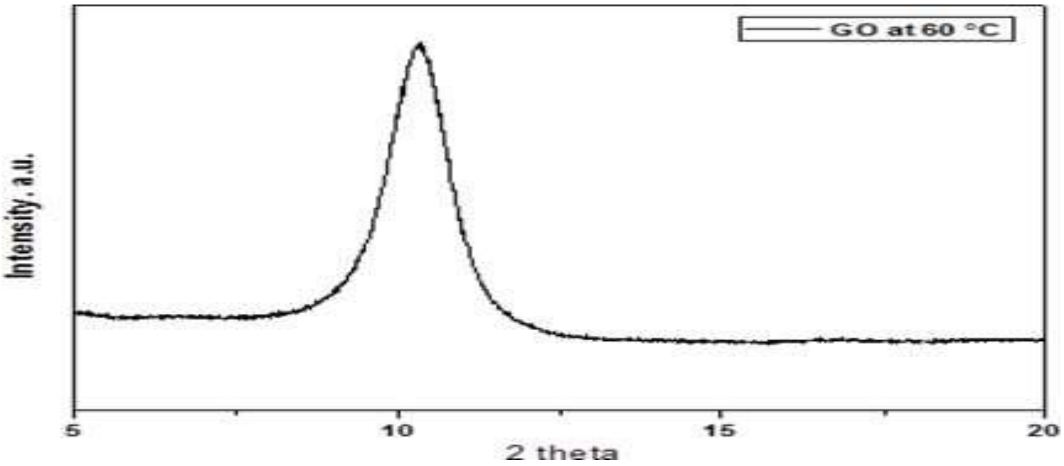

Fig. 2 XRD patterns of GO at 60 ℃ in oven

Fig. 3 AFM image of the GO membrane on an AAO filter disc.

In Fig.3, AFM was used to describe a 50 nm GO membrane on an AAO filter disc. The surface morphology of the GO membranes is shown on the right, while the AAO filter disc is shown on the left.

The water flow is compared in Fig. 4 for only the AAO filter disc and GO membrane addition cases. AAO membranes had a water flux of 2083 L m 2 h 1 bar-1, but the water flow of GO on AAO filter was 31.26 L m 2 h 1 bar-1. It's roughly a third of the size of the AAO filter.

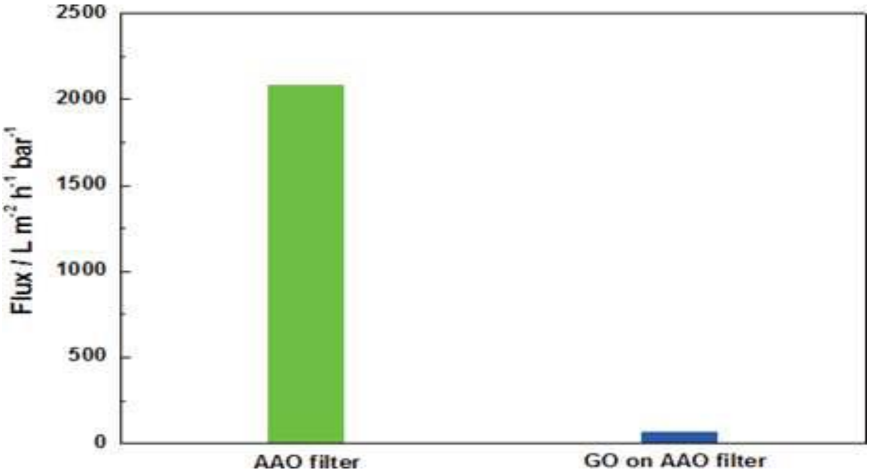

Fig. 4 The water flux test of AAO filter and GO on AAO filter

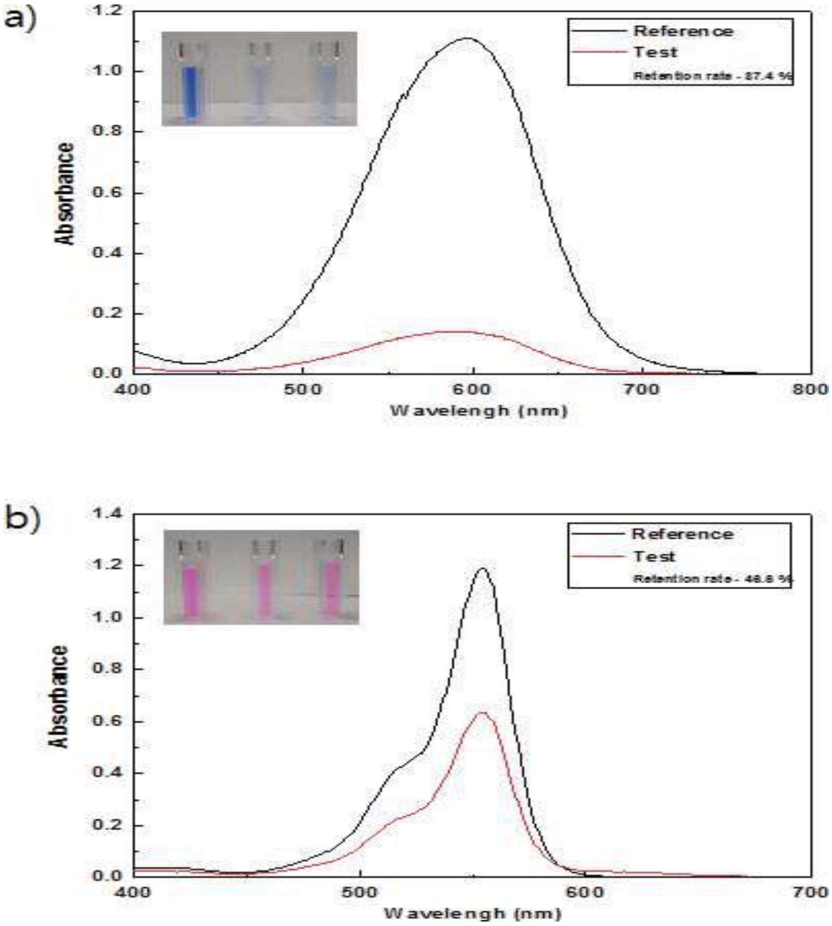

Fig. 5 UV-Vis absorbance and photos of filtrated obtained by filtration of Methyl Blue and Rhodamine B

I looked on the purification of GO membranes for organic dyes further. Low pressure (2 bar) retention rate measurements for negatively charged methyl blue (MB) and electroneutral rhodamine B (RB) dye solutions were performed, followed by UV-Vis examination (Fig. 5). The retention rate for MB on GO membranes with a diameter of roughly 50 nm.

The percentage is 87.4 percent. These findings suggest that physical sieving and electrostatic interactions between negatively charged dyes and negatively charged GO sheets dominate dye purification in GO membranes [14]. I used electroneutral rhodamine B to demonstrate the importance of electrostatic contact in the purification procedure (RB). The retention rate for RB is 46.6 percent, which is much lower than the retention rate for MB. The findings highlight the significance of electrostatic interaction in water filtration.

4. CONCLUSION:

In summary, the picture and SEM images demonstrated that the GO membrane on the AAO filter disc was evenly coated utilizing a vacuum filtration approach. The water flux test and XRD pattern analysis findings suggest that water can flow via the 2D nanochannels between GO layers, and the GO membrane on AAO filter disc has a substantially lower water flux than pure AAO filter disc. Purification tests utilizing pressure flow demonstrate outstanding purification performance for organic dye retention, particularly for negatively charged dyes. I proposed a purifying process based on physical sieving and electrostatic contact.

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