Supporting Information

Directional Fluid Gating By Janus Membranes With Heterogeneous Wetting Properties For Selective Oil-Water Separation

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Cost Analysis

we have explored various products (both at research stage as well as in market) designed for oil-spill cleanups. The compared study is provided in the table below:

Table 1. Cost comparison of various commercially available and reported Janus membranes

Market/Research	Fabrication Technique	Cost	Properties
Argonne National Laboratory (Reusable Sponge)[1,2]	Sequential infiltration synthesis	Cost details are not available in public domain	Superhydrophobic/ Superoleophilic
HygraTek (Hygro-Responsive Membranes)[3,4]	Dip-coating and Spin-coating followed by Nitrogen Drying.	Approximately 1$ per sq.ft. (Depends on the type of membrane coated and can be expensive for ceramic membranes).	Superhydrophobic/ Superoleophilic, Anti-fouling
UniSA Ventures (Oil-water separation hydrophillic membranes)[5]	Coating	Details of the price are not available	Hydrophilic/ Superoleophobic
Pham et al. (Superhydrophobic Silanized Melamine Sponges)[6]	Dip-Coating followed by oven drying	Price details not available in public domain	Superhydrophobic/ Superoleophillic

Superhydrophobic/ Superoleophillic Sponge[7]	Dip-Coating followed by oven drying	Commercial details are not available in public domain	Superhydrophobic/ Superoleophilic
Superhydrophobic Cotton fabric[8]	Vapour Phase deposition followed by oven drying	Details of cost is not provided by X. Zhou *et al.*	Superhydrophobic/ Superoleophilic, Durable in harsh atmospheric conditions.
Polyester materials with superwetting nanofilaments[9]	Chemical vapour deposition	Commercial details are not provided by J. Zhang *et al.* in Advanced functional materials	Superhydrophobic /Superoleophilic
This Work	Meyer rod Coating follwed by oven drying	Depends upon the Substrate coated.	Superhydrophobic/ Superoleophilic, Icephobic, Flame-retardant, Durable in harsh atmospheric conditions.

Most of the commercial products and the reported literatures cited above are designed for oil-spill clean-ups, either awaiting for provisional patents or haven't provided details regarding the cost of their products. However, our product exhibits multifunctional properties, such as icephoicity, flame retardancy and durability in harsh atmospheric conditions compared to the other reported membranes. Moreover, our coating can be utilized to transform even a waste cotton fabric to an advantageous Janus membrane having multifunctional properties for oil-water separation. The coating process can be explored to scale-up continuous productionization by Gravure printing (Roller and Blade/Knife).

References:

1. https://www.anl.gov/articles/argonne-invents-reusable-sponge-soaks-oil-could-revolutionize-oil-spill-and-diesel-cleanup
2. Barry, E., Mane, A., Libera, J., Elam, J. W., & Darling, S. (2017). Advanced Oil Sorbents Using Sequential Infiltration Synthesis. *Journal of Materials Chemistry A*.
3. http://hygratek.com/technology
4. Kota, A. K., Kwon, G., Choi, W., Mabry, J. M., & Tuteja, A. (2012). Hygro-responsive membranes for effective oil–water separation. *Nature communications*, *3*, 1025.
5. http://www.itek.com.au/portfolio/sustainability/item/oil-water-separation-membranes.html
6. Pham, V. H., & Dickerson, J. H. (2014). Superhydrophobic silanized melamine sponges as high efficiency oil absorbent materials. *ACS applied materials & interfaces*, *6*(16), 14181-14188.
7. Wang, C. F., & Lin, S. J. (2013). Robust superhydrophobic/superoleophilic sponge for effective continuous absorption and expulsion of oil pollutants from water. *ACS applied materials & interfaces*, *5*(18), 8861-8864.
8. Zhou, X., Zhang, Z., Xu, X., Guo, F., Zhu, X., Men, X., & Ge, B. (2013). Robust and durable superhydrophobic cotton fabrics for oil/water separation. *ACS applied materials & interfaces*, *5*(15), 7208-7214.
9. Zhang, J., & Seeger, S. (2011). Polyester materials with superwetting silicone nanofilaments for oil/water separation and selective oil absorption. *Advanced Functional Materials*, *21*(24), 4699-4704.

FE-SEM Micrograph of Janus Membrane:

The average cylinder radius and average intercylinder spacing of Janus membrane was calculated using low magnification FE-SEM micrograph via ImageJ software as illustrated in Figure S1.

Average Cylinder Radius = 220µm

Average Inter Cylinder Spacing = 550µm.

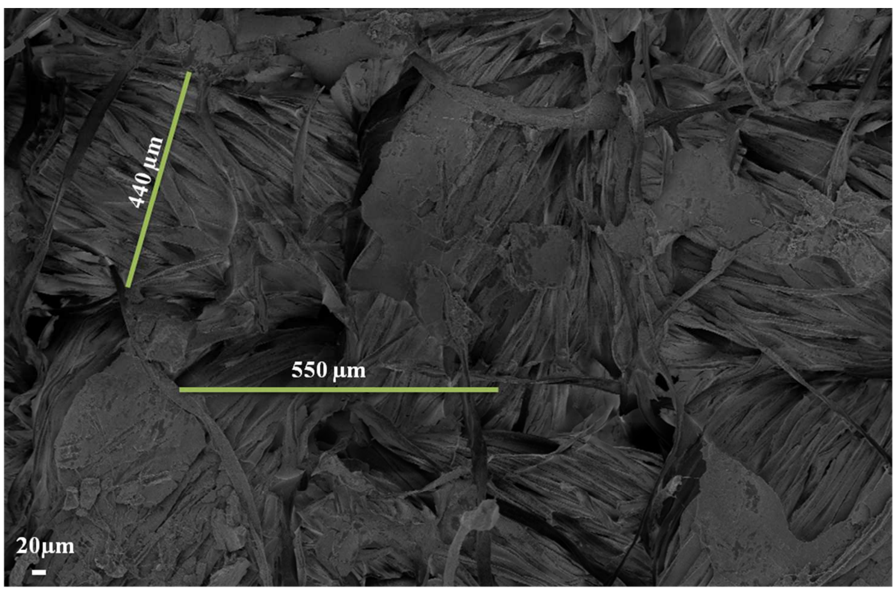

Figure S1. FE-SEM micrigraph of Janus membrane

Water/Organic Solvent Separation Analysis:

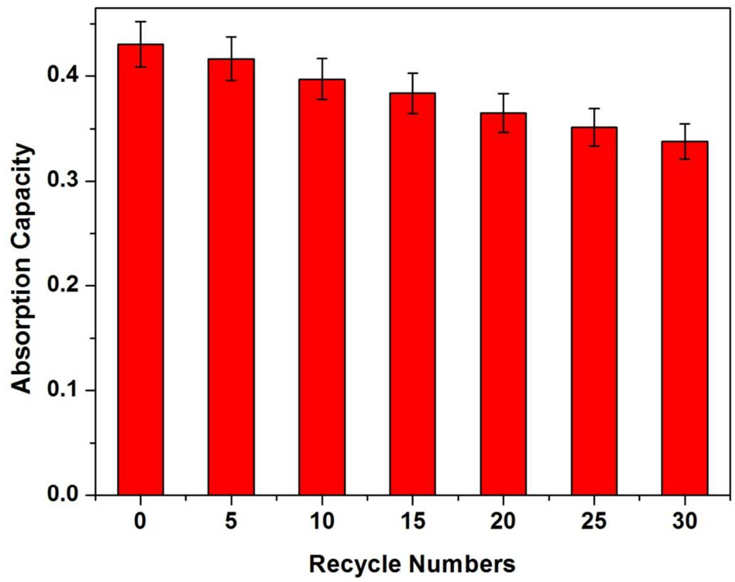

Figure S2. Absorption capacity of Janus membrane versus recycle numbers for n-Hexane/water mixture.

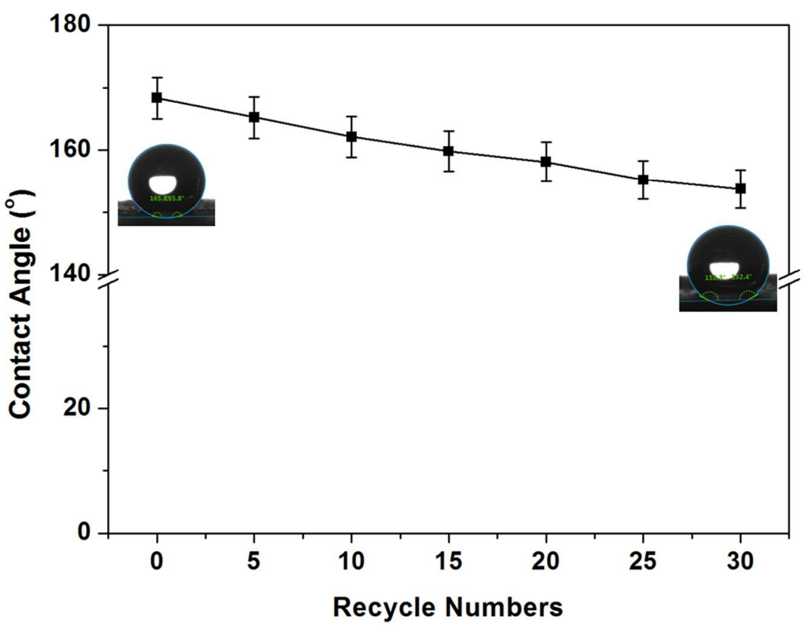

Figure S3. Contact Angle variation of Janus membrane versus recycle numbers for n-Hexane/water mixture.

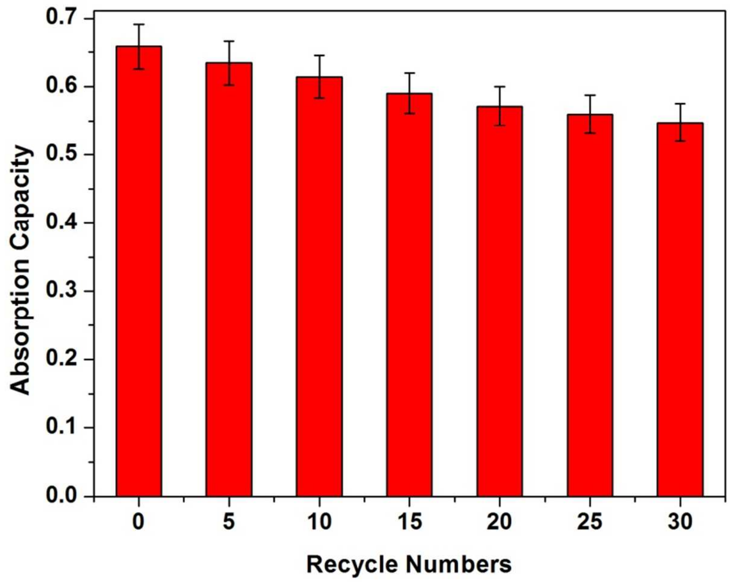

Figure S4. Absorption capacity of Janus membrane versus recycle numbers for Benzene/water mixture.

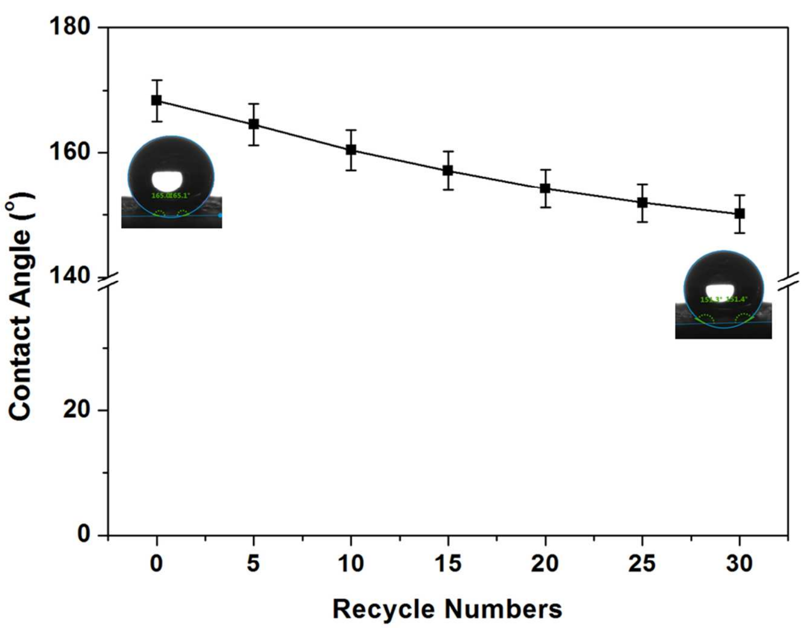

Figure S5. Contact Angle variation of Janus membrane versus recycle numbers for Benzene/water mixture.

Figure S2-S5 depicts the variation of absorption capacity and contact angle of Janus membrane with recycle numbers of water and organic solvent mixtures. Similar to oil/water mixture, the absorption capacity of Janus membrane slightly decreases with recycle numbers (from 0.43 to 0.33 in case of n-Hexane/water and from 0.65 to 0.54 in case of Benzene/water) and the contact angle of membrane also decreases with recycle numbers (from $168^o \pm 3^o$ to $152^o \pm 3^o$ in case of n-Hexane/water and from $168^o \pm 3^o$ to $151^o \pm 3^o$ in case of Benzenel/water) but the innate Superhydrophobic characteristic of Janus membrane is retained for atleast 30 cycles.

Flame Retardancy by Janus Membrane:

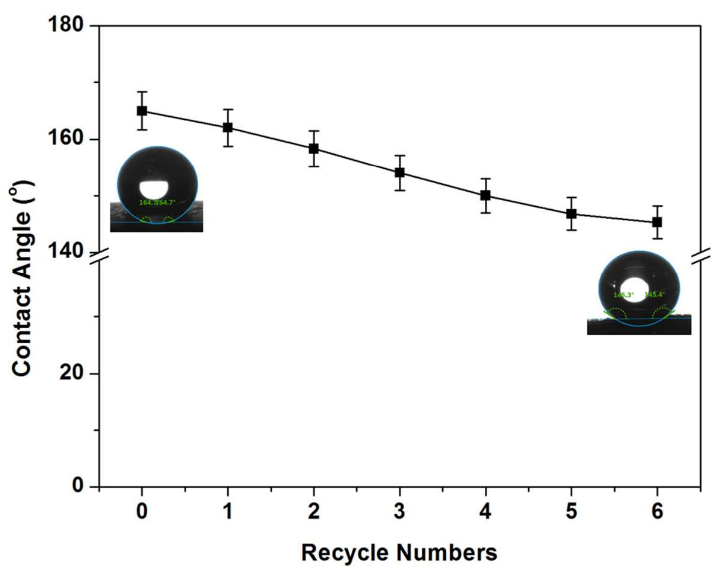

Figure S6. Variation of water contact angle of Janus membrane with combustion recycles

Figure S6 depicts the variation of wettability behavior of Janus membrane with each combustion cycles, which suggests that the intrnsic properties of Janus membranes is retained even after exposure to flame.

Stabile wettability of Janus membrane in extreme environments:

The developed Janus membrane retained its superhydrophobicity after exposure to UV irradiation of wavelength 254 nm for 72 hours, suggesting the UV-unresponsive behavior of the membrane as shown in Figure S7. Similar behavior was observed when exposed to an extremely hot environment of 150^{o}C for 72 hours as depicted in Figure S8.

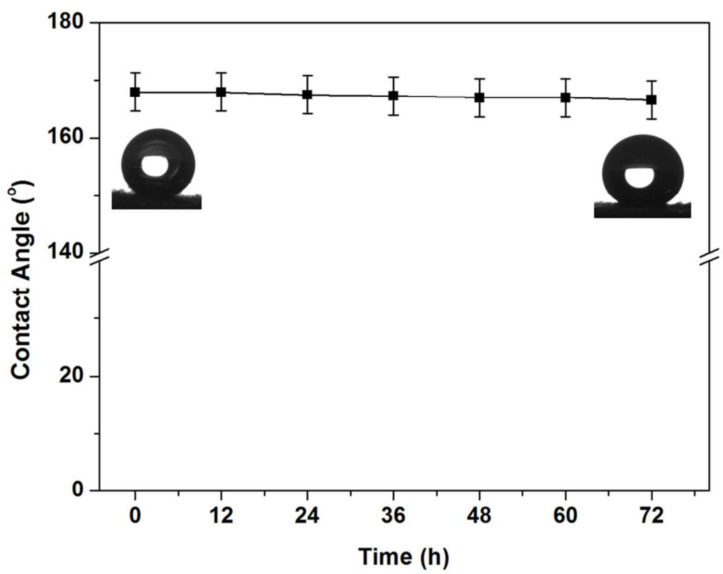

Figure S7. Variation of water contact angle of Janus membrane exposed to UV-radiation

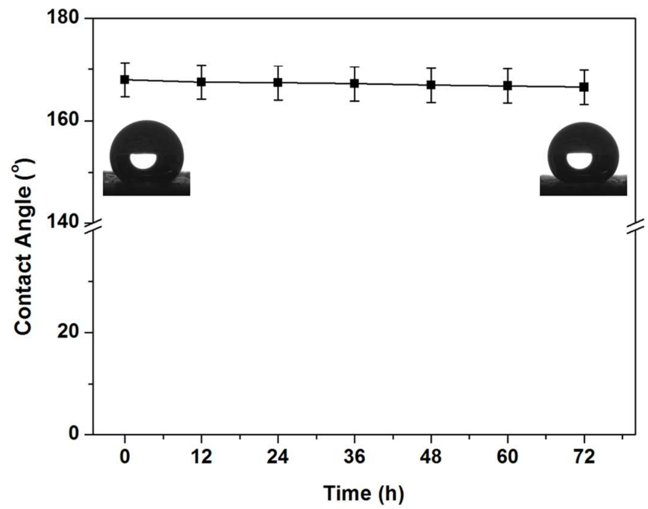

Figure S8. Variation of water contact angle of Janus membrane exposed to extremely hot environment of 150°C.