Supplementary Materials

2S-Soy Protein-Based Biopolymer as a Non-Covalent Surfactant and its Effects on
Electrical Conduction and Dielectric Relaxation of Polymer Nanocomposites

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Figure S1. AC conductivity of 1 wt% nanocomposites from RT to 180°C: (a) 1wt% CNF, (b) 1wt% sCNF-1:1, (c) 1wt% sCNF-1:3

Figure S2. Conductivity master curves of 1wt% nanocomposites: (a) 1wt% CNF, (b) 1wt% sCNF-1:1, (c) 1wt% sCNF-1:3
Figure S3. Dielectric constant ($\varepsilon'$) and loss factor ($\tan \delta$) of pure PVDF and the nanocomposites at (a, b) RT and (c, d) 180°C, respectively.

Figure S4. $M''$ vs. frequency plots of 1 wt% nanocomposites from RT to 180°C: (a) 1 wt% CNF, (b) 1 wt% sCNF-1:1, (c) 1 wt% sCNF-1:3
Figure S5. Self-convolution peak fitting examples: 1wt% sCNF-1:1 nanocomposite at RT and 180°C, respectively.

Figure S6. Arrhenius plots for (a) conductivity relaxation, (b) MWS relaxation, and (c) $\alpha_c$ relaxation for pure PVDF and 1wt% nanocomposites.
Table S1. Activation energy (in eV) of conductivity, MWS and $\alpha_c$ relaxations from HN fitting

<table>
<thead>
<tr>
<th></th>
<th>PVDF</th>
<th>0.1wt% CNF</th>
<th>0.1wt% sCNF-1:1</th>
<th>0.1wt% sCNF-1:3</th>
<th>1wt% CNF</th>
<th>1wt% sCNF-1:1</th>
<th>1wt% sCNF-1:3</th>
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<tbody>
<tr>
<td>Conductivity relaxation</td>
<td>0.182</td>
<td>0.167</td>
<td>0.186</td>
<td>0.184</td>
<td>0.125</td>
<td>0.309</td>
<td>0.372</td>
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<tr>
<td>MWS $\geq$ 100°C</td>
<td>0.491</td>
<td>0.501</td>
<td>0.568</td>
<td>0.511</td>
<td>0.318</td>
<td>0.570</td>
<td>0.707</td>
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<tr>
<td>MWS $\leq$ 100°C</td>
<td>0.300</td>
<td>0.370</td>
<td>0.443</td>
<td>0.266</td>
<td>0.209</td>
<td>0.269</td>
<td>0.148</td>
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<tr>
<td>$\alpha_c$ relaxation $\leq$ 80°C</td>
<td>0.018</td>
<td>0.015</td>
<td>0.018</td>
<td>0.012</td>
<td>0.018</td>
<td>0.026</td>
<td>0.025</td>
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Note: HN fitting was not able to obtain $E_a$ for $\alpha_c$ relaxation $\geq$ 80°C, due to large fitting error caused by very small $\Delta\varepsilon$ for $\alpha_c$ relaxation in equation (5)

Table S2. Havriliak-Negami function parameters for conductivity and MWS relaxations at 160°C

<table>
<thead>
<tr>
<th>Relaxation type</th>
<th>PVDF</th>
<th>0.1wt% CNF</th>
<th>0.1wt% sCNF-1:1</th>
<th>0.1wt% sCNF-1:3</th>
<th>1wt% CNF</th>
<th>1wt% sCNF-1:1</th>
<th>1wt% sCNF-1:3</th>
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<tr>
<td>Conductivity relaxation</td>
<td>$\alpha_1$</td>
<td>1.00</td>
<td>0.98</td>
<td>1.00</td>
<td>1.00</td>
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<td></td>
<td>$\beta_1$</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.63</td>
<td>0.21</td>
<td>0.61</td>
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<tr>
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<td>$\tau_1$</td>
<td>3.00E-01</td>
<td>1.45E-01</td>
<td>2.25E-01</td>
<td>2.29E-01</td>
<td>4.16E-01</td>
<td>8.62E-02</td>
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<td>$\Delta\varepsilon_1$</td>
<td>179.83</td>
<td>1.80</td>
<td>35.90</td>
<td>27.02</td>
<td>1.55</td>
<td>216.50</td>
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<td>MWS</td>
<td>$\alpha_2$</td>
<td>0.66</td>
<td>0.62</td>
<td>1.00</td>
<td>0.55</td>
<td>1.00</td>
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<td>$\beta_2$</td>
<td>0.71</td>
<td>1.00</td>
<td>0.39</td>
<td>1.00</td>
<td>1.00</td>
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<td>$\tau_2$</td>
<td>1.90E-02</td>
<td>2.26E-04</td>
<td>1.15E-02</td>
<td>1.35E-04</td>
<td>3.80E-03</td>
<td>1.64E-04</td>
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<td>$\Delta\varepsilon_2$</td>
<td>15.06</td>
<td>2.34</td>
<td>8.73</td>
<td>11.58</td>
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