1. Introduction

Manipulating and controlling the wetting behavior of solid surfaces, such as superhydrophilicity and superhydrophobicity, have drawn enormous attention with fundamental research and practical applications arising during the previous decades. Most were inspired by natural materials such as lotus leaves, butterfly wing, shark skin, and mosquito compound eyes. Superhydrophilicity denotes the extreme water-loving behavior of specifically designed surfaces, which was first proposed by Fujishima in 2000. Water droplets on these surfaces spread rapidly and lead to a static water contact angle of nearly zero. The interesting properties of these surfaces were intensively explored. The superhydrophilicity endowed the surface with extreme performance for self-cleaning, anti-fogging, water-harvesting, and heat transfer, as well as membranes and biomedical applications.

It is well documented that two parameters are very important to govern surface wettability, i.e., chemical structure and surface roughness. Young’s equation, the Wenzel equation and the Cassie-Baxter equation were introduced to interpret the effect of surface roughness on wettability. A variety of methods or techniques have been developed and investigated to manufacture superhydrophilic and superhydrophobic surfaces. Among them, the phase separation method exhibits great potential for constructing superhydrophilic/superhydrophobic surfaces based on the following merits: facile fabrication, an extremely wettable surface and large-scale manufacturing ability at an affordable cost. Nylon 6,6 surfaces with unique wettability were prepared via vapor phase separation. Moreover, porous TiO2/SiO2 composite thin films were prepared through a versatile template-free sol–gel process. With the help of phase separation, these porous structure rendered surfaces with superhydrophilic performance.

In the past few years, polymerization-induced viscoelastic phase separation (PIVPS) on thermoplastic modified thermoset systems have been widely investigated by our research group and others. Contrary to the common sense of classical phase separation, there exists a dynamic asymmetry between the two components induced by a large difference either in size or glass-transition temperature. In these cases, a fast dynamic phase domain appears in a slow dynamic phase matrix and sponge-like or network-like structures are formed by the domain growth. Finally, a continuous slow dynamic phase develops into a dispersed phase by shrinkage. Therefore, even the minority phase transiently forms a continuous structure, which always results in bicontinuous and sponge-like morphology during PIVPS. In other words, with the addition of a small amount of slow-dynamic thermoplastic, multi-phase structure with complicated topography and surface conditions could be tailored through controlling the curing agent, curing condition,
thermoplastic concentration, as well as the thermoplastic molecular weight.

In this study, PEG was chosen for modification of epoxy on the basis of two reasons: first, a multi-phase structure could be obtained due to PIVPS between PEG and epoxy resin system; second, the PEG-rich phase could be etched easily by water. The influences of curing condition, PEG concentration as well as PEG molecular weight on surface roughness and wetting behavior were investigated. To the best of our knowledge, this is the first report on fabricating superhydrophilic surfaces by resin thermosetting that utilizes such a method. Such epoxy resins with superhydrophilic surfaces have potential applications in oil transportation and self-cleaning surfaces. As PIVPS is a common phenomenon in thermoplastic modified thermoset blends, so by varying the composition of thermoplastic or thermoset, it was likely a rough surface with unique wettability could be obtained.

2. Experimental section

2.1. Materials and samples preparation

The epoxy oligomer DER 331 was provided by Dow Chemical Co. and it is a low molecular weight liquid diglycidyl ether of bisphenol A (DGEBA) with an epoxide equivalent of 182–192 g mol\(^{-1}\). Polyethylene glycol (PEG) were obtained from Sino-pharm Chemical Reagent Co., Ltd, and had 20 000 g mol\(^{-1}\) and 10 000 g mol\(^{-1}\) number-average molecular weights. The curing agent was 2-ethyl-4-methylimidazole (2E4MI) from Aladdin Industrial Co. The chemical structure of DGEBA, 2E4MI, and PEG are given in Scheme 1.

The homogeneous mixture of PEG/DGEBA was prepared by adding PEG to the stirred epoxy resin at 80 °C under nitrogen gas. Then 2E4MI was added and the mixture was stirred vigorously for a few minutes until 2E4MI was completely dissolved. The mixture was degassed and stored below 0 °C to avoid further curing reaction. The samples were cured at 80 °C for 4 h and some were post cured at 150 °C for 2 h. After curing, the samples were etched in deionized water at 60 °C thrice, for 15 min each time. The compositions of the formulations are collected in Table 1.

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2.2. Characterization

2.2.1. Scanning electron microscope (SEM). The morphologies of samples were observed with a scanning electron microscope (TESCAN, TS 5136 MM). All samples were sprayed with gold and mounted on copper mounts.

<table>
<thead>
<tr>
<th>Samples</th>
<th>DER 331</th>
<th>2E4MI</th>
<th>PEG</th>
<th>Curing condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control epoxy</td>
<td>100</td>
<td>5</td>
<td>0</td>
<td>80 °C/4 h</td>
</tr>
<tr>
<td>20phrPEG-2W</td>
<td>100</td>
<td>5</td>
<td>20</td>
<td>80 °C/4 h</td>
</tr>
<tr>
<td>30phrPEG-2W</td>
<td>100</td>
<td>5</td>
<td>30</td>
<td>80 °C/4 h</td>
</tr>
<tr>
<td>40phrPEG-2W</td>
<td>100</td>
<td>5</td>
<td>40</td>
<td>80 °C/4 h</td>
</tr>
<tr>
<td>40phrPEG-1W</td>
<td>100</td>
<td>5</td>
<td>40</td>
<td>80 °C/4 h</td>
</tr>
<tr>
<td>20phrPEG-2W-post</td>
<td>100</td>
<td>5</td>
<td>20</td>
<td>80 °C/4 h, 150 °C/2 h</td>
</tr>
<tr>
<td>30phrPEG-2W-post</td>
<td>100</td>
<td>5</td>
<td>30</td>
<td>80 °C/4 h, 150 °C/2 h</td>
</tr>
<tr>
<td>40phrPEG-2W-post</td>
<td>100</td>
<td>5</td>
<td>40</td>
<td>80 °C/4 h, 150 °C/2 h</td>
</tr>
</tbody>
</table>

Scheme 1 The chemical structure of DGEBA, 2E4MI, PEG and the reaction of DGEBA and 2E4MI.
2.2.2. Atomic force microscopy (AFM). The measurement was performed on a Nanoscope IV (Bruker, multimode 8). Images were acquired in tapping mode. A RTESPA probe with a 40 N m\(^{-1}\) force constant and 300 kHz resonance frequency was utilized to probe the surfaces.

2.2.3. Contact angle measurements. Surface wettability of the sample was evaluated by the sessile drop method with a pure water droplet (ca. 3 μL) using a contact angle goniometer (Dataphysics, OCA15, Germany). The average value of five measurements made at different surface locations on the same sample was adopted as the contact angle.

2.2.4. Time-resolved light scattering (TRLS). The phase separation during isothermal curing reaction was tracked in situ by TRLS equipped with a controllable hot chamber, which was assembled ourselves. The data were recorded at appropriate time intervals. The sample blends were pressed into films before TRLS observation.

2.2.5. Energy-dispersive X-ray (EDX) spectroscopic measurements. The chemical composition of surfaces was determined by a Field-Emission Scanning Microscope (Zeiss, Ultra 55) which was equipped with an Oxford Instrument X-MAX 50.

3. Results and discussion

For the epoxy/PEG blend, it was a homogenous mixture before the curing reaction. During the curing process, 2E4MI initiated the polymerization of epoxy resin, which mainly included two steps, i.e., adduct formation and etherification process: the amine groups of 2E4MI reacted with epoxide groups first to form OH groups and reactive alkoxide anions, which further initiates the propagating of epoxide ring to ultimately form a cross-linked network with ether-linkages (as shown in Scheme 1). With the increase of epoxy molecular weight, the decrease of the entropy induced PIVPS, in other words, the thermodynamic miscibility of the components in the blends decreased with polymerization, at the same time, dynamic asymmetry between two components affected the process of phase separation. In general, the final morphologies of thermoplastic-epoxy blends depend on thermodynamic imputes and kinetic restrain. In this study, we focused on the effect of molecular weight and concentration of PEG as well as curing conditions on the modified systems morphology.

3.1. Morphology, surface conditions, and viscoelastic phase separation of PEG modified epoxy resin

3.1.1. Morphology and surface roughness. Fig. 1 shows the SEM micrographs of the etched surfaces of PEG/epoxy blends cured at 80 °C, in which the molecular weight of PEG was 20 000 g mol\(^{-1}\). In all images presented here, the spherical particles of about 1–2 μm diameter correspond to the epoxy-rich phase, whereas continuous voids were left by etching the PEG with deionized water. As one can observe, epoxy particles connected with each other, so did the void, and these systems seem to have exhibited bicontinuous phase structure. However, epoxy spherical particles of 20phrPEG-2W system were irregular with a size larger than that of the 30phrPEG-2W and 40phrPEG-2W system.

As an example, SEM image with higher magnification of 40phrPEG-2W are also shown in Fig. 1c, and it is obvious that the nano-scale structure distributed on the surface of each epoxy particle. As a supplement, more refined and sophisticated structures on the surface of epoxy spherical particles were investigated in detail by AFM. As shown in Fig. 2, more nanometer-scale particles were decorated on each epoxy particle; moreover, these nano-particles were irregularly shaped. With the increase of PEG content, the surfaces vertical depth increased as shown in the profiles from the section analysis. The roughness (R\(_q\)) result was 3.8 nm, 11.1 nm and 22.0 nm for the 20phrPEG-2W, 30phrPEG-2W and 40phrPEG-2W surfaces, respectively. This suggests that the surface roughness became enlarged with increased PEG concentration.

In the present dynamic asymmetry system of PEG and epoxy monomer/oligomer, the mixture was homogeneous at the
initial time. As the polymerization proceeded, the fast dynamic epoxy phase diffused out of the slow dynamic PEG-rich phase. Thus, the slower dynamic PEG-rich phase became, more and more viscoelastic and eventually behaved as an elastic body. At the same time, the epoxy phase grew larger and connected to each other and the elastic force balance controlled the morphology instead of the interfacial tension, resulting in the anisotropic shape of the domain. This phase evolution process is typical for viscoelastic phase separation and was demonstrated in previous studies.\textsuperscript{32,38}

3.1.2. Polymerization-induced viscoelastic phase separation. To verify the process, TRLS was applied to monitor the phase separation process of the modified epoxy system. The change of the light-scattering profiles was recorded at appropriate time intervals during isothermal curing. Fig. 4a shows the TRLS profiles of the light scattering vector ($q$) and the scattering intensity ($I$) for these systems cured at 80 °C isothermally with a 20 s time interval. The scattering vector with maximum scattering intensity, $q_m$, appeared after the beginning of phase separation and then shifted to lower $q_m$ values with time due to the epoxy phase coarsening, and finally it became constant. Furthermore, the scattering intensity increased continuously from the beginning of phase separation. In other words, the phase size increased with the polymerization proceeding and finally the morphology was fixed by gelation. Moreover, the evolution of $q_m$ corresponded to the precursor droplets thermostetting and follows a Maxwell-type relaxation equation (eqn (1)) as confirmed in our previous studies\textsuperscript{33,40,41} as follows:

$$q_m(t) = q_0 + A_1 e^{-t/\tau}$$  \hspace{1cm} (1)

where $q_m(t)$ is the scattering vector at time $t$, $q_0$ is the initial value at the beginning of phase separation, and $\tau$ is the characteristic relaxation time that indicates the coarsening capability of the epoxy droplets.

As shown in Fig. 3b, the time-dependent $q_m$ of each system fits the Maxwell-type relaxation equation very well. This suggests that the relaxation movement in the PEG modified epoxy system is a type of viscoelastic phase separation process. The relaxation time of the blends became much larger with the increased PEG concentration. A similar phenomenon was also found at all temperatures. The simulation results of the three systems cured at different temperatures are listed in Table 2.

The relaxation time at different temperatures were fit with the Williams–Landel–Ferry (WLF) equation, which can be written as follows:\textsuperscript{28,40–42}

$$\tau = \tau_s \exp \left( \frac{-2.303 \times 8.86 \times (T - T_s)}{101.6 + T - T_s} \right).$$  \hspace{1cm} (2)

As shown in Fig. 3c, the simulation data of the three blends obeys the time–temperature superposition principle and fit the WLF equation quite well, which suggests that the coarsening process of the epoxy droplets were mainly controlled by viscoelastic diffusion.

According to the theory of viscoelastic phase separation\textsuperscript{43–46} and previous research on TRLS and morphology evolution, at the beginning of phase separation following a spinodal decomposition mechanism (as present systems), a micro-bicontinuous phase structure is formed due to lower dynamic asymmetry between epoxy-rich and PEG-rich phases. As the polymerization proceeds, the epoxy precursors diffuse out from the PEG-rich phase and coarsen rapidly. Then, the morphology
shifts into a phase inverted structure quickly with small epoxy-rich dispersed particles.

In the present dynamic asymmetry system of PEG and epoxy precursor with large differences in molecular mobility and molecular weight, during phase separation, the viscoelasticity of the slower dynamic phase (PEG rich phase) increased with the escape of the epoxy precursor from the PEG-rich phase and eventually behaved as an elastic body. Moreover, the less viscoelastic phase (epoxy-rich phase) started to coarsen with time and the elastic force balance dominated the morphology instead of the interfacial tension, which leads to the anisotropic shape of the domains and a highly roughened surface.

It can be observed clearly that the viscoelasticity increased with the addition amount of PEG in the epoxy blend systems as the relaxation value of \( \tau \) from TRLS tests got larger with PEG content, which is recorded in Table 2. The increased viscoelastic effect may eliminate interfacial tension on the particle surface and thus results in rougher particles for high PEG content systems.

3.1.3. Effect of PEG molecular weight on PIVPS. Except the effect of content, molecular weight of thermoplastic is another important factor that affects the PIVPS. To compare with higher molecular weight PEG modified systems, PEG with lower molecular weight of 10 000 g mol\(^{-1}\) was utilized to study the changes. As an example, 40phrPEG-1W was cured at 80 °C for 4 h, the morphology of the sample also exhibited a bicontinuous phase structure, as shown in Fig. 4a, and there was little difference between 40phrPEG-1W and previous blends. The refined and sophisticated structure was also displayed on the
epoxy particles as explored by AFM (Fig. 4b). The roughness ($R_q$) of this surface was 16 nm, which is smaller than that of 40phrPEG-2W, as was the surface vertical depth. The phase separation process of the system was monitored by TRLS, it was obvious that the result of 40phrPEG-1W fit the Maxwell-type equation well, which indicated that this system is also a typical viscoelastic phase separation. From the point view of viscoelastic phase separation, the increase of PEG molecular weight will enhance the dynamic asymmetry between thermoplastic and thermoset oligomer, while a higher molecular weight PEG system would tend to induce earlier phase separation (at lower curing conversion of epoxy), which further enlarges the dynamic asymmetry and favors formation of PEG continuous structure.

As the lower molecular weight PEG became disentangled easily, the epoxy droplets could escape from the PEG cage easily. While lower dynamic asymmetry decreased the elastic force during phase separation, thus interfacial tension played some roles as compared with the high molecular weight PEG systems. Therefore, it is reasonable that the 40phrPEG-1W system relaxation time was lower than that of the 40phrPEG-2W system; furthermore, the surface roughness decreased in the lower molecular weight PEG systems.

### 3.2. Surface properties of PEG modified epoxy system

It is well confirmed that wettability of a surface is determined by chemical composition and the roughness geometry. The static water contact angles of the samples were measured and the data is collected in Table 3. In the present study, epoxy resin shows a naturally hydrophilic surface attributed to a large number of hydroxyl groups. The static water contact angle of the control epoxy system was 60°, as shown in Fig. 5a. Moreover, the contact angle of the surfaces tended to decrease drastically with the addition of PEG content, the surface of PEG modified epoxy system behaved more hydrophilically as compared with the control epoxy system. The more PEG content introduced, the lower contact angle that could be obtained. It is worth noting that a 3 µL water droplet spread on the surface of the 40phrPEG-2W system rapidly and the resulting static water contact angle was 5°, which classified the epoxy surface as superhydrophilic.

It was well demonstrated that the surface of the PEG modified epoxy system exhibited micro–nano structure based on SEM and AFM, the viscoelastic effect of these systems was strengthened with the increased PEG concentration and molecular weight, which induced more elastic deformation of the PEG-rich phase and thus resulted in a rougher surface that was rendered more hydrophilic. The static water contact angle would approach 0°, and finally, the surface had superhydrophilic behavior.

To understanding the effect of roughness on wettability of surface, Wenzel’s equation was given by \( \cos \theta_a = r \cos \theta \), where \( \theta_a \) corresponds to the inherent contact angle of the smooth surface, \( \theta_a \) is the apparent contact angle of the rough surface and \( r \) is the surface roughness. The equation suggests that the wetting characteristic of surfaces is enhanced by the roughness. Therefore, roughness drives the hydrophilic surface to be more hydrophilic and rendered the hydrophobic surface more hydrophobic.

### Table 3 Static water contact angles of epoxy surfaces

<table>
<thead>
<tr>
<th>Samples</th>
<th>Control epoxy</th>
<th>20phrPEG-2W</th>
<th>30phrPEG-2W</th>
<th>40phrPEG-2W</th>
<th>40phrPEG-1W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static water contact angle</td>
<td>60</td>
<td>30</td>
<td>18</td>
<td>5</td>
<td>16</td>
</tr>
</tbody>
</table>
With respect to the effect of PEG molecular weight on wetting performance, it is obvious that contact angle of the 40phrPEG-1W surface was 16°, which was larger than that of the 40phrPEG-2W surface. From the discussion above, it is plausible to propose that the effect of viscoelasticity on phase separation of PEG modified epoxy system exerts a great impact on surface roughness, and followed by the wetting performance.

3.3. The effect of structure on the wetting properties

3.3.1. Elimination of nano-structure through chain disentanglement. As one can observe, a more hydrophilic surface, especially superhydrophilic surface can be fabricated through the PIVPS method. The micro–nano hierarchically structure is proposed to be the most important factor for this super-wetting ability.27 To further confirm the proposition above, we attempted to eliminate the sophisticated nano-scale structure on the surface of epoxy spherical particles. As the modified systems were exposed to higher curing temperature above the glass transition temperature of the blends, the freezing polymer segments again started to move. Therefore, the surface tended to be smooth and flat due to the interfacial tension. When the blends were post cured at 150 °C for 2 h, the size of epoxy particles decreased slightly in comparison with those in Fig. 1 and 6, which may be attributed to the escape of PEG from epoxy-rich phase. The micro-scale structure seems to be more flat as compared with the blends without post-curing (shown in Fig. 6). Choosing the 40phrPEG-2W-post system as an example, the higher magnification image in Fig. 6c showed smooth particles. AFM was also applied, as shown in Fig. 7, and it was obvious that the sophisticated nano-scale structure vanished and was
replaced by a smooth surface. The static water contact angle of the 40phrPEG-2W-post system was 44° (Fig. 8c), which is larger than that of 40phrPEG-2W, though smaller than that of control epoxy system. Moreover, EDX measurements were also applied to characterize the surfaces chemical composition. The EDX results for the 40phrPEG-2W system and 40phrPEG-2W-post system are in Table 4. The ratios of the element C to O on these two surfaces were very close, which indicates that the elemental distribution on the surface was rarely altered. In other words, post-cure treatment did not vary the chemical composition of the epoxy surfaces; therefore, the hydrophilicity weakening of the post-cured system was more likely attributed to eliminating the nanostructure on the epoxy particles surface and to a minor decrease of the epoxy particles microstructure.

### Table 4 The results of elemental analysis on 40phrPEG-2W and 40phrPEG-2W-post

<table>
<thead>
<tr>
<th>Sample</th>
<th>Content of C (%)</th>
<th>Content of O (%)</th>
<th>C:O</th>
</tr>
</thead>
<tbody>
<tr>
<td>40phrPEG-2W</td>
<td>84.3</td>
<td>15.7</td>
<td>5.37</td>
</tr>
<tr>
<td>40phrPEG-2W-post</td>
<td>83.6</td>
<td>16.4</td>
<td>5.10</td>
</tr>
</tbody>
</table>

3.3.2. **The effect of porosity on wetting performance.** It can be observed from the abovementioned experimental results that the sophisticated nanostructure on the surface of epoxy particles from PIVPS exerts a great influence on the hydrophilic performance. With the increased roughness, the surface contact angle tends to be reduced. As known from the Cassie–Baxter equation, for rough or porous surfaces, the wettability relates to the asperities and air pockets. In this section, the effect of different porosity on water contact angle of epoxy surface was investigated.

To eliminate the effects lead by surface roughness of spherical particles from the elastic balance force of PIVPS, all samples were treated at higher temperature through chain disentanglement. With post-curing at 150 °C for 2 h, the sophisticated nanostructure of the epoxy spherical particle was well eradicated and the water contact angle was presumably only related to the porosity of surface. The phase structure of all
the samples after post-curing is shown in Fig. 6. The porosity of these epoxy surfaces was determined by SEM and is listed in Table 5. It is obvious that the increase of PEG content led to more porosity. However, it was difficult to obtain higher porosity with the mere aid of increasing the PEG content. Fig. 8 provides images of representative static water contact angles measured on these epoxy samples and the results are listed in Table 5. The surfaces of the modified systems exhibited hydrophilicity.

In addition, theoretical water contact angle values calculated by Cassie–Baxter equation is also provided in Table 5. The Cassie–Baxter model (eqn (3)) has been widely applied to predict the contact angle of liquid drop on porous materials surface as follows:

$$\cos \theta = f \cos \theta_s + (1 - f) \cos \theta_x,$$

where $f$ is the fraction of the liquid base in contact with the solid surface, and $(1 - f)$ is the remaining fraction of the drop base. $\theta$ is the contact angle of the liquid on the rough surface, $\theta_s$ is the contact angle of the liquid on a smooth surface with the same chemistry as the rough surface, $\theta_x$ is the contact angle of a liquid on air. For a porous surface filled with a liquid $\theta_x$ would become $0^\circ$ for droplets of the same liquid.

Eqn (3) is reduced to eqn (4) as follows:

$$\cos \theta = f(\cos \theta_s - 1) + 1$$

Based on the microstructure of the samples as demonstrated by SEM studies, the Cassie–Baxter equation was well utilized to calculate the theoretical water contact angles on these epoxy surfaces. It should be mentioned that $(1 - f)$ corresponds to the porosity of surfaces and the theoretical contact angle of the control epoxy surface was the same as the experimentally measured value for approximate calculation.

Obviously, the values of experimentally measured contact angle were very close to that of theoretical contact angle calculated from Cassie–Baxter equation. This indicates that Cassie–Baxter is very useful to estimate the water contact angle on these porous surfaces formed by phase separation. Moreover, it suggests that the increase of porosity in blends leads to a more hydrophilic surface. However, even the highest porosity without the nano-structure cannot contribute to superhydrophilicity in these epoxy systems with an intrinsic contact angle of $60^\circ$. As a result, roughening the surfaces with micro–nano structure is probably a more effective approach than adjusting porous structure alone for forming superhydrophilic surfaces.

### 3.4. The relationship between roughness and phase separation

A schematic illustrating the evolution of micro–nano structure on PEG modified epoxy system according to the result of SEM and AFM is given in Scheme 2. When the PIVPS of PEG modified epoxy system happens at low temperature, a micro-bicontinuous structure was formed at the initial stage and the size of the epoxy particles grew with phase separation, while the elastic force of PEG-rich rather than interfacial tension dominated the phase boundary, and as a result, many burrs were decorated on the edge of each phase. However, after post-curing, chain disentanglement induced a smooth surface of the phase boundary due to interfacial tension governed free energy.

In our studied system, phase separation obeyed an SD mechanism as confirmed by TRLS. A bicontinuous phase structure was easily established at $80^\circ \text{C}$, as concentration and

### Table 5  Experimentally measured and calculated static water contact angles of different samples

<table>
<thead>
<tr>
<th>Samples</th>
<th>Porosity (1 – f)</th>
<th>Static water contact angle (°)</th>
<th>Measured</th>
<th>Calculated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control epoxy</td>
<td>0</td>
<td>60.0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>20phrPEG-2W-post</td>
<td>36.9%</td>
<td>49.9</td>
<td>46.8</td>
<td></td>
</tr>
<tr>
<td>30phrPEG-2W-post</td>
<td>46.1%</td>
<td>46.6</td>
<td>43.1</td>
<td></td>
</tr>
<tr>
<td>40phrPEG-2W-post</td>
<td>50.0%</td>
<td>44.0</td>
<td>41.4</td>
<td></td>
</tr>
</tbody>
</table>

Based on the microstructure of the samples as demonstrated by SEM studies, the Cassie–Baxter equation was well utilized to calculate the theoretical water contact angles on these epoxy surfaces. It should be mentioned that $(1 - f)$ corresponds to the porosity of surfaces and the theoretical contact angle of the control epoxy surface was the same as the experimentally measured value for approximate calculation.

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molecular weight of the thermoplastic were increased, and the
dynamic asymmetry and viscoelastic effect of the blends were
strengthened. The phase structure was fixed in the elastic
regime at 80 °C, in which the elastic force balance controlled the
final morphology rather than the interfacial tension. Herein,
a rougher surface with micro-nano structure was created.
According to the time–temperature superposition principle,
with the increase in temperature, the morphology evolution
becomes less sensitive. When the blends were post-cured at 150
°C, the polymer chain tended to relax again and the interface
tension that dominated the final morphology, resulted in
rounded shape domains with the lowest interfacial energy, and
there is no doubt that the nano-scale structure had vanished.

4. Conclusions

In this study, a facile method, based on polymerization-induced
viscoelastic phase separation of PEG modified epoxy was
developed to fabricate hydrophilic and superhydrophilic
surfaces. The effect of the curing procedure and concentration
and molecular weight of PEG on phase separation was well
demonstrated. The PIVPS mechanism was confirmed by SEM
and TRLS. The micro–nano hierarchical structure was well
proven as a significant factor governing the superhydrophilic
surface, in which the nanostructure of the rough phase
boundary from PIVPS plays a major role in determining the
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