

Lignin-based membrane fabricated with deep eutectic solvent

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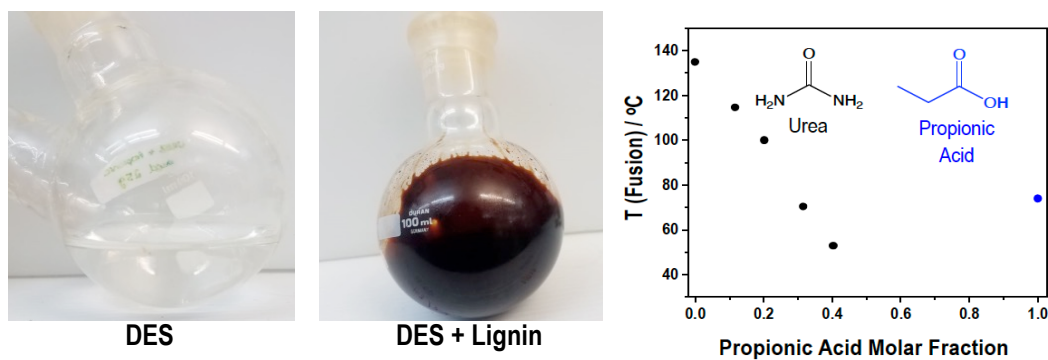


Figure S1. Deep eutectic solvent (urea and propionic acid mixture) (DES); lignin dissolved in DES and phase diagram for propionic the acid: urea mixture.



Figure S2. Stability of lignin membranes in ethanol, methanol, isopropanol, acetone, acetonitrile, hexane, toluene, tetrahydrofuran, and *N,N*-dimethylformamide solution under static condition at 23°C, 8 weeks after soaking.

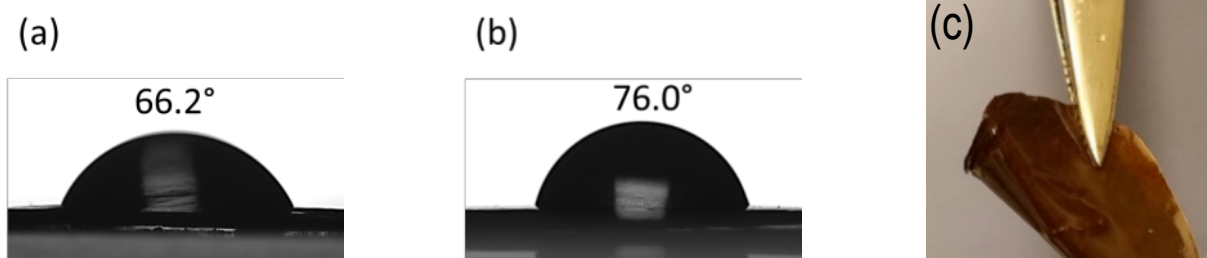


Figure S3. Water contact angle (a) before crosslinking, (b) after crosslinking, and (c) photograph of a bent membrane.

Table S1. Physicochemical properties of solvents used in the permeation test ³⁷⁻³⁹.

Solvent	d _m (nm)	η _{25°C} (mPa s)	HSP (MPa ^{0.5})			Swelling		
			δ _p	δ _H	δ _D	Mass Before (mg)	Mass After (mg)	Degree of Swelling (%)
Water	0.26	0.92	16	42	16	0.9	1.8	99
Acetone	0.47	0.31	10	7	16	1.2	1.8	50
Methanol	0.38	0.54	12	22	15	0.6	1.8	200
Kraft lignin		-	14	17	22	-	-	-

Viscosity (η); Kinetic diameter (d); Hansen solubility parameter (HSP).

Degree of swelling

The degree of swelling of the cross-linked membrane was measured by soaking the membrane (vacuum dried) in various organic solvents for 48 h. To measure the gel content, the samples were weighed and then dried in a vacuum oven at 60°C for 24 h. The degree of swelling, solvent uptake, and weight loss are calculated using equation S1.

$$Q = \frac{1}{\rho} * \frac{W_{wet} - W_{dry}}{W_{dry}} \quad 1$$

where, Q the degree of swelling, ρ the liquid density, W_{wet} and W_{dry} the weight of the membrane sample before and after soaking.

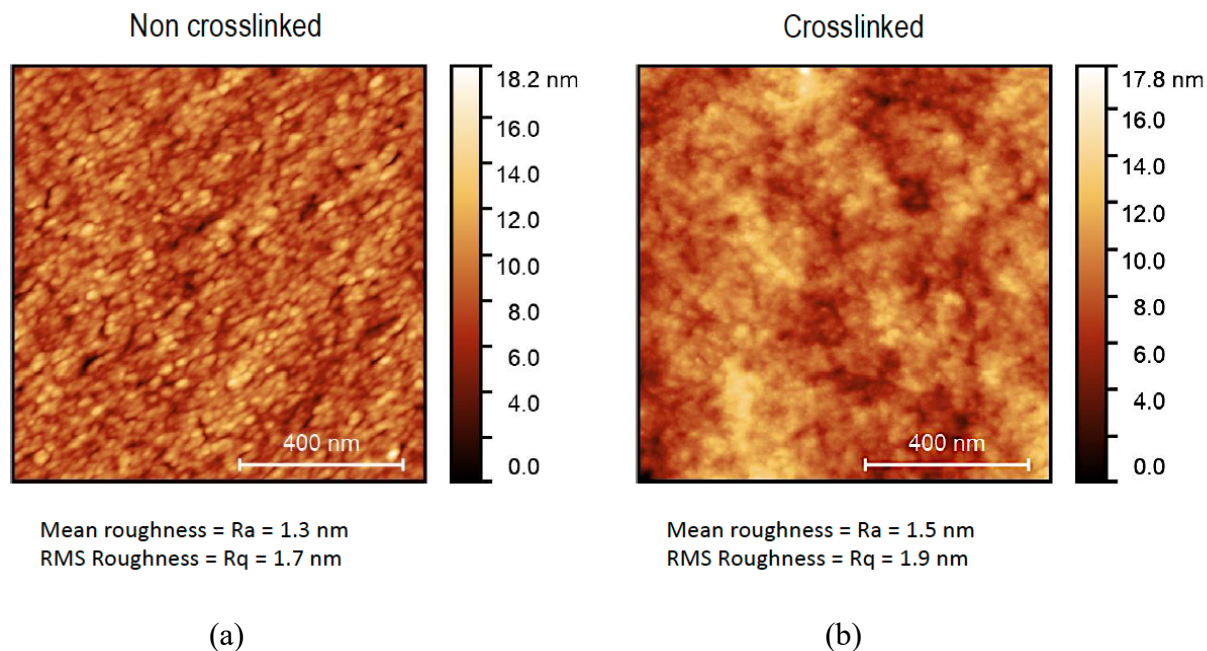


Figure S4. AFM images of membranes cast from a solution of 22 wt % lignin in DES (a) before and (b) after crosslinking with 5% 1,4-butanediol diglycidyl ether and storing in water.

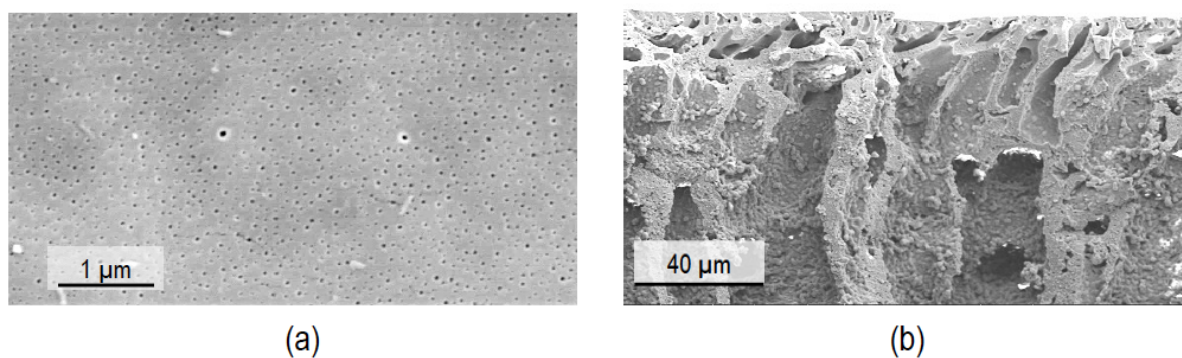


Figure S5. SEM images of (a) cross-section and (b) surface of a membrane cast from a solution of 20 wt % lignin in DES after crosslinking with 5% 1,4-butanediol diglycidyl ether and storing in water.

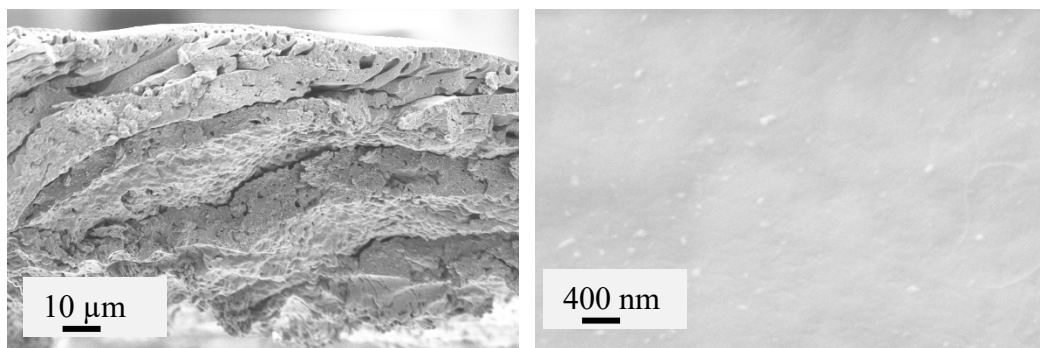


Figure S6. SEM images of (a) cross-section and (b) surface of a membrane cast from a 22 wt% lignin solution in DES, after crosslinking and sequential filtration of water, methanol and acetone at 19 bar.