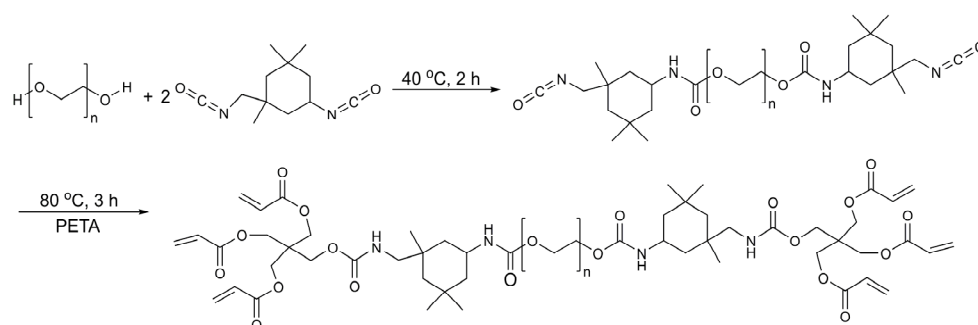




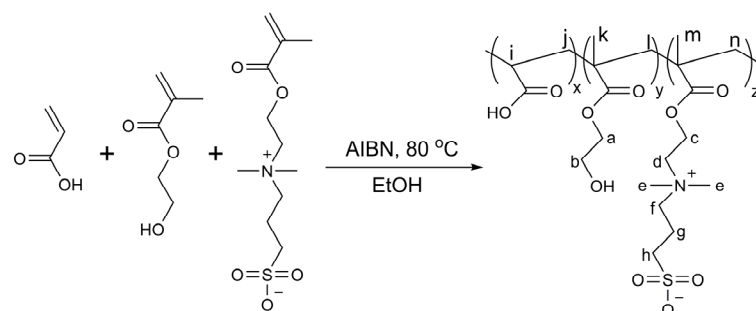
### Instruments

The SEM images were acquired from the Zeiss SUPRATM 55 SAPPHERE field-emission scanning electron microscope. The AFM images were acquired from the Bruker Icon atomic force microscope. FTIR spectra were collected in wavenumber range of 4000–400  $\text{cm}^{-1}$  on a Thermo Nicolet IS5 instrument. Raman scattering was conducted on a Horiba Jobin-Yvon Lab Ram HR VIS high-resolution confocal Raman microscope equipped with a 633 nm laser.  $^1\text{H}$  NMR spectroscopy was performed on the Bruker Advance DRX-300

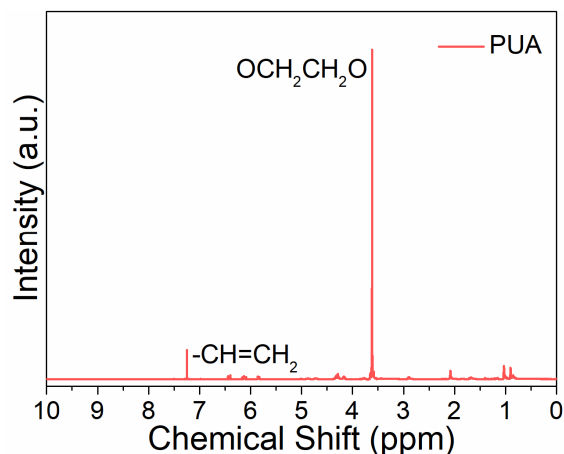
spectrometer (Bruker, Germany) at 25 °C. The XPS spectra were obtained from a Thermo Escalab 250Xi spectrometer equipped with an X-ray source producing Al  $K\alpha$  radiation (1486.6 eV). The friction tests were completed by a MS-T3001 ball disc friction tester. Water contact angle tests were carried out by a SDP 260 contact angle/surface tension analyzer at room temperature.



**Figure S1.** Schematic diagram of synthesis of polyurethane acrylate (PUA).



**Figure S2.** Schematic diagram of synthesis of P(AA-HEMA-SBMA) acrylic resin (PAHS).



The figure displays the  $^1\text{H}$  NMR spectrum of PAHS (poly(allyl hydrogensulfate)) in  $\text{D}_2\text{O}$ . The x-axis represents the chemical shift in ppm, ranging from 0 to 6. The y-axis represents the intensity in arbitrary units (a.u.). The spectrum shows several distinct peaks labeled with letters corresponding to the protons in the chemical structure of the polymer repeat unit shown in the inset:

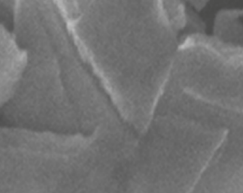
- Peak a:** Protons on the carbon adjacent to the sulfate group ( $\text{CH}_2$ ).
- Peak b:** Protons on the carbon adjacent to the hydroxyl group ( $\text{CH}_2$ ).
- Peak c:** Protons on the carbon bearing the hydroxyl group ( $\text{CH}$ ).
- Peak d:** Protons on the carbon adjacent to the sulfate group ( $\text{CH}_2$ ).
- Peak e:** Protons on the carbon adjacent to the hydroxyl group ( $\text{CH}_2$ ).
- Peak f:** Protons on the carbon bearing the hydroxyl group ( $\text{CH}$ ).
- Peak g:** Protons on the carbon adjacent to the sulfate group ( $\text{CH}_2$ ).
- Peak h:** Protons on the carbon adjacent to the hydroxyl group ( $\text{CH}_2$ ).
- Peak i:** Protons on the carbon bearing the hydroxyl group ( $\text{CH}$ ).
- Peak j:** Protons on the carbon adjacent to the sulfate group ( $\text{CH}_2$ ).
- Peak k, l, m, n:** Protons on the carbon bearing the hydroxyl group ( $\text{CH}$ ).

The inset shows the chemical structure of the PAHS repeat unit, with protons labeled a through n. The structure is a poly(allyl hydrogensulfate) chain, where the repeating unit is  $[\text{CH}_2\text{CH}(\text{CH}_2\text{CH}_2\text{OSO}_3\text{H})\text{CH}_2\text{CH}(\text{CH}_2\text{CH}_2\text{OSO}_3\text{H})]_n$ . The protons are labeled as follows: a (backbone  $\text{CH}_2$ ), b (backbone  $\text{CH}_2$ ), c (backbone  $\text{CH}$ ), d (backbone  $\text{CH}_2$ ), e (backbone  $\text{CH}_2$ ), f (backbone  $\text{CH}$ ), g (backbone  $\text{CH}_2$ ), h (backbone  $\text{CH}_2$ ), i (backbone  $\text{CH}$ ), j (backbone  $\text{CH}_2$ ), k, l, m, n (backbone  $\text{CH}$ ).

Figure 1 displays the FTIR spectra of PUA (a) and PAHS (b). The x-axis represents Wavenumber ( $\text{cm}^{-1}$ ) from 3500 to 1000, and the y-axis represents Transmittance (%).

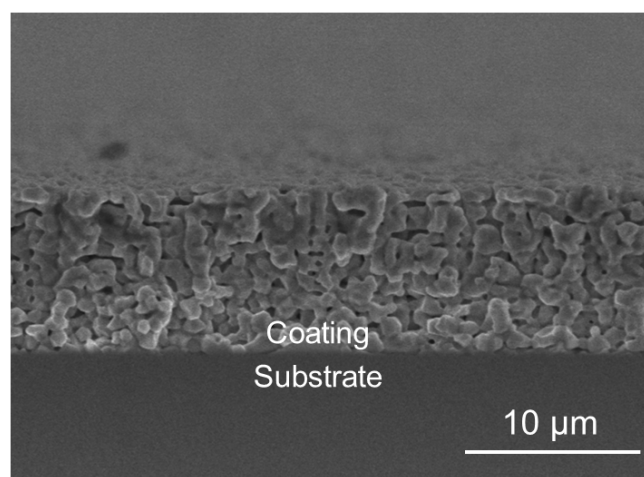
**(a) PUA Spectrum:** The spectrum shows characteristic peaks for PUA, including N-H stretching around 3400  $\text{cm}^{-1}$ , C=C-H stretching around 3000  $\text{cm}^{-1}$ , C-C-H stretching around 2900  $\text{cm}^{-1}$ , C=O stretching around 1700  $\text{cm}^{-1}$ , C=N stretching around 1600  $\text{cm}^{-1}$ , and C=C stretching around 1500  $\text{cm}^{-1}$ .

**(b) PAHS Spectrum:** The spectrum shows characteristic peaks for PAHS, including O-H stretching around 3400  $\text{cm}^{-1}$ , C-H stretching around 3000  $\text{cm}^{-1}$ , C=O stretching around 1700  $\text{cm}^{-1}$ , C-N stretching around 1500  $\text{cm}^{-1}$ , and S=O stretching around 1000  $\text{cm}^{-1}$ .

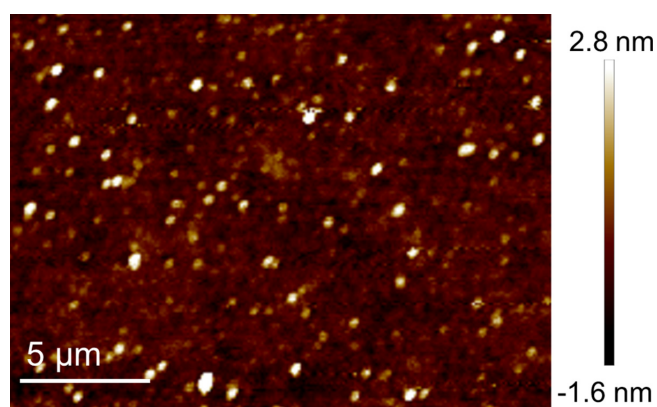


200 nm

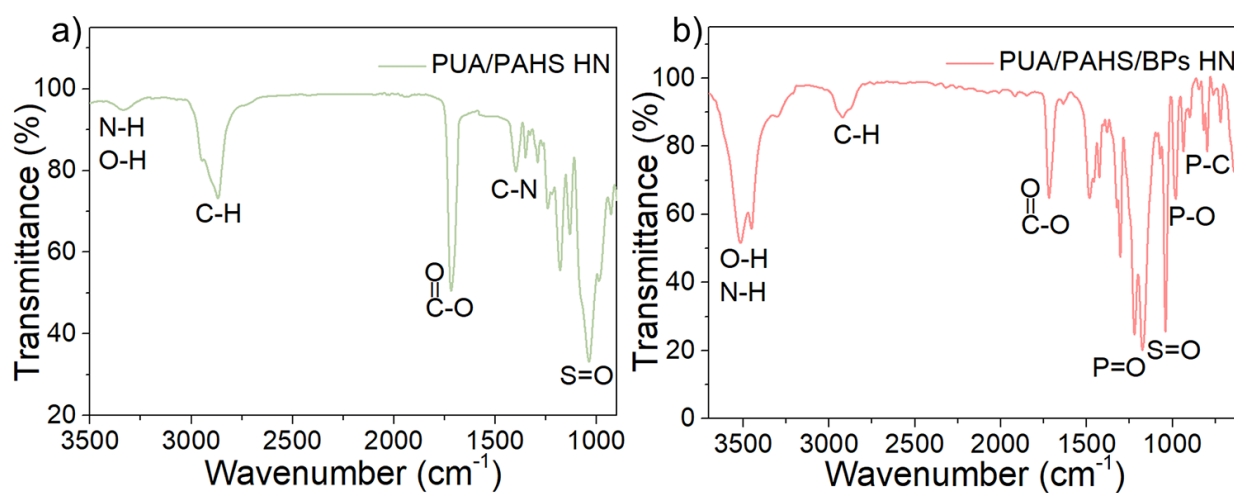
**Figure S6.** SEM image of black phosphorus nanosheets (BPs).



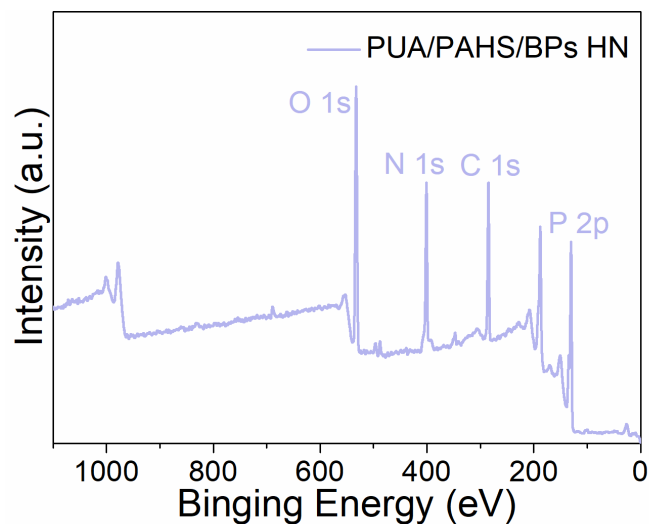
**Figure S7.** The cross-section SEM image of PUA/PAHS/BPs HN.



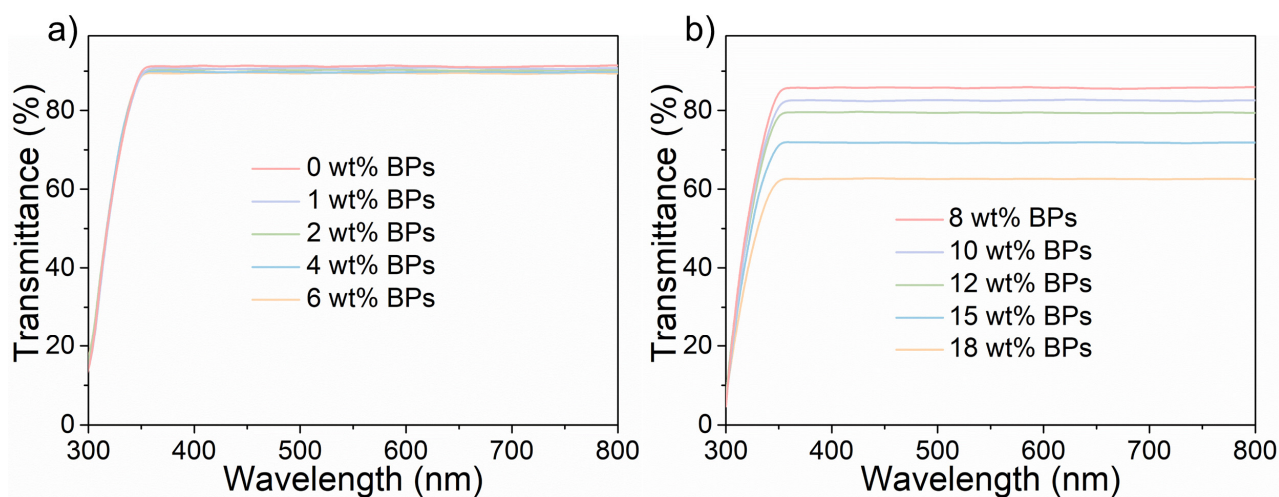
**Figure S8.** AFM image of PUA/PAHS/BPs HN.



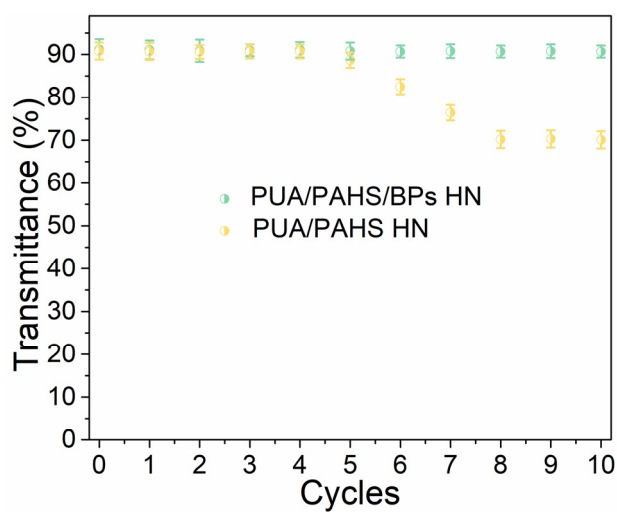
**Figure S9.** a) FTIR spectrum of PUA/PAHS HN. b) FTIR spectrum of PUA/PAHS/BPs HN.



**Figure S10.** XPS spectrum of PUA/PAHS/BPs HN.



**Figure S11.** a) Transmission spectra of PUA/PAHS/BPs HN with 0 wt%, 1 wt%, 2 wt%, 4 wt% and 6 wt% BPs respectively. b) Transmission spectra of PUA/PAHS HN with 8 wt%, 10 wt%, 12 wt%, 15 wt%, 18 wt% BPs respectively.



**Figure S12.** The average transmittance of a PMMA slide coated with PUA/PAHS/BPs HN during antifogging tests after high and low temperature cycles.