Supporting Information: Network Polymers incorporating Lipid-Bilayer Disrupting Polymers: Towards Antiviral Functionality

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Experimental Section

General

All materials were purchased from commercial sources (Table S1) and used as received unless otherwise specified. 2-(((dodecylthio)-carbonothioyl)thio) propanoic acid (PADTC),[50] 2-(((ethylthio)-carbonothioyl)thio) propanoic acid (PAETC),[52] and, 2-[(ethoxythioxomethyl)thio]ethyl ester (EXEA)[53] were synthesized according to the previously published procedures.

Reagent Sources

Table S1. Reagents and materials used in the study. All reagents were used as received from the suppliers below unless

Reagent	Source
1-Dodecanethiol (DDT)	Acros Organics

Tetrapropylammonium bromide (TPAB)	Acros Organics
Sodium hydroxide (Pellets), ACS Reagent Grade	Ricca Chemical
Carbon disulfide, Laboratory Grade	Fisher Scientific
Hydrochloric acid, Certified ACS Plus Safe-cote	Fisher Chemical
Ethanethiol, 99+%	Acros Organics
2-bromopropionic acid, 98% Liquid	Alfa Aesar
Sodium carbonate anhydrous (Granular)	Tedia Company, Inc.
Potassium ethyl xanthogenate, 97+%	Alfa Aesar
2-bromoethanol, 97%	Alfa Aesar
Ammonium chloride, 98+%	Alfa Aesar
4-dimethyl amino pyridine, 99%	Acros Organics
Acrylic acid (Stabilized with hydroquinone monomethyl ether) for synthesis	EMD Millipore Corporation
1-ethyl-3(3-dimethyl aminopropyl) carbodiimide.HCl	Carbosynth Limited
2-Hydroxyethl acrylate (Stabilized with MEHQ), 96+%	TCI America
Azobisisobutyronitrile (AIBN), 98%	Sigma-Aldrich
Mono-isopropyl amine (IPA), ≥ 99.5%	Sigma-Aldrich
Tributylphosphine, 95%	Alfa Aesar
Styrene, Stabilized, 99%	Acros
Maleic anhydride, 98+%	Alfa Aesar
1,4-dioxane, 99+%, Stab. With ca 5-10 ppm BHT	Alfa-Aesar
Tetrahydrofuran (THF) Optima®Submicron filtered	Fisher Chemical
ACHN, Glass distilled, Filtered through 0.5micron filters	Aldrich HPLC
N,N-Dimethyl formamide (DMF), ≥ 99.5%	TCI America
N,N-Dimethylethylenediamine, ≥ 98%	TCI America
1-Palmitoyl-2-oleoyl-sn-glycero-3-phosphocholine (POPC)	Avanti Polar Lipids, Inc.
1-palmitoyl-2-oleoyl-sn-glycero-3-phospho-(1′-rac-glycerol (POPG)	Avanti Polar Lipids, Inc.
Carboxyfluorescein	Acros Organics
SARS-CoV-2 S1 subunit of spike protein	RayBiotech. Inc
12% Polyacrylamide gel	BIO-RAD
0.2μm nitrocellulose membrane	BIO-RAD
Trans-Blot®Transfer System	BIO-RAD
Blocking Buffer	ROCKLAND
6 x His Tag Monoclonal Antibody	Invitrogen
Tris Hydrochloride, Ultra Pure	Gold Biotechnology
Sodium Chloride, Crystalline	Fisher Chemical
Tween®20	Fisher bioreagents
IRDye®800 CW Goat antimouse IgG secondary antibody	LI-COR
Glycerin droplet fog machine	Party City Inc.
N,N-Dimethyl formamide (DMF) for GPC, Certified ACS	Fisher Chemical
Lithium bromide, Reagent Plus ®, ≥ 99%	Sigma-Aldrich
Tetrahydrofuran (THF) Optima®Submicron filtered for GPC	Fisher Chemical

Typical one-pot synthesis and deprotection of poly(hydroxyethyl acrylate-r-ethyl xanthate ethyl acrylate) (HEA/EXEA) copolymer

In this example, the copolymer is target chain length 100, crosslinker density 6%. To a 50 ml round bottom flask were added: PAETC (0.181 mg, 0.861 mmol), HEA (10.0 g, 86.1 mmol), EXEA (1.14 g, 5.17 mmol), AIBN (0.0283 g, 0.172 mmol), and a 1:1 v/v mixture of methanol and water (11.3 g). The flask was fitted with a rubber stopper and purged by argon sparging for 20 minutes. The escape needle remained in the flask attached to the bubbler filled with mineral oil for pressure release. Then, the flask was heated to 65 ^{o}C for 24 hr. With sufficient (>95%) conversion, the flask could be stored at 4^{o}C until ready for deprotection.

Deprotection was performed as follows. The flask was purged by nitrogen sparging, along with a flask of mono-isopropylamine (IPA), for 15 minutes. A gastight 25 ml syringe was also purged with nitrogen during this period. Then the deoxygenated IPA (9.9 ml, 121 mmol) was transferred to the polymer flask by gastight syringe. Tributylphosphine (60 µl, 0.24 mmol) was then added to the polymer flask as well. The headspace of the reaction mixture was then purged with nitrogen for another 15 minutes, and the reaction was stirred at room temperature overnight. Deprotection was measured using UV-Vis absorbance in a Take 3 micro-volume plate (BioTek) in a BioTek Synergy H1 plate reader. Disappearance of the 310 nm peak belonging to xanthates/trithiocarbonates was indicative of successful deprotection to the HEA-SH copolymer. Upon deprotection, the HEA-SH copolymer was used for molding as soon as possible, to avoid premature oxidative crosslinking.

One-pot synthesis of poly((styrene-*alt*-maleic anhydride)-b-styrene) copolymer (1.5-1 SMAn)

To a 25 ml round bottom flask were added: PADTC (0.1616 g, 0.46 mmol), styrene (4.0 g, 38mmol), maleic anhydride (1.506 g, 15.3 mmol), AIBN (4.5 mg, 27 µmol), and dry dioxane (11.3 g). A pre-reaction NMR sample was obtained for calculating conversion. The flask was fitted with a stir bar and rubber stopper and purged by nitrogen sparging for 20 minutes. Then the flask was heated at 65 ^{o}C for 22 hours. The conversion was checked by NMR, using dioxane as an internal standard. If the conversion of styrene was

below 60%, an additional 4.5 mg AIBN was added and the reaction sparged and heated as before, until 60% conversion was achieved, resulting in the 1.5:1 styrene: maleic anhydride ratio. The polymer was isolated by trituration in cold hexanes (20:1 solvent: polymer), rinsed with cold hexanes (10:1 solvent: polymer), and then dried under reduced pressure at 30-40 °C. An additional trituration step was often necessary to achieve a powdery (rather than viscous) consistency. In that case, the polymer was dissolved in dry tetrahydrofuran (THF) and triturated from cold hexanes. The resulting yellow powder was then stored in a desiccator at room temperature until use.

Synthesis of poly(styrene-*alt*-maleic anhydride) copolymer (1-1 SMAn)

To a 50ml round bottom flask were added: PADTC (0.2693 g, 0.768 mmol), styrene (4.0 g, 38.4 mmol), maleic anhydride (3.77 g, 38.4 mmol), ACHN (5.6 mg, 23 μmol), and dry dioxane (20.1 g). The flask was fitted with a stir bar and rubber stopper and purged by nitrogen sparging for 20 minutes. Then the flask was heated at 65 ^{o}C for 18 hours. The conversion was checked by NMR, using dioxane as an internal standard. The polymer was isolated by trituration in cold hexanes (20:1 solvent: polymer), rinsed with cold hexanes (10:1 solvent: polymer), and then dried under reduced pressure at 30-40 °C. An additional trituration step was often necessary to achieve a powdery (rather than viscous) consistency. In that case, the polymer was dissolved in dry THF and triturated from cold hexanes. The resulting yellow powder was then stored in a desiccator at room temperature until use.

Typical hydrolysis and deprotection of 1.5-1 SMAn (synthesis of SMA-SH)

To a 10 ml round bottom flask were added: 1.5:1 SMAn (1.1 g, 0.124 mmol polymer, 4.1 mmol anhydride), and THF (1.65 g). Once dissolved, aqueous NaOH (4.0 M, 1.04 ml) was added dropwise, and the solution was stirred for 4 h at 40 °C. Then, the flask was purged by nitrogen sparging, along with a flask of IPA, for 15 minutes. Then tributyl phosphine (~ 50 mg), followed by air-free IPA (770 μL, 13 μmol) were added by gastight syringe. The flask was purged for an additional 15 minutes and then stirred at room temperature overnight. Approximately 85%. transformation of trithiocarbonate confirmed by UV-Vis indicated the formation of SMA-SH. The solution was then thinned with water (0.8ml, ca. 75% vs mass of initial

polymer). The polymer was isolated by trituration in cold isopropanol (33ml, 30:1 vs initial polymer), and rinsed with additional isopropanol (16ml), and dried under reduced pressure at 30-40 °C , yielding a fine, off-white powder (1.1g yield), which was stored at -20oC until ready for use.

Typical derivatization/deprotection of 1-1 SMAn (synthesis of Neut-SH)

To a 10ml round bottom flask were added: 1:1 SMAn (0.7 g, 67 μmol polymer, 3.3 mmol anhydride), and dry DMF (2.29 g). Once the contents were dissolved, the flask was purged by nitrogen sparging for 15 minutes. Then, tributyl phosphine (~50 mg), followed by N,N-dimethylethylenediamine (0.55 ml, 5.0 mmol) were added dropwise by syringe, and the reaction was purged for an additional 15 minutes. Then, the reaction was stirred overnight at 40 °C. After transformation of the trithiocarbonate was confirmed by UV/Vis, the solution was thinned with water (0.75 ml). The polymer was isolated by trituration in a cold mixture of 80/20 diethyl ether/isopropanol (40 ml, 40:1 vs final polymer mass), and rinsed with 20 ml of the same mixture. The triturated polymer was dried briefly under N_2 stream to remove excess ether and prevent vigorous popping, and then dried under reduced pressure at 30-40 °C, yielding a glassy orange solid, which was stored at -20 °C until ready for use. The successful synthesis of Neut-SH was later confirmed by ^{1}H NMR.

Casting of functional polymer networks

To prepare for polymer casting, Neut-SH was dissolved in 100% methanol at a 1:2 polymer: solvent ratio, and SMA-SH was dissolved in water at a 1:4 polymer: solvent ratio. The deprotected EXEA/HEA polymers were used as described above, without purification. Molding of 100/6% materials with 20% functional polymers in “dogbone” molds is used as an example. The Teflon molds were preheated to 40 °C on a hotplate. To these molds was first added the HEA mixture (1.15 ml, 0.4 g HEA-SH) by plastic syringe. For 20% Neut materials, the prepared Neut-SH methanol solution (240 μl, 80 mg) was added to each mold. For 20% SMA materials, the prepared SMA-SH water solution (400 μL, 80 mg) was added to each mold. Then, the HEA/functional polymer molds were blended manually with clean plastic transfer pipets to disperse the functional polymers. Finally, the Teflon molds were covered with a glass pane and cured at 40 °C for 48

hr. At the end of 48 hr, the solid materials were removed from the molds (using a small amount of hexanes to help liberate them), and dried under reduced pressure at 30-40 °C for 48-72 hr. The dried materials were stored at room temperature until use.

Functionalization of KN95 and Surgical Masks

To coat KN95 and surgical masks, Neut-SH was dissolved in 100% methanol at two different polymer: solvent ratio, 1:1 and 1:2, to achieve 0.1 g/mL and 0.05 g/mL concentrated solutions with each having volume of 4 mL. The solutions were then sprayed from a spray bottle onto the mask for coating purposes. The coated masks were dried in the hood for two days. The surface density of polymer on the the mask was determined by gravimetry on a sample of known area.

Liposome encapsulation of fluorophore

Liposomes were prepared in a similar manner to a previously published report.[54] In short, POPC and POPG were mixed at a 9:1 mass ratio and distributed into 120 μL aliquots, which were purged briefly with nitrogen and stored at -20 ^{o}C in the dark until use. To prepare the liposomes, an aliquot was transferred by pipet to a 25 ml pear-shaped flask. The solvent was driven off by N_2 stream, leaving a thin layer of lipids on the walls of the flask. The flask was then dried at room temperature under vacuum overnight. The following day, the lipids were suspended in carboxyfluorescein buffer (30 mM in 100 mM phosphate, pH 7.5), and underwent 5 freeze/sonication cycles. The vesicles were extruded through a 100 nm pore size filter 21 times, and then run over two subsequent desalting columns using 100 mM phosphate buffer as eluent. The prepared liposomes were used on the same day and stored at 4 °C in the dark when not in use.

Liposome disruption assay

The prepared liposome solution was handled with utmost care to avoid mechanical disruption, and all pipetting steps were done using Eppendorf Xplorer electronic pipets on the slowest aspiration/dispensing speed. The solution was diluted 1:300 with 100 mM phosphate buffer in a 50ml conical tube masked with aluminum foil, and gently mixed by inversion. Then, 600 μL of the diluted liposome solution was added

to 1.5 ml plastic centrifuge tubes containing 30±1.5mg slices of HEA materials. In general, the HEA materials were run in triplicate, using slices from separate dogbones in each tube. Immediately after combining the diluted liposome solution and HEA slices, the tubes were gently rotated for 80 s (10 full rotations). Then, the diluted liposome solution was dispensed into a 384-well polypropylene fluorescence plate (50 µl/well, 3 wells/sample, for a total of 9 reads per material). The fluorescence was measured using 485 nm excitation and 528 nm emission in a BioTek Synergy H1 plate reader. The negative control was 50 µl diluted liposome solution dispensed directly into the fluorescence plate, and the positive control was a 1:300 dilution of liposome in 10% v/v Triton X-100 buffer. Relative fluorescence is determined by:

$$\text{Relative Fluorescence} = \frac{Fluorescence\ of\ sample - Fluorescence\ of\ Negative\ control}{Fluorescence\ of\ Positive\ Control - Fluorescence\ of\ Negative\ Control} \times 100. \quad (1)$$

Where 10% triton serve as the positive control and undisturbed vesicles serve as the negative control.

The recycling assay is a slight modification of the above protocol. A 1% w/v solution of lipids was prepared in phosphate buffer. Six tubes containing 30±1.5mg slices of 50/6% HEA/20% Neut were prepared. To three of the tubes was added 60 µL of the 1% lipids solution. To the other three was added 60 µL of phosphate buffer. The tubes were vortexed for 90 seconds to saturate the materials with lipids/buffer. Then, 600 µL phosphate buffer was added, then all the liquid contents were pipetted out. Immediately, 600 µL of diluted liposome-fluorophore solution was added to all the tubes, and measurement was done as described above.

Spike protein capture and Western blot

The polymer materials, SMA-SH, HEA-SH and Neut-SH were also subjected to treatment with host cell receptor binding domain (HCRBD) of recombinant SARS-CoV-2 S1 subunit of spike protein (RayBiotech.Inc.). For the treatment, about 3 mg of polymer material were initially soaked in 1xPhosphate buffered saline (1xPBS, pH 7.5) overnight. When the materials were swelled enough, the materials were

treated with 20 μL of HCRBD (0.14mg/mL) for two hours. Accordingly, sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) was carried out to resolve the protein samples using a 12% polyacrylamide gel (BIO-RAD). Then, the resolved protein samples were transferred to a 0.2μm nitrocellulose membrane (BIO-RAD) by Trans-Blot®Transfer System (BIO-RAD). Followed by the treatment with blocking buffer (ROCKLAND) overnight, the membrane was incubated with 6x His Tag Monoclonal Antibody at a 1:2,000 dilution (Invitrogen) overnight. After incubation, the membrane was washed with Tris-Buffered Saline, 0.1% w/v Tween (10mM Tris base, 150mM NaCl, 0.1% w/v Tween®20 detergent, pH 8.0) five times at five minutes intervals before being incubated with IRDye® 800CW Goat anti-Mouse IgG Secondary Antibody (1:15,000 dilution) (LI-COR). Finally, the membrane was visualized using a LI-COR Image Studio Software.

NMR

All nuclear magnetic resonance (NMR) was performed on a Bruker 500 MHz Spectrometer or a Bruker 400 MHz Spectrometer.

Size Exclusion Chromatography (SEC)

Size exclusion chromatography (SEC) was accomplished using Agilent 1260 SEC system equipped with an auto-sampler, an Agilent 1260 isocratic pump, column oven and an Agilent 1260 refractive index (RI detector). The eluent was DMF with 0.1 wt% LiBr for the HEA/XEA copolymers, and THF for the SMAn copolymers. When DMF with 0.1 wt% LiBr was used as the eluent, the column temperature was at 50 °C using Agilent Polargel-M columns with a flow rate of 1 mL/min. When THF was used as the eluent, the column temperature was 30 °C using Agilent Mixed-B columns with a flow rate of 1 mL/min. All the samples were filtered before the injection to instrument. The system was calibrated with poly(methyl methacrylate) standards in the range of 617,000 to 1010.

Dynamic Light Scattering (DLS)

DLS data were obtained using a Malvern Zeta sizer ZEN1600 Nano series instrument at 25 °C.

Contact angle Measurement

All contact angles were determined using a Gardco PGX+ Contact Angle Goniometer on a polystyrene substrate at ambient temperature and pressure.

Scanning Electron Microscopy (SEM)

Samples were trimmed and mounted on edge with conductive adhesive to reveal internal organization. Samples were imaged in a Zeiss Supra-35 FEG VP with secondary electron imaging at 1 or 2Kv.

Differential Scanning Calorimetry (DSC)

All the transition temperatures (T_g) were obtained using a TA instrument DSC Q2000. The data was obtained in a heat cool heat cycle ranging from -80 °C to 160 °C with 10 °C per minute heating rate. The data was plotted only from the second heating cycle.

Thermogravimetric analysis (TGA)

Thermogravimetric analyses of 100/6 20% Neut materials were carried out in a TA instrument Q500 (TGA). The experiments were carried out from 25 °C to 400 °C at heating rate of 10 °C/min under nitrogen with a flow rate of 40 mL/min.

Tensile testing

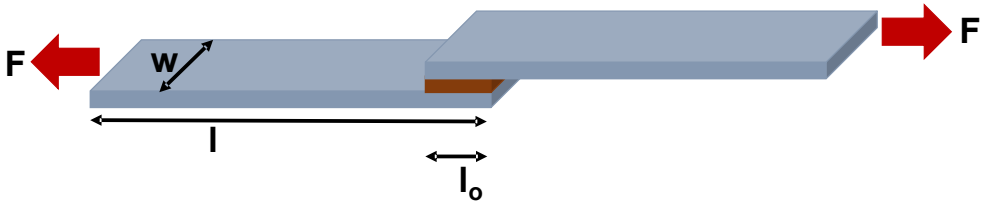
Uniaxial tensile testing experiments were carried out on dog bone shaped materials in an Instron 3344 universal testing system equipped with a 100 N or 1000 N load cell. The extension rate was 0.5 mm/s and data were collected until the material failed.

Fracture energy determination

An Instron 3344 universal testing system equipped with a 100 N load cell was used at room temperature for all fracture tests except 1000 N load cell used for 150/6 HEA materials. Total samples were divided into two groups which are designate as “cut” and “uncut”. The materials belong to “cut” group were notched halfway through their respective width before being loaded onto the Instron in a manner that maintains the notch on a horizontal plane and then subjected to tensile tests with the extension rate of 0.5 mm/s. Uncut materials were left without a notch and subject to the tensile tests in similar manner. Fracture energy was determined by integrating the stress-strain curve of the uncut samples up to the mean strain at break for the cut samples.

Adhesive testing

Uniaxial tensile testing experiments were carried out on different materials (Delrin, aluminum, PVC and wood). The polymer materials were sandwiched between two surfaces and then they were attached to the Instron 3344 universal testing system equipped with a 1000 N load cell. The extension rate was 1 mm/s and data were collected until the material failed.



$$Joint\ Strength = Lap\ Shear\ Strength$$

$$\Gamma_{joint} = \frac{F_{max}}{l_0.w}$$

Swelling Ratio Determination

Small samples of the materials were weighed out and placed in petri dishes (W_{Sample}). The weight of the petri dishes containing samples were measured (PD_{before}). An excess volume of distilled water was added to the dishes. After overnight swelling, the excess water was removed from the

petri dishes and the materials were blotted with wipes. The weight of the petridish with swelled samples were measured (PD_{after}). The swelling ratio was determined using the following equation

$$Swelling\ Ratio = \frac{PD_{after} - PD_{before}}{W_{sample}}$$

Pressure Drop and Filtration Efficiency Tests

A custom made apparatus was developed to measure the coated mask's pressure drop and filtration efficiency. The system was a sealed clear polycarbonate box connected to an air pump (Pawfly, 0.025 MPa max pressure and 0.2667 L/s max flow rate) and a pressure sensor (Vernier) on the two opposite sides of the box. An outlet was inserted for the apparatus using a 2-inch diameter polyvinylchloride pipe to place the mask under observation (KN95 or Surgical). Closed and open systems were used as reference states for measuring pressure and flow. The outlet pipe was kept open for the open system, while it was sealed using parafilm in the closed system. Pressure was applied from the pump in the pressure drop test, measuring the pressure in the box with the outlet pipe covered by masks or in the open or closed state over time. For filtration efficiency tests, blue light was irradiated on one side of the box and a light sensor (Vernier) was placed on the opposite side of the box. Accordingly, fog was placed into the box (glycerin droplet fog machine, Party City Inc.) and pressure from the pump into the arrangement. Filtration of the glycerin droplets was observed as gradual fog clearance from the apparatus through the masks by measuring the light intensity using the light sensor. This was compared against a system in the open or closed state, both with and without pressure applied from the pump.

Supplemental Data

Table S2. Network materials synthesized in this work

Name	Network polymer chain length[a]	Network polymer crosslinker density[b]	Percent functional polymer[c]
50/6 HEA	50	6%	None
100/4 HEA	100	4%	None
100/6 HEA	100	6%	None
100/8 HEA	100	8%	None
150/6 HEA	150	6%	None
50/6 20% Neut	50	6%	20% Neut-SH
100/4 20% Neut	100	4%	20% Neut-SH
100/6 10% Neut	100	6%	10% Neut-SH
100/6 20% Neut	100	6%	20% Neut-SH
100/6 40% Neut	100	6%	40% Neut-SH
100/8 20% Neut	100	8%	20% Neut-SH
150/6 20% Neut	150	6%	20% Neut-SH
50/6 20% SMA	50	6%	20% SMA-SH
100/4 20% SMA	100	4%	20% SMA-SH
100/6 20% SMA	100	6%	20% SMA-SH
100/8 20% SMA	100	8%	20% SMA-SH
150/6 20% SMA	150	6%	20% SMA-SH

[a] Target number of HEA units per polymer chain
[b] Target percentage of EXEA vs. HEA, e.g., there are 6 units of EXEA in a chain length 100 polymer
[c] Target mass percent of functional polymer vs. network polymer, e.g., there is 80mg of functional polymer in a mold with 400mg of network polymer.

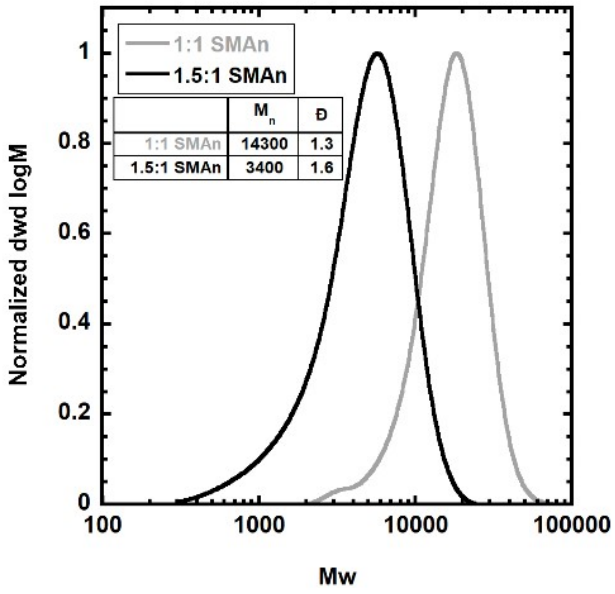
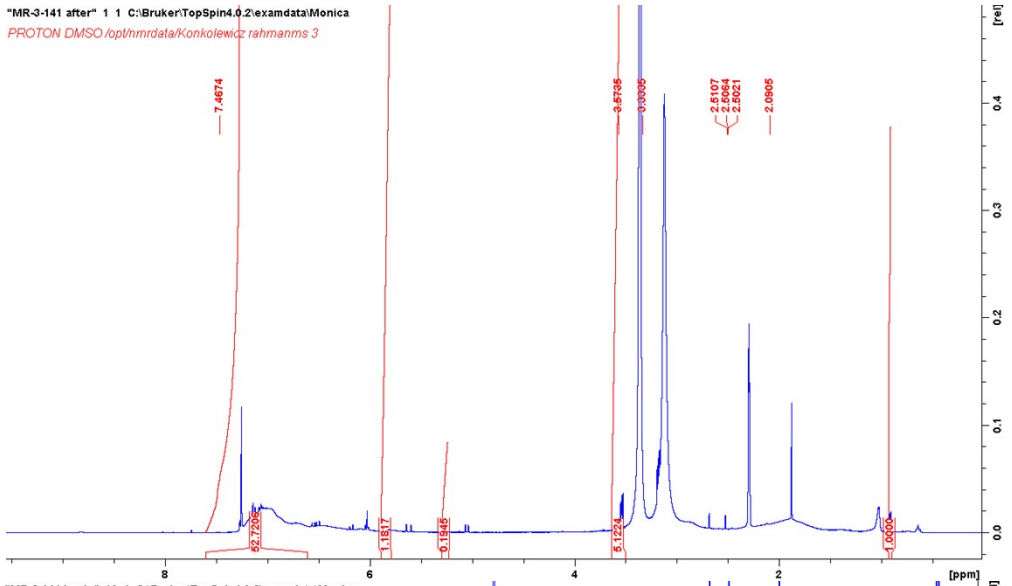


Figure S1. SEC characterization of pre-functionalized styrene-maleic anhydride polymers. Samples were run with THF as eluent.

Table S3. MW characteristics of HEA/EXEA copolymers

Polymer	M_n	$Đ$	$M_{n,th}$
50/6 HEA	10200	1.2	6700
100/4 HEA	20800	1.2	12700
100/6 HEA	23200	1.3	13100
100/8 HEA	23300	1.2	13600
150/6 HEA	29600	1.3	19600

a



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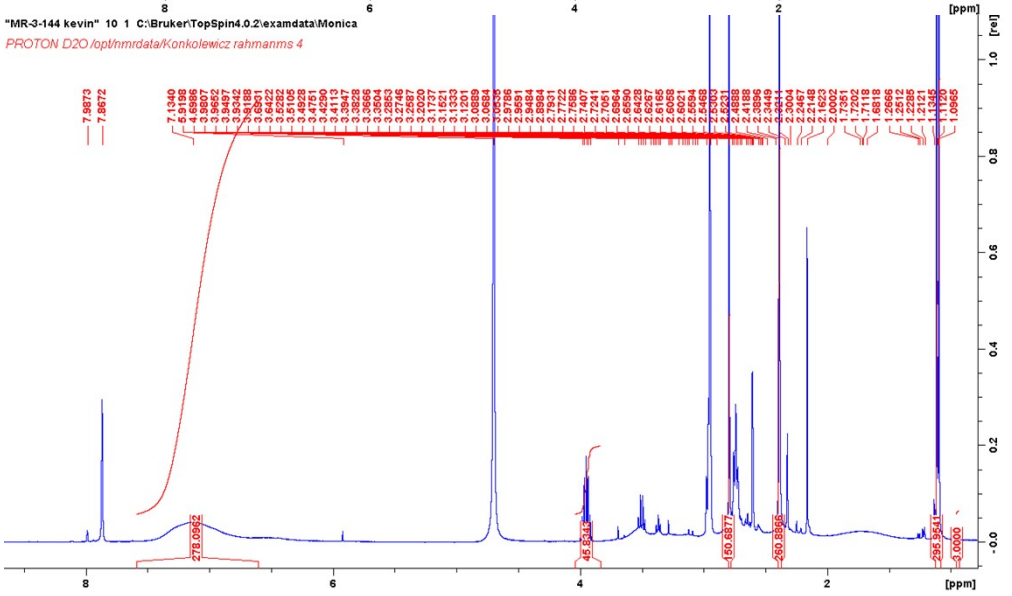

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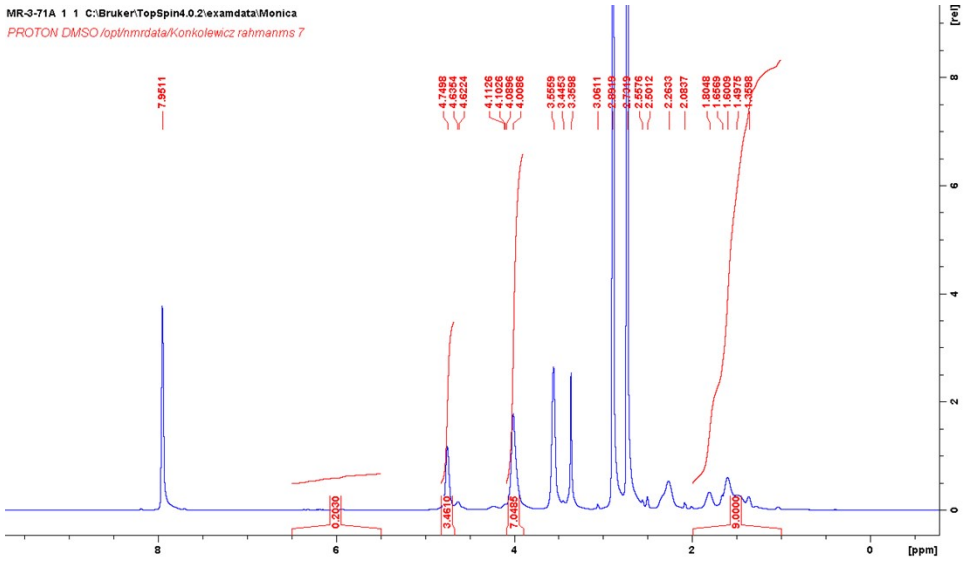
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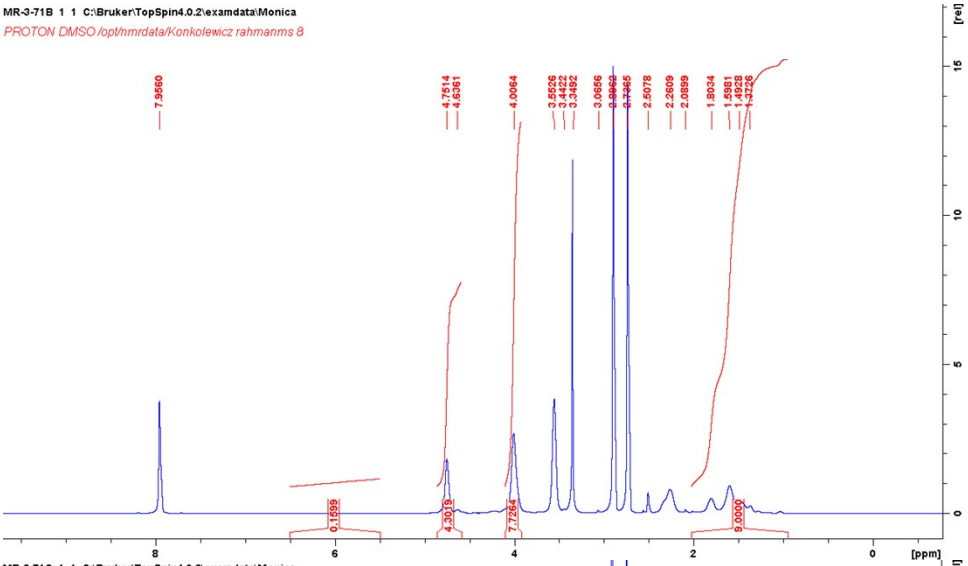
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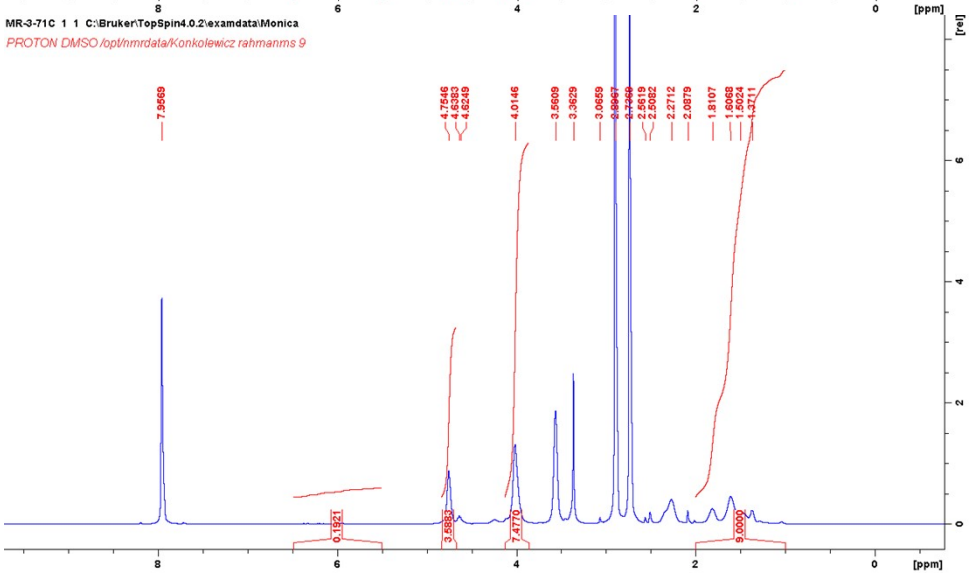
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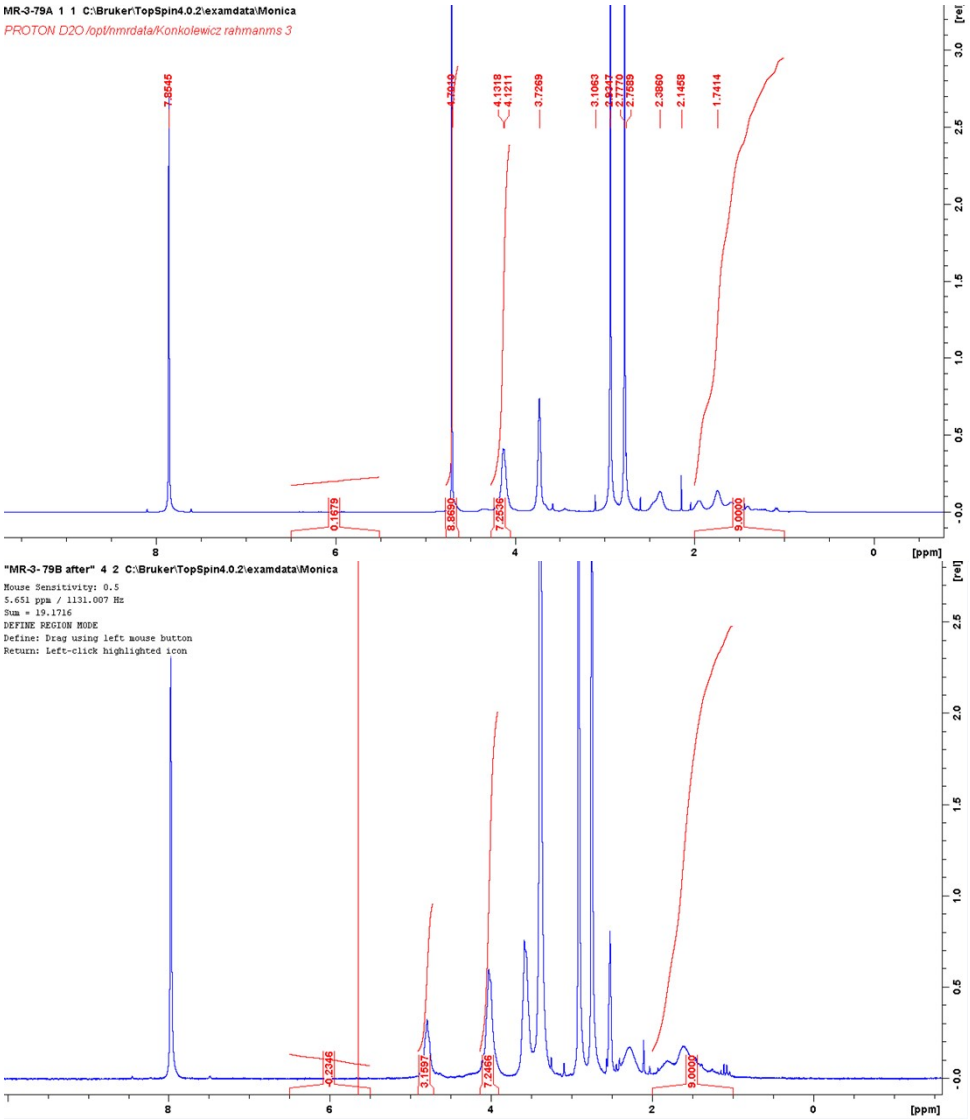


Figure S2. ^{1}H NMR characterization of network materials: (a) 1-1-SMAn; (b) Neut-SH; (c)HEA CL100 XL6; (d)HEA CL100 XL4; (e)HEA CL100 XL8; (f) HEA CL50 XL6; (g)HEA CL150 XL6.

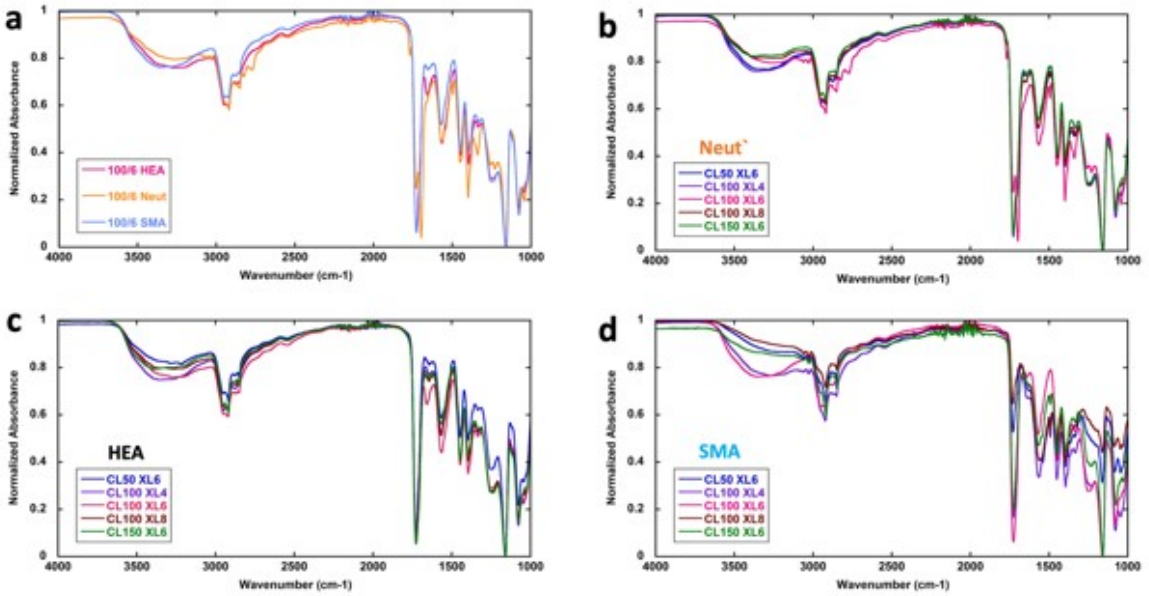


Figure S3. IR characterization of network materials: (a) comparing across functional polymers; (b) comparing across 20% Neut materials of varying chain length and crosslinker density; (c) comparing across HEA network materials with no functional polymer with varying chain length and crosslinker density; (d) comparing across 20% SMA materials of varying chain length and crosslinker density.

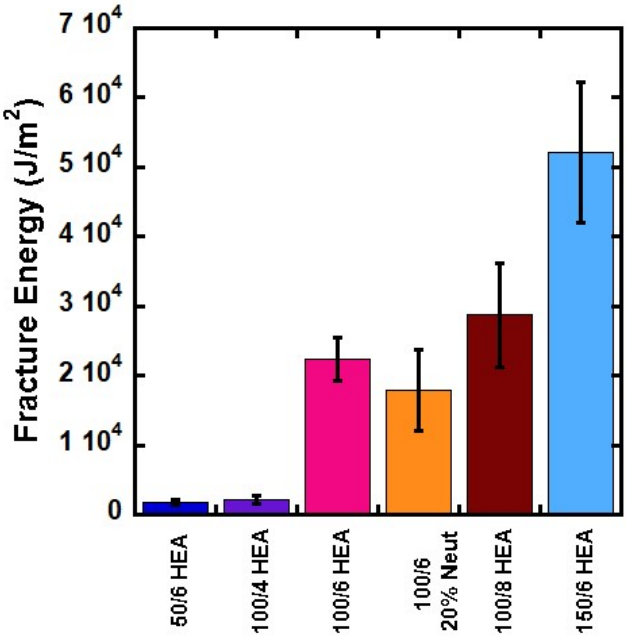


Figure S4. Fracture energies of HEA-EXEA networks and 100/6 20% Neut. Materials were notched with a razor and then underwent tensile testing. The difference in performance of notched materials vs. uncut materials is expressed as fracture energy.

Table S4. Mechanical and thermal Properties of the Materials

Material	Chain Length	Thiol Crosslink density	T_g (℃)	Strain at break ε_{break} (kPa)	Stress at break σ_{peak} (kPa)	Young's Modulus (kPa)	Swelling Ratio
HEA	50	0.06	9.02	1.1 ±0.1	980 ±60	1200 ±100	3.70 ±0.06
HEA	100	0.04	8.35	1.6 ±0.2	1100 ±200	1500 ±100	3.0 ±0.2
HEA	100	0.06	13.58	1.6 ±0.1	4000 ±400	4400 ±500	1.80 ±0.03
HEA	100	0.08	24.97	1.4 ±0.2	7000±600	9800 ±600	1.30 ±0.05
HEA	150	0.06	26.70	0.6 ±0.1	31000±2000	310000 ±20000	1.30 ±0.05
HEA + 20%SMA	50	0.06	18.79	0.7 ±0.1	700 ±100	1800 ±200	6.4 ±0.1
HEA + 20%Neut	50	0.06	15.65	0.9 ±0.2	670 ±40	1400 ±200	5.3 ±0.2
HEA + 20%SMA	100	0.04	14.71	1.4 ±0.2	760 ±20	1600 ±100	5.5 ±0.4
HEA + 20%Neut	100	0.04	13.23	1.2 ±0.1	1090 ±70	1990 ±60	4.30 ±0.01
HEA + 20%SMA	100	0.06	21.54	0.60 ±0.03	4400 ±400	17000 ±1000	2.30 ±0.08
HEA + 10%Neut	100	0.06	18.75	1.00 ±0.03	4200 ±600	6900 ±800	2.7 ±0.2
HEA +	100	0.06	23.63	0.8	6700 ±600	14000 ±2000	2.00 ±0.04

20%Neut				±0.1			
HEA + 40%Neut	100	0.06	24.56	0.70 ±0.05	8300 ±500	14780 ±1000	1.60 ±0.05
HEA + 20%SMA	100	0.08	36.95	1.4 ±0.2	5100±300	16720 ±3000	2.2 ±0.2
HEA + 20%Neut	100	0.08	32.71	1.0 ±0.1	6900±900	17130 ±4000	1.70 ±0.03
HEA + 20%SMA	150	0.06	32.45	0.020 ±0.001	14000±1000	800000 ±40000	1.80 ±0.07
HEA + 20%Neut	150	0.06	35.79	0.05 ±0.02	23000±1000	650000 ±40000	1.40 ±0.02

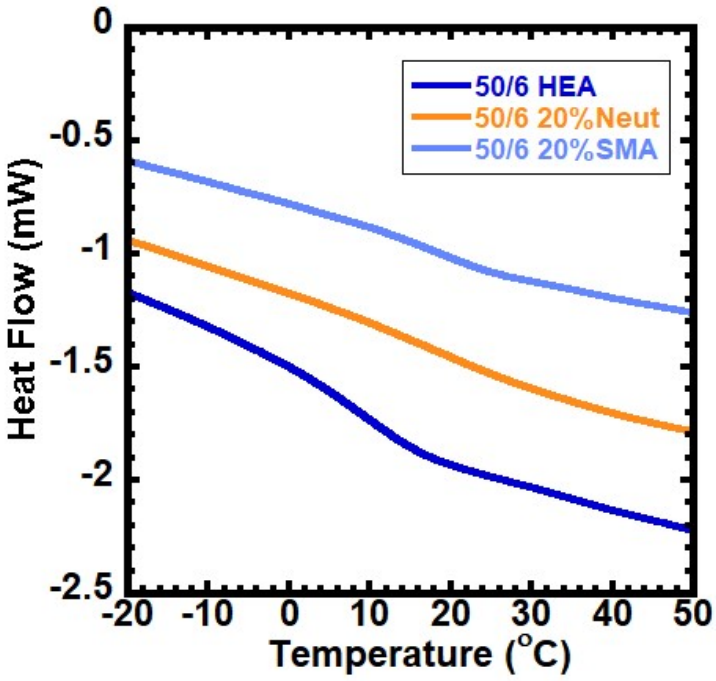


Figure S5. DSC Curves of 50/6 materials

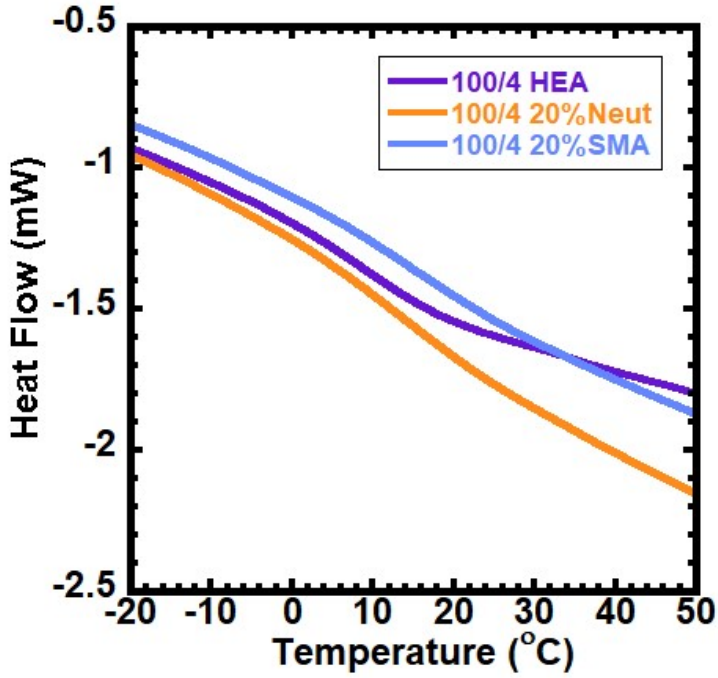


Figure S6. DSC Curves of 100/4 materials

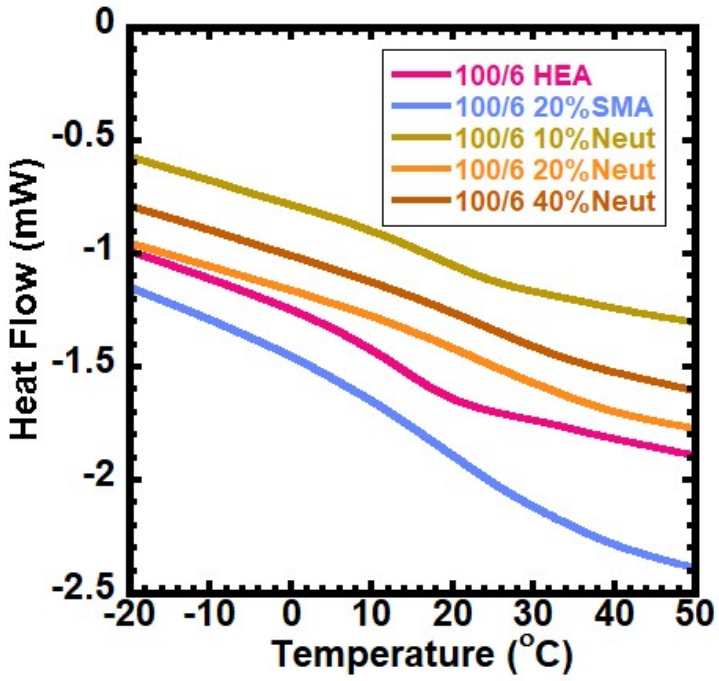


Figure S7. DSC Curves of 100/6 materials

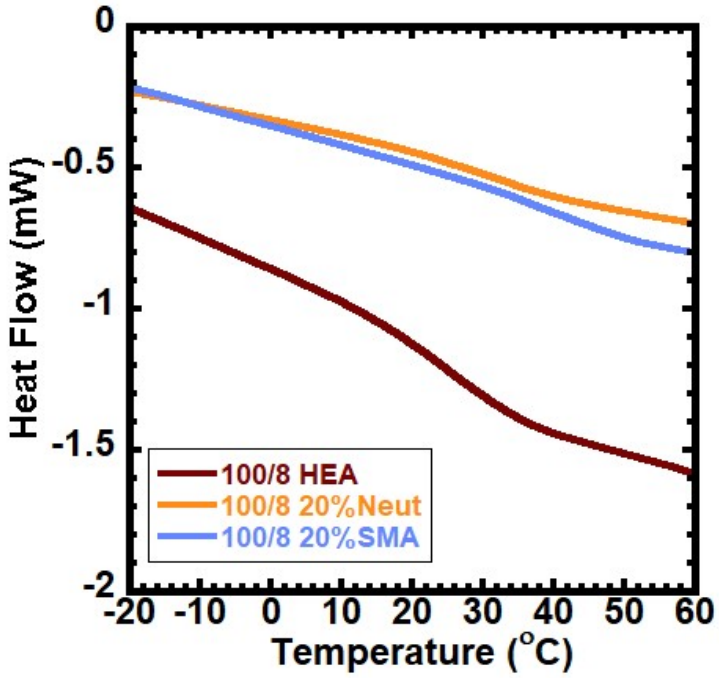


Figure S8. DSC Curves of 100/8 materials

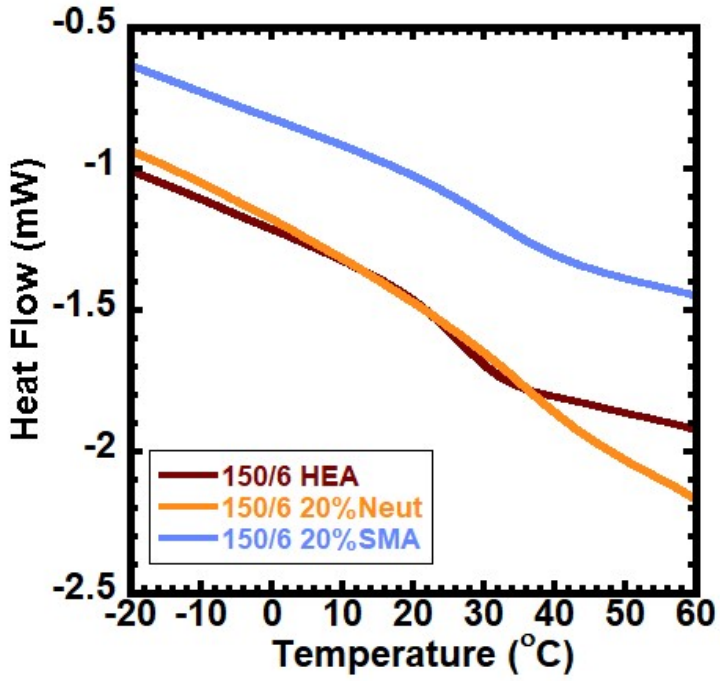


Figure S9. DSC Curves of 150/6 materials

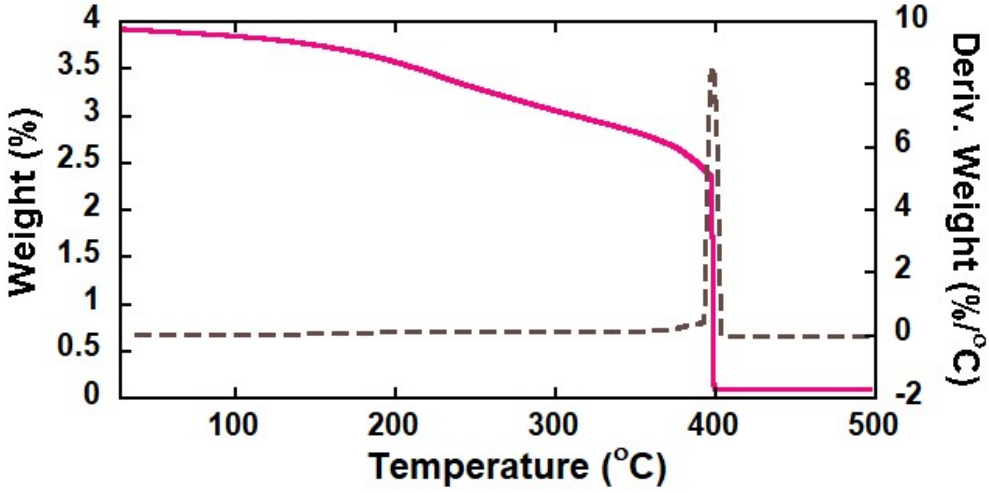


Figure S10. TGA Curve of 100/6 HEA materials.

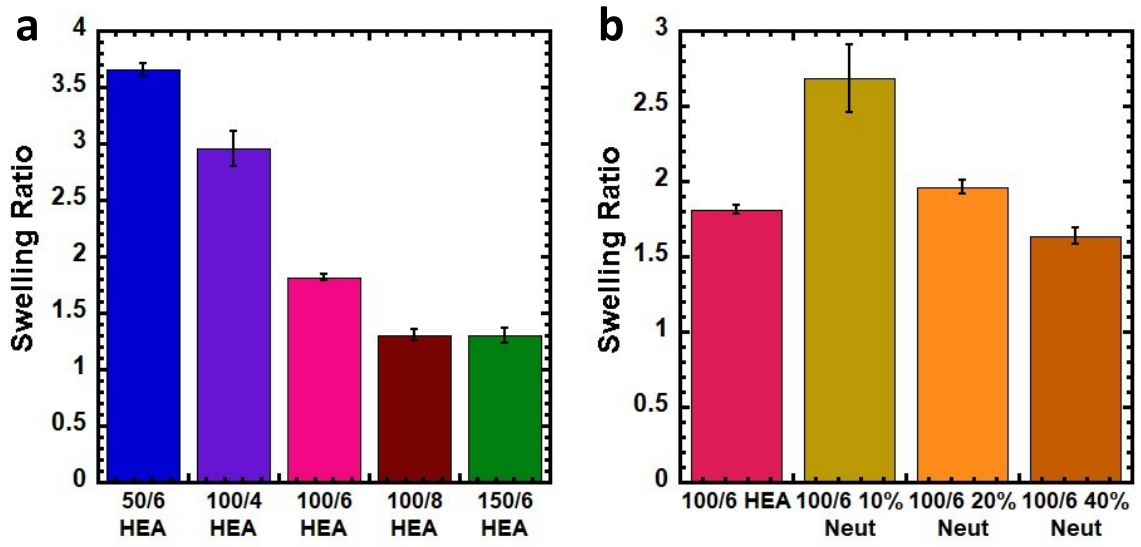


Figure S11. Swelling ratios of a) different poly(HEA) networks and b) Poly(HEA + Neut) materials at different loadings of Neut.

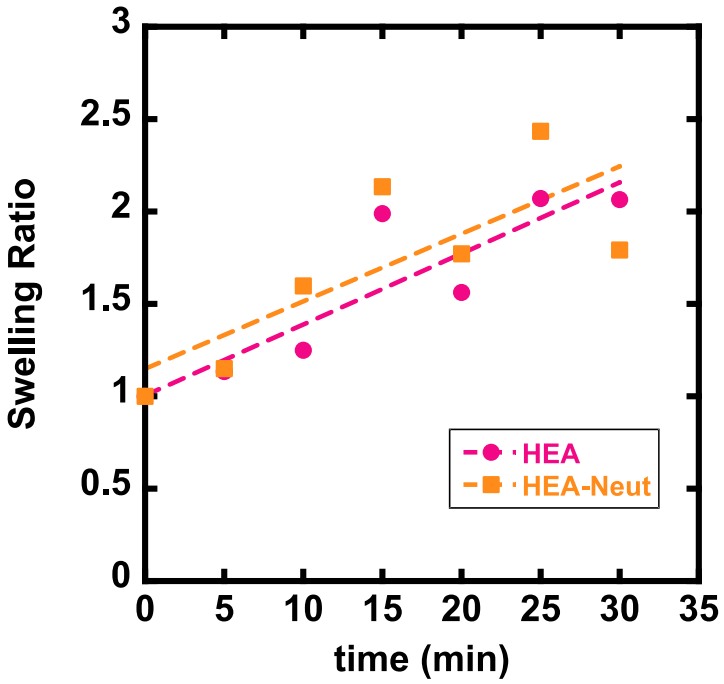
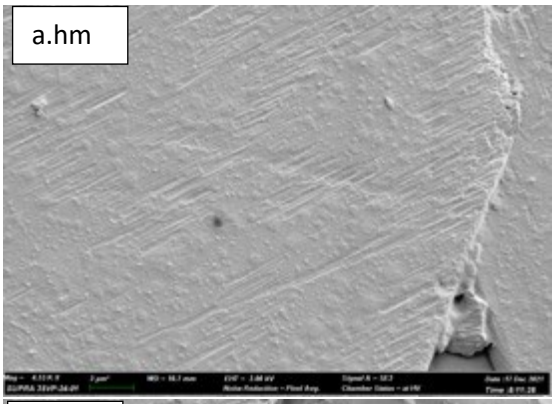


Figure S12. Change in Swelling ratio over time for 100/6 HEA and 100/6 20% Neut materials.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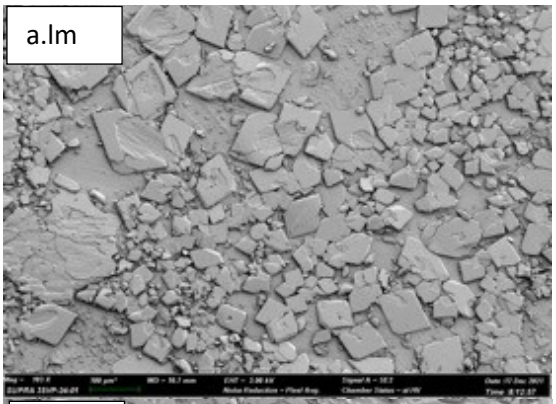
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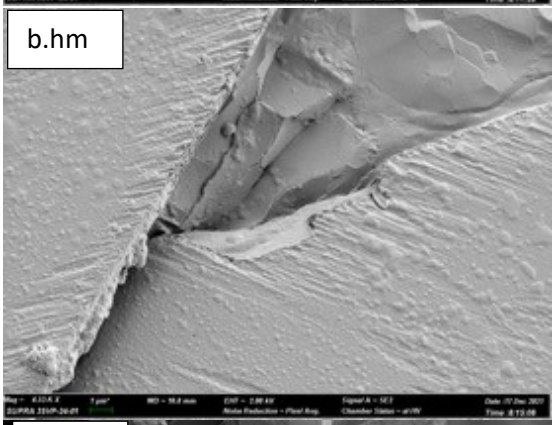
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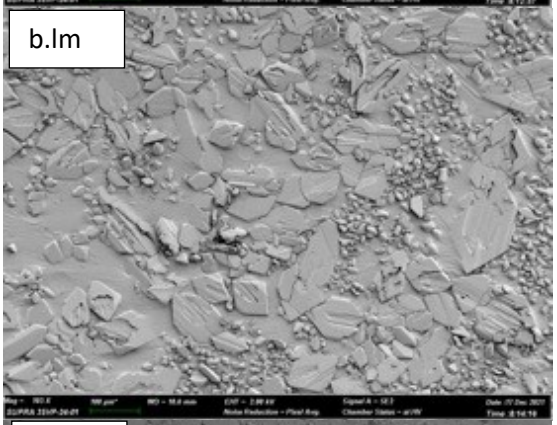
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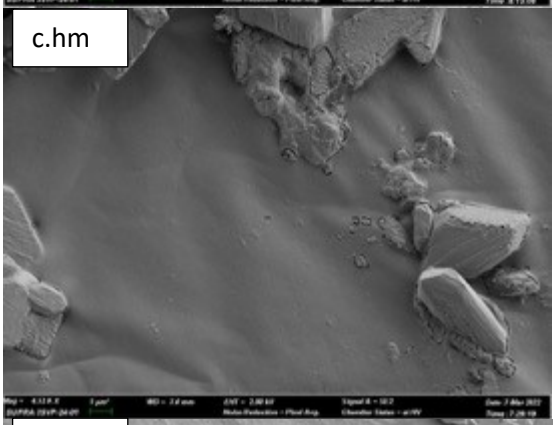
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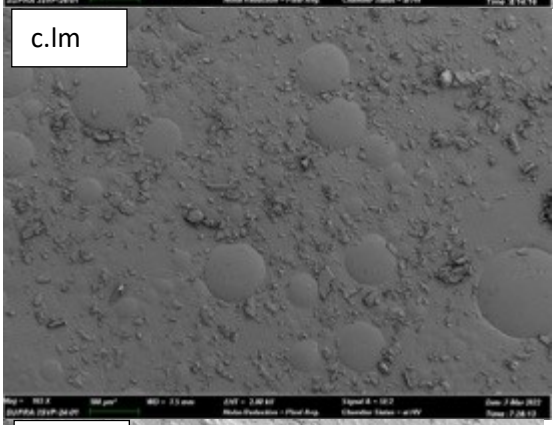
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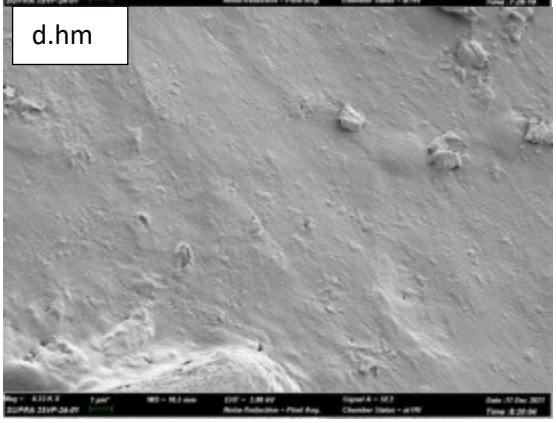
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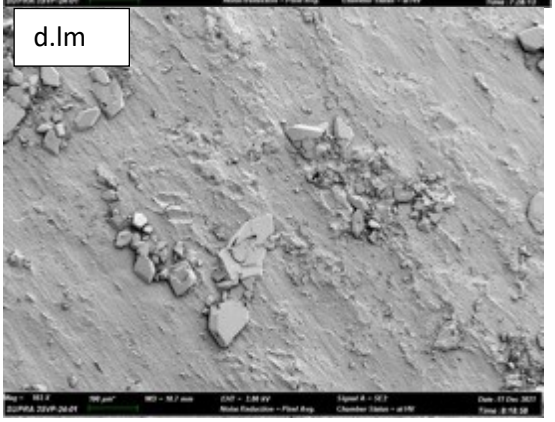
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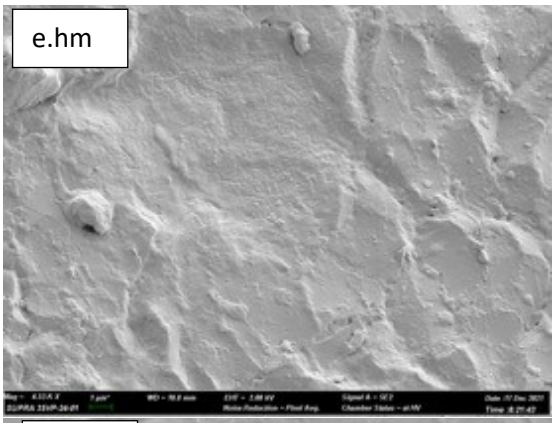
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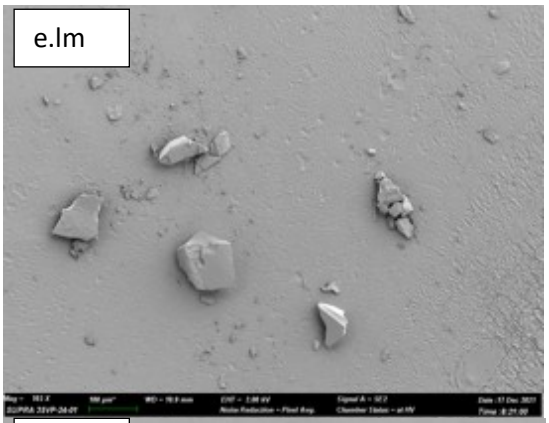
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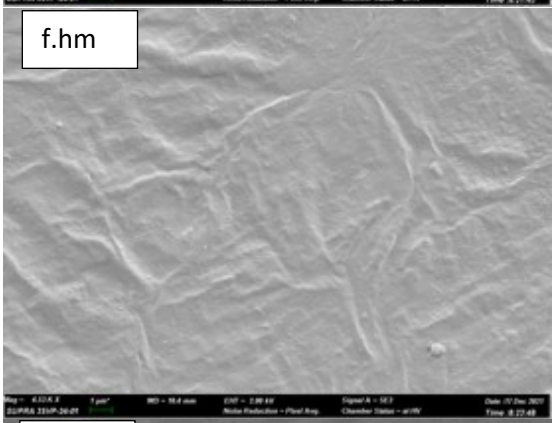
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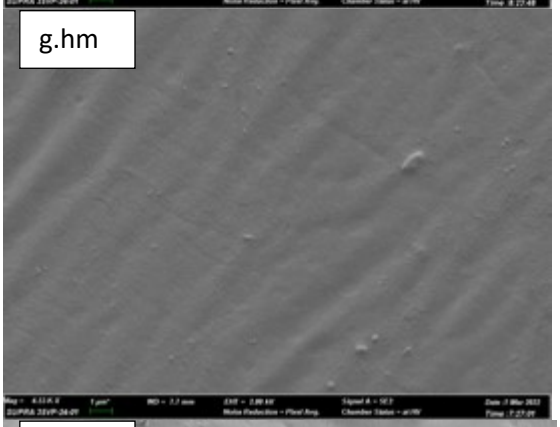
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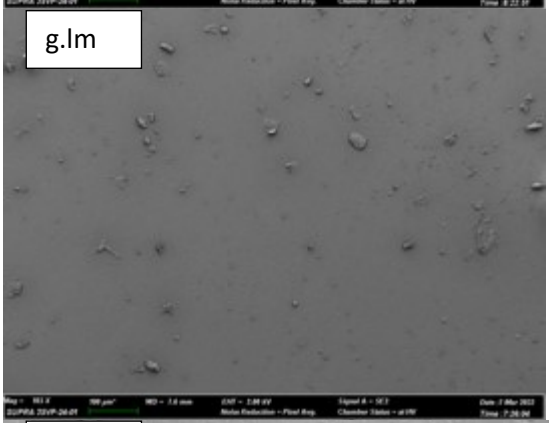
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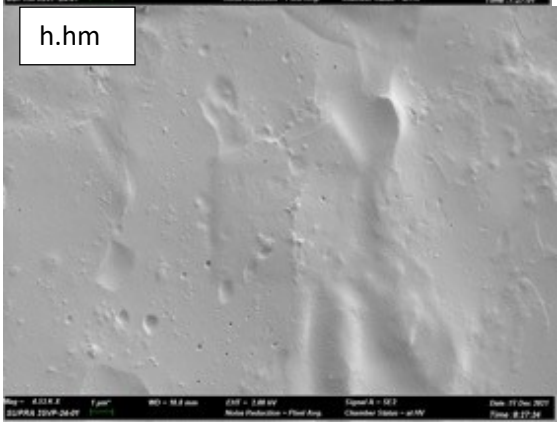
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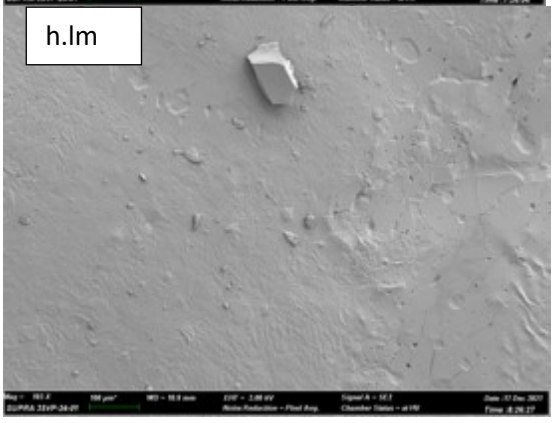
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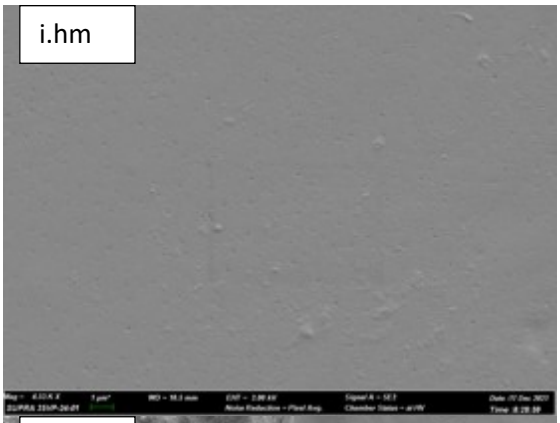
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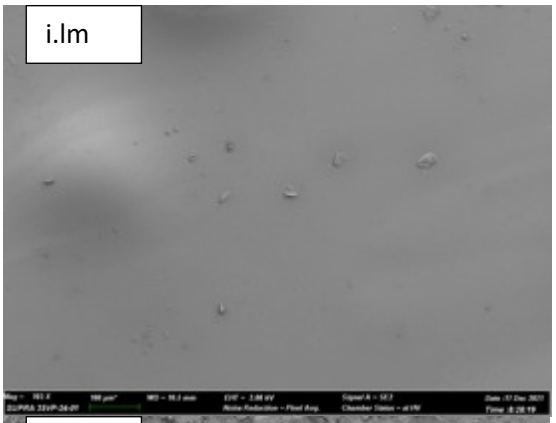
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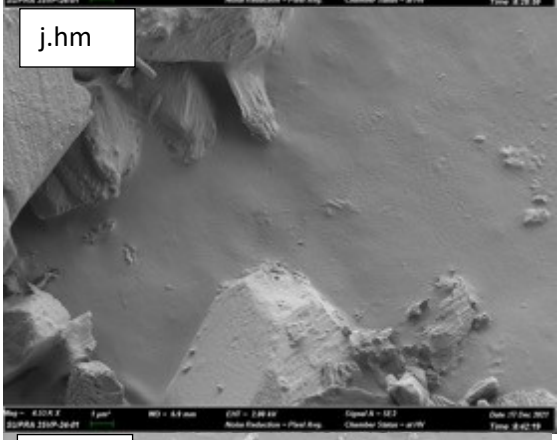
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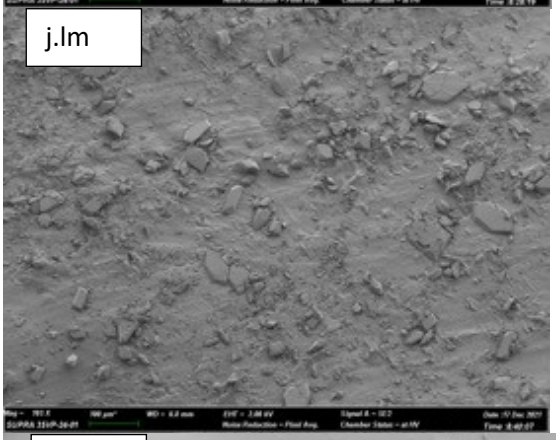
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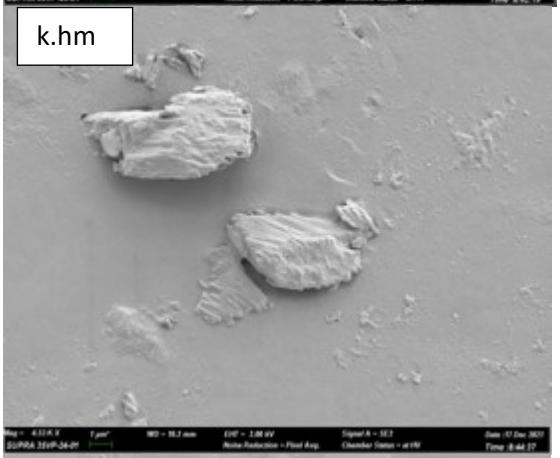
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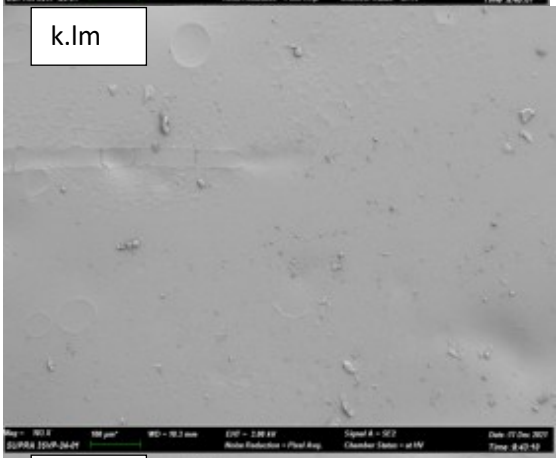
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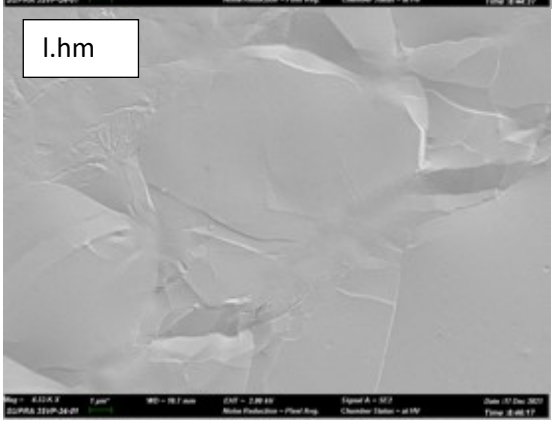
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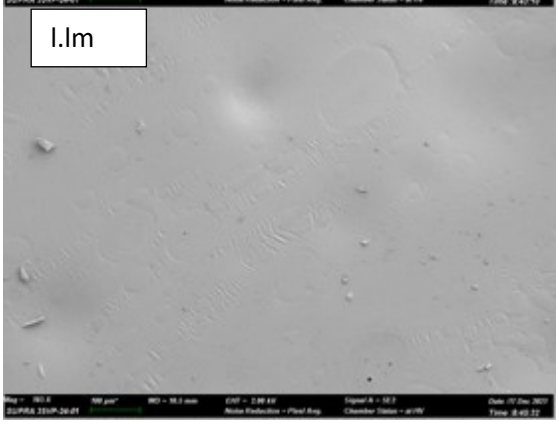
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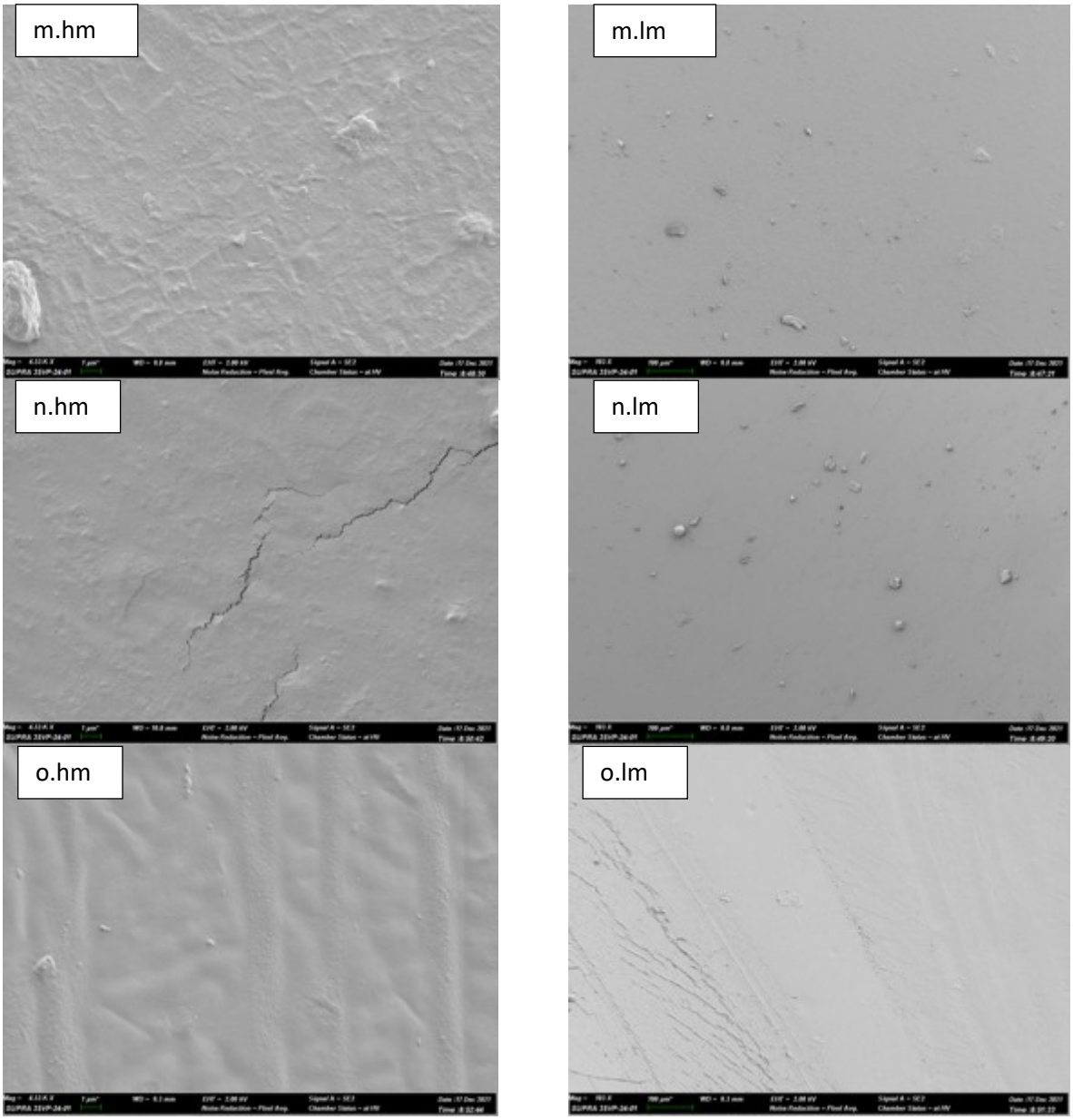

Figure S13. Scanning electron microscopy images of network materials. (a)HEA 50/6; (b)HEA 50/6 20%SMA; (c)HEA 50/6 20%Neut; (d)HEA 100/8; (e)HEA 100/8 20%SMA; (f)HEA 100/8 20%Neut; (g)HEA 150/6; (h)HEA 150/6 20%SMA; (i)HEA 150/6 20%Neut; (j)HEA 100/4; (k)HEA 100/4 20%SMA; (l)HEA 100/4 20%Neut; (m)HEA 100/6; (n)HEA 100/6 20%SMA; (o)HEA 100/6 20%Neut. Hm signifies high magnification and lm signifies low magnification for images.

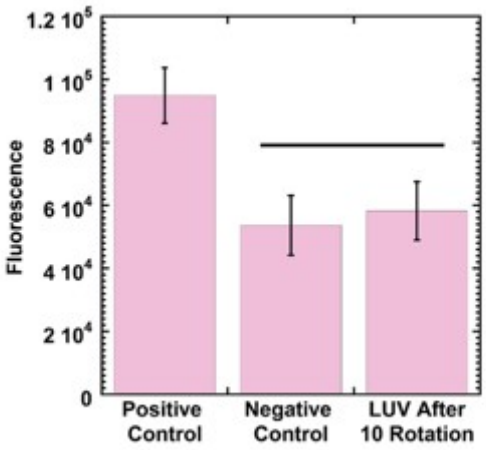

Figure S14. Fluorescence of diluted liposome solution after 10 full rotations. Fluorescence of positive control (10% Triton X-100 detergent) and negative control (diluted liposome solution without any rotation) have been included for reference. T-test between negative control and diluted liposome solution showed statistically insignificant difference ($p<0.05$).

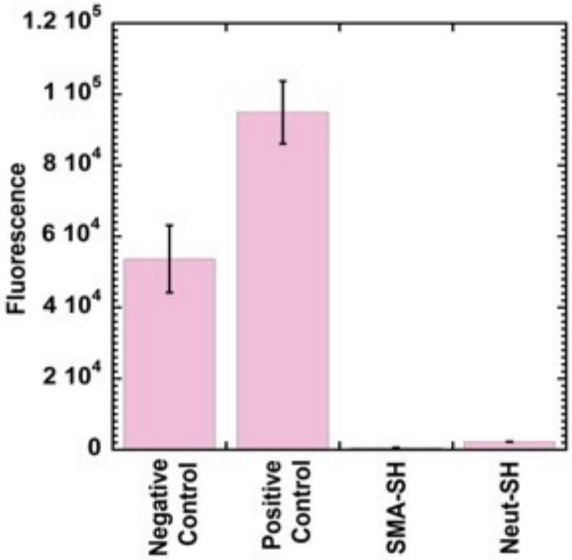

Figure S15. Fluorescence of SMA-SH and Neut-SH solutions. Fluorescence of positive control (10% Triton X-100 detergent) and negative control (diluted liposome solution) have been included for reference.

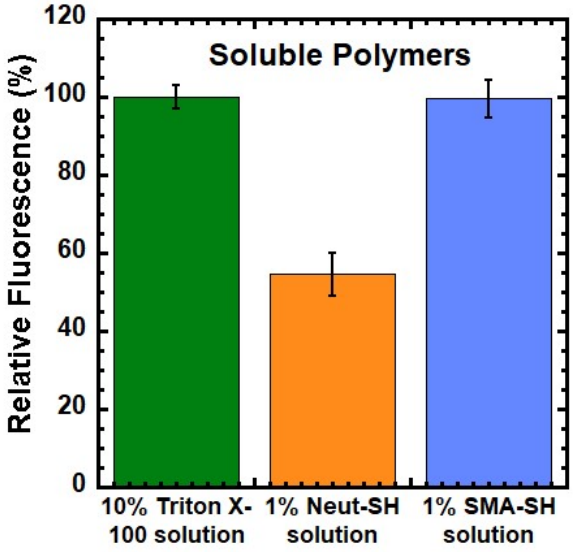

Figure S16. Liposome disruption performance of functional polymers in solution. All samples were inverted 10 times over the course of 80 sec. Fluorescence is normalized between a positive control (10% triton solution) at 100% and the completely undisturbed liposomes as the negative control at 0%.

$$\text{Relative Fluorescence} = \frac{Fluorescence\ of\ sample - Fluorescence\ of\ Negative\ control}{Fluorescence\ of\ Positive\ Control - Fluorescence\ of\ Negative\ Control} \times 100$$

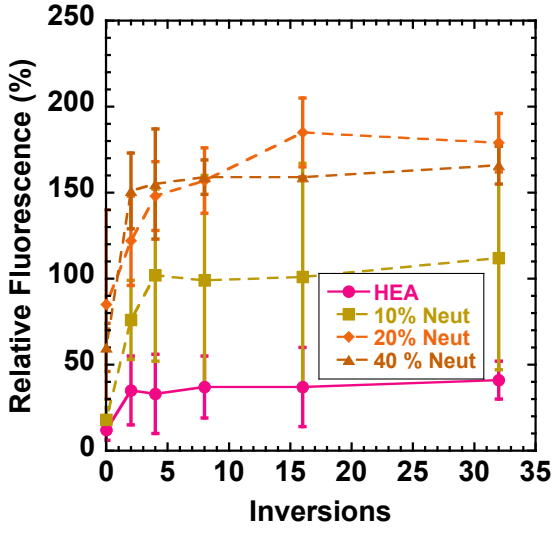

Figure S17. Timescale of liposome disruption. 100/6 HEA Liposome disruption performance of functional polymer materials with different loadings of Neut polymer from 0% (HEA) to 40% Neut. Each inversion is a full 8 second rotation.

$$\text{Relative Fluorescence} = \frac{Fluorescence\ of\ sample - Fluorescence\ of\ Negative\ control}{Fluorescence\ of\ Positive\ Control - Fluorescence\ of\ Negative\ Control} \times 100$$

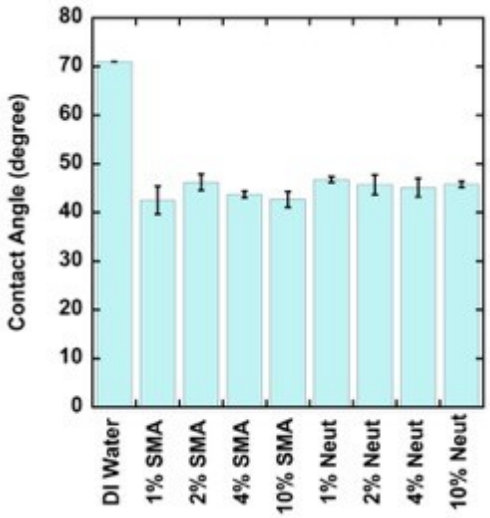

Figure S18. Contact angles of the SMA-SH and SMA-Neut surfactant solutions at different concentrations. Contact angle of DI (deionized) water is added for reference.

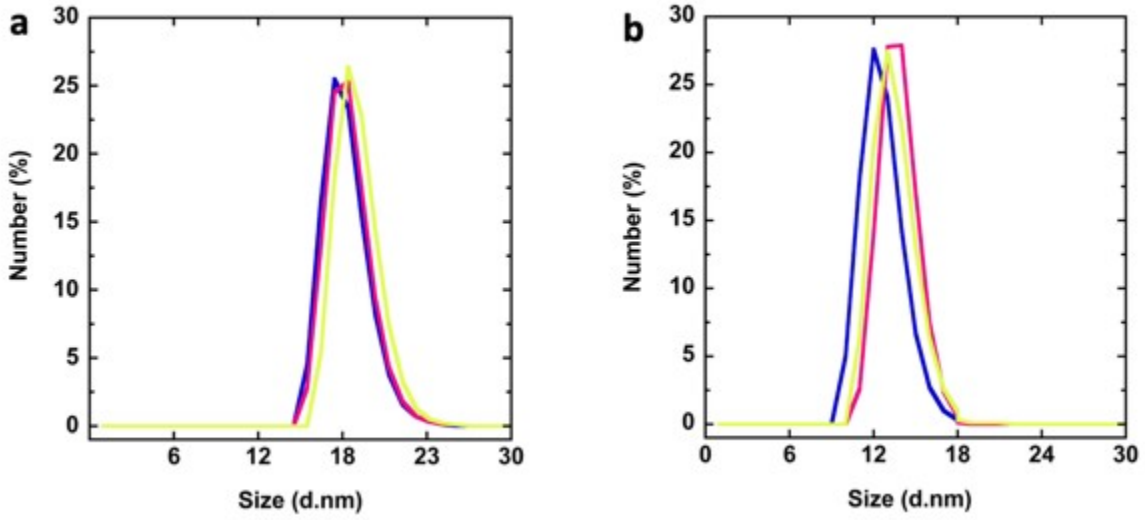

Figure S19. Dynamic light scattering data of the polymer (a)SMA-SH and (b)SMA-Neut solutions. For each type of materials, three measurements are shown here.

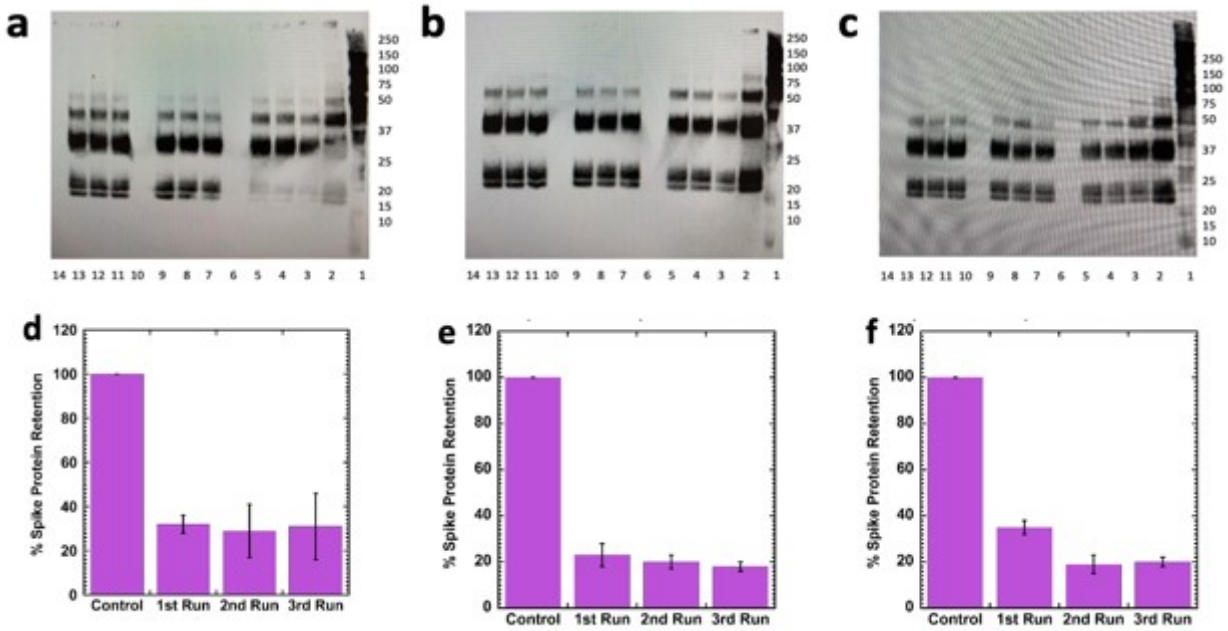

Figure S20. Reusability of network materials in spike protein capture. The soluble domain of spike protein (HCRBD) was incubated with network materials and then assayed by Western blot. After each run, the network materials were washed with buffer. (a-c) Western blot image of recovered

HCRBD in first (a), second (b), and third run (C). Lanes: 1. Ladder 2. HCRBD (free protein control) (0.14mg/mL) 3-5. HCRBD (0.14mg/mL) treated with 100/6 20% SMA. 6. Buffer treated with 100/6 20% SMA. 7-9. HCRBD (0.14mg/mL) treated with 100/6% HEA. 10. Buffer treated with 100/6 HEA. 11-13. HCRBD (0.14mg/mL) treated with 100/6 20% Neut. 14. Buffer treated with 100/6 20% Neut. (d) Analysis of Western blot band intensities followed by treatment with 100/6 HEA+20% SMA relative to control. (e) Analysis of Western blot band intensities followed by treatment with 100/6 HEA relative to control. (f) Analysis of Western blot intensities followed by treatment with 100/6+20%Neut relative to control. Error bars are for the 3 lanes shown for each network polymer.

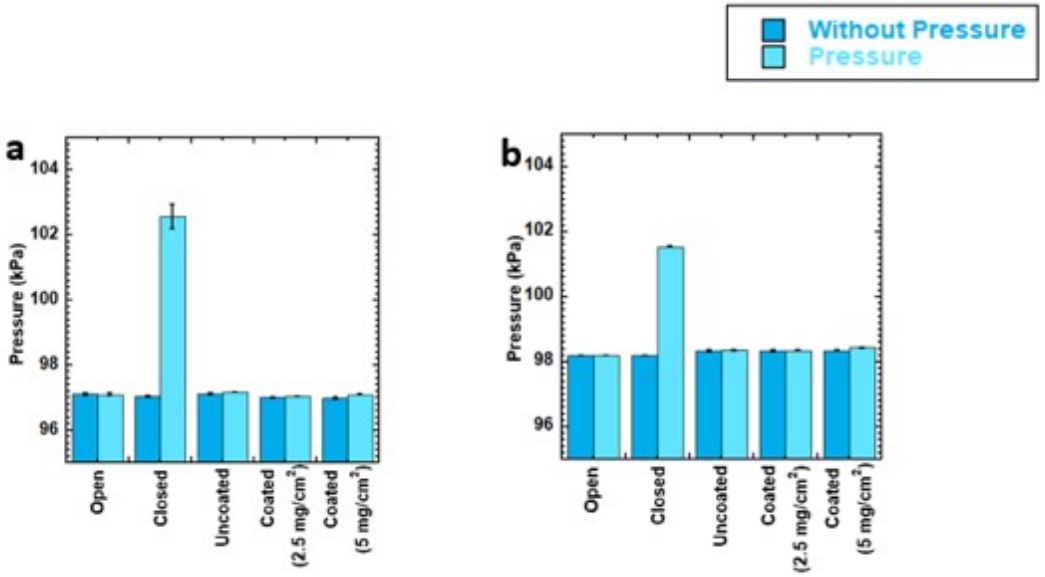

Figure S21. Pressure drop test for (a) KN95 and (b) surgical masks coated with 50/6 20% Neut (the highest-performing material in the chain length/crosslinker series). Each type of masks was coated in two different concentrations, 2.5 mg/cm^2 and 5 mg/cm^2. Open system and closed system (parafilm) are added as reference.

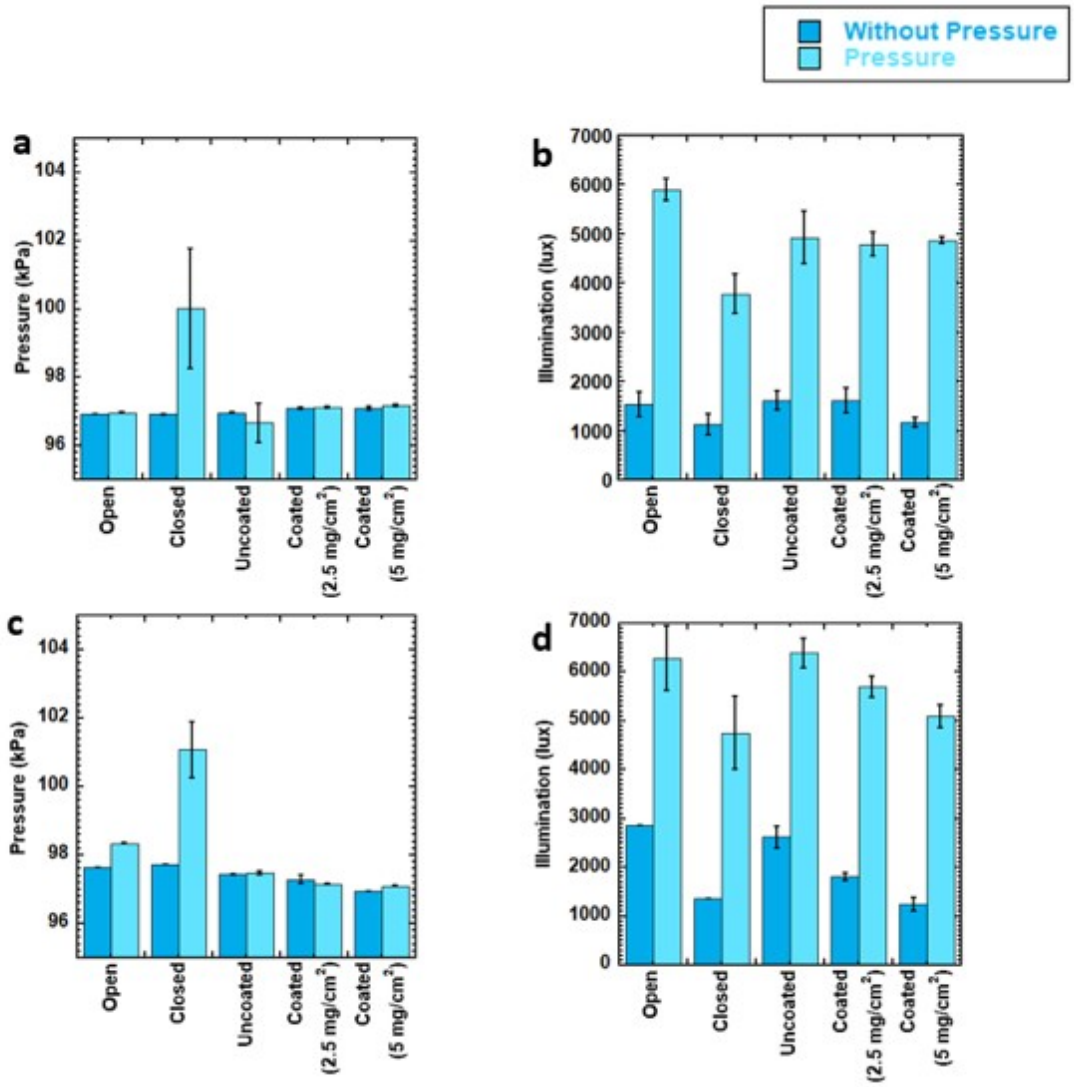

Figure S22. Filtration efficiency of (a-b) KN95 and (c-d) surgical masks coated with 50/6 20% Neut (the highest-performing material in the chain length/crosslinker series). Each type of masks was coated in two different concentrations 2.5 mg/cm^2 and 5 mg/cm^2. Open system and close system (parafilm) are added as reference.