Superhydrophobic self-cleaning solar reflective orange-gray paint coating

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A B S T R A C T

A method of fabricating an industrially scalable, widely applicable, and easily repairable superhydrophobic self-cleaning cool orange-gray coating using commercially available materials and following a simple industrial procedure is introduced. Grinding the coating surfaces using an appropriate emery paper creates microgrooves with suitable widths and exposes micro- and nanoparticles on the coating surface. Both factors together endow the coating surfaces with superhydrophobic self-cleaning properties. The hydrophobicity of the coating possesses good resistance to alkali, acid and mechanical abrasion. Grinding the coating surfaces using emery papers also increases the solar reflectance of the coating. The cooling effect of the superhydrophobic coating, which has a solar reflectance of 0.815, is estimated to be 23 °C relative to concrete on a typical clear summer sunny day. Although the superhydrophobic self-cleaning property and solar reflectance of the coating may be compromised by artificial accelerated weathering, the superhydrophobic self-cleaning property can be easily and fully re-established and the inclined solar reflectance may be partially restored after the coating surfaces are ground using an appropriate emery paper.

1. Introduction


The solar reflectance of cool light-colored coatings exposed to outdoor conditions may attenuate over time, owing mainly to soiling of the surface [4,5] rather than weathering [4] because more than 90% of the initial solar reflectance can be restored by washing [6]. However, nearly all conventional architectural coatings are hydrophilic and hence tend to be contaminated by water-soluble pollutants [7] and dust deposition [4,5]. Cleaning the coating surfaces requires manpower and thus is not cost-effective [4,7].

Clearly, to maximize the benefits of chromatic cool gray coatings, it is of practical significance to make them self-cleaning. A superhydrophobic coating surface with a minimum water contact angle (WCA) of 150°, a contact angle hysteresis (CAH) less than 10°, and/or a maximum sliding angle (SA) of 10° may effectively allow water and water-soluble pollutants to roll off easily and carry away any resting surface contamination [8,9]. This self-cleaning behavior, termed the lotus effect [10], has inspired numerous scientists to develop many techniques to fabricate superhydrophobic surfaces on different substrates using various materials during the past three decades [8–10].

Essentially, a superhydrophobic surface can be fabricated either by roughening a surface with inherently low surface free energy (SFE) or by chemically modifying an intrinsically rough surface using low-SFE materials [8–10]. In the former case, many surface roughening techniques require numerous procedures and/or specialized, complicated, and sometimes expensive equipment [8,9]; in the latter case, fluorooalkylsilanes are the most commonly used chemicals because of the extremely low SFE and simple reaction between the hydroxyl group and the silane group [11] However, most of fluorooalkylsilanes are less cost-effective and probably harmful to human health and the environment [12]. Moreover, most previous works focused on the fabrication of superhydrophobic film coatings rather than superhydrophobic paint coatings [7]. In addition, in the literature to date, there are relatively few reports on combining superhydrophobic performance with other functions including antireflective [13], fluorescent [14] and reflective...
Cromophtal Orange, octyltriethoxysilane (2.5 wt%), leveling agent (0.5 wt%), and coalescent (0.7 wt%).

Cromophtal Orange (0.02 wt%), water (27 wt%), wetting agent (0.2 wt%)

The cool orange-gray paint coating was fabricated as follows: The optimized composition of the coating was as follows: styrene–acrylic emulsion binder, grade EC0702, purchased from BASF Corporation; commercially available titanium dioxide rutile (TiO₂), cobalt aluminate blue (CoAl₂O₄), Cromophthal Orange, octyltriethoxysilane, and paint additives including a wetting agent, dispersant, antifoaming agent, suspending agent, leveling agent, and coalescent.

2.2. Chemical modification

TiO₂ and CoAl₂O₄ powders were separately added to mixing setups containing an appropriate amount of octyltriethoxysilane, and the mixtures were stirred for 60 min. Subsequently, the mixtures were filtrated, and the obtained powders were dried at 110 °C.

2.3. Preparation of the coating and samples

The cool orange-gray paint coating was fabricated as follows: the styrene–acrylic emulsion, chemically modified TiO₂ and CoAl₂O₄, Cromophthal Orange, and a prescribed amount of water were first added to the mixing setup, followed by the addition of the wetting agent, dispersant, antifoaming agent, and suspending agent. The mixture was stirred at high speed for 60 min. Subsequently, the antifoaming agent and coalescent were added, and the mixture was continuously mixed at high speed for an additional 30 min. The obtained coating was sprayed onto fiber cement boards with white basecoats developed in our laboratory, whose UV, visible (VIS), NIR, and solar reflectance values are 0.064, 0.964, 0.909, and 0.892, respectively [16]. The dry coating thicknesses of the basecoats and topcoats were approximately 200 and 100 μm, respectively.

2.4. Characterization of hydrophobic property

A Dataphysics Contact Angle System OCA 15EC was employed to measure the WCA, CAH, and SA of the coating surfaces. Water droplets (3, 5, and 7 μL) were used to measure the static water contact angles of the coating surfaces with contact angles much smaller than 150°, approximately 150°, and larger than 150°, respectively. The results are reported as the average of six parallel measurements at different places on the surfaces, unless otherwise indicated.

The CAH was determined as the difference between the advancing and receding angles measured using the “needle-in-drop” technique to increase or decrease the volume of the droplet at a speed of 1 μL step⁻¹. The initial volume of the water droplets was 7 μL. The reported advancing and receding contact angles were the average of six measurements performed at different positions on the coating surfaces.

Water droplets (10 μL) were used to examine the sliding angle of the coating surfaces. The results are reported as the average of six parallel measurements at different places on the surfaces.

2.5. Roughening treatment of coating surfaces

The coating surfaces were roughened using an angle grinder equipped with emery papers having various grit numbers.

2.6. Morphological characterization

The surface morphologies of the coatings were examined using a Zeiss-supra 55 field emission Scanning Electron Microscopy (SEM).

2.7. Measurements of optical properties

Following ASTM E903-12 (Standard test method for determining the solar absorbance, reflectance, and transmittance of materials using integrating spheres), a UV/VIS/NIR spectrophotometer (Perkin Elmer Lambda750) equipped with an integrating sphere (150 mm diameter, Labsphere RSA-PE-19) was used to determine the spectral reflectance of the coating. The solar reflectance was computed by integrating the measured spectral data weighted with the air mass 1.5 beam-normal solar spectral irradiance, as described in ASTM E891-87 (Tables for Terrestrial Direct Normal Solar Spectral Irradiance for Air Mass 1.5).

2.8. Measurement of thermal emittance

Following ASTM C 1371 (Standard test method for determining the emittance of materials near room temperature using portable emitters), a portable differential thermopile emissiometer was employed to measure the thermal emittance.

2.9. Artificial accelerated weathering tests

Following ISO 11341-2004 (Paints and varnishes – Artificial weathering and exposure to artificial radiation – Exposure to filtered xenon-arc radiation), artificial accelerated weathering tests were conducted for 400 h using a xenon lamp in a weather-resistant test chamber (SN-66, Beijing Beifang Lihui Test Instrument Equipment Co., Ltd.). During the tests, the upper surfaces of the coating specimens were exposed to the light source and sprayed with water using an 18/102 spray cycle (18 min of water spray/102 min of dryness). The chamber temperature, black panel temperature, and relative humidity (RH) during the dry period were (38 ± 3) °C, (63 ± 2) °C, and (40–60%), respectively.

3. Results and discussion

3.1. Hydrophobicity before surface roughening

In general, low SFE and enhanced surface roughness are essential for fabricating superhydrophobic surfaces [10,17]. TiO₂ and CoAl₂O₄ pigments are inherently hydrophilic because of the presence of hydroxyl groups (-OH) on the powder surfaces [4]. To decrease the SFE of the coating, the hydrophilic TiO₂ and CoAl₂O₄ were treated with...
octyltriethoxysilane. The reaction between hydroxyl groups and octyltriethoxysilane occurred as follows (Fig. 1):

As a result, superhydrophobic TiO₂ and CoAl₂O₄ powders with average WCA values of (160.6 ± 2.4)° and (158.7 ± 1.1)° (Figs. S1 and S2, Supporting information), respectively, were obtained and used to formulate the coating. The optimized coating had an average WCA of (109.9 ± 1.3)° (Fig. S3, Supporting information), indicating that it had a sufficiently low SFE, considering that the upper limit of the WCA observable on a flat substrate is approximately 130° [17]. Additionally, the polymer surface roughness cannot be readily obtained via self-assembly [18]. To obtain superhydrophobic surfaces, an angle grinder was used to roughen the coating surface, and the effects of the grinding process on the hydrophobicity were studied. Note that only the dynamic hydrophobicity was evaluated for the superhydrophobic specimens because the main concern of this paper is superhydrophobicity.

3.2. Superhydrophobicity after surface roughening

Fig. 2a shows the variation of the WCA of the coating surfaces as a function of the grit number of the emery paper. Although the WCAs of the coating surfaces ground using 120-, 180-, and 240-grit emery paper are greater than 150°, those of the coating surfaces ground using 80-, 320-, and 600-grit emery paper are less than 150°, indicating that the appropriate roughness is a key factor influencing the superhydrophobicity. Fig. 2b shows the grit number dependence of the CAH and SA of the coating surfaces. The coating surfaces ground using 120-, 180-, and 240-grit emery paper have a low CAH (< 5°) and small SA (< 3°), implying that these surfaces were in the “slippy” Cassie–Baxter state [8,9,17]. Fig. 2c shows the grinding depth dependence of the WCA of the coating surfaces ground using 180-grit emery paper. The effects of the grinding depth on the WCA appear to be negligible within the experimental uncertainties, provided the grinding depth is not less than 20 µm, indicating that the surface roughness is associated mainly with the grit number of the emery paper.

A high WCA indicates that water is repelled by a coating surface, whereas a low CAH and small SA reveal that water droplets have low adhesion to the coating surface and can roll off the surface easily [19] and thus the coating surface is self-cleaning [10]. Fig. 3a–c illustrate the static superhydrophobicity, sliding behavior, and self-cleaning process, respectively, of the coating surface ground using 180-grit emery paper. In Fig. 3a, transparent and blue, white, green, red droplets were pure water and dyed water, emulsion used in this work, hydrochloric acid (1 mol L⁻¹) + methyl violet indicator, sodium hydroxide (1 mol L⁻¹) + phenolphthalein indicator, respectively. As observed in Fig. 3a, liquid droplets remained perfectly spherical on the flat coating surface, and they appeared glittering and translucent when pictures were taken from different directions. Concurrently, the superhydrophobicity of the coating surface showed good alkali and acid tolerance. If the coating
surface was slightly tilted by 1.3°, a 10 μL water droplet quickly rolled off the surface once it was released onto it (Fig. 3b). Fly ash was used as a contaminant and spread on the coating surface at a slope angle of 2°. When water droplets rolled off the coating surface, they picked up the “dirty” particles and effectively cleaned the coating surface (Fig. 3c).

3.3. Surface topologies

To scientifically explain the above phenomena, the microstructures of the coating surfaces were determined using a SEM. The results are presented in Figs. 4a and b and S4 (Supporting information). As observed in these images, after surface roughening, many microgrooves with different average widths were formed and randomly distributed on the coating surfaces (Figs. 4a and S4a, b, d–f); micro- and nano-scale particles were exposed on the coating surfaces (Figs. 4b and S4d–i). Furthermore, the appropriate roughness can be created only using 120-, 180-, and 240-grit emery paper, which correspond to average groove widths of (36.29 ± 1.94), (23.57 ± 0.97), and (20.82 ± 2.14) μm, respectively. It is well established that at a suitable roughness level, air is trapped inside the grooves. This trapped air provides a floating force against the liquid droplets and results in a high WCA, small SA, and low CAH [10]. Emery papers with high grit numbers are generally used to obtain a smooth mirror finish, and the width of the grooves created using the 80-grit emery paper is (45.21 ± 2.83) μm, so water droplets can partially wet the grooves. Therefore, the appropriate roughness has a profound effect on the wettability of surfaces.

Fig. 3. Images of static and dynamic superhydrophobicity. Photos of liquid droplets on the flat coating surface ground using 180-grit emery paper, illustrating the static superhydrophobicity (a). Snapshots of the sliding behavior of a 10 μL water droplet on the identical coating surface tilted by 1.3° (b) and the self-cleaning process of the identical coating surface tilted by 2° (c).

Fig. 4. Surface topologies. SEM images of the coating surface ground using 180-grit emery paper with low (a) and high (b) magnifications. Da and Db are the particle diameter and particle area, respectively.
3.4. Optical properties

The orange-gray coating has not only a superhydrophobic self-cleaning property but also a good cooling effect. The spectral reflectance curves of the superhydrophobic coating and pigments are shown in Fig. 5. For comparison, the spectral reflectance curve of Portland cement concrete is shown in Fig. 5. The computed spectral and solar reflectances of the coating and concrete are listed in Table 1. Several observations can be made from Fig. 5. First, the spectral reflectance curve of the coating lies between the curve of TiO2 and those of Cromophtal Orange and CoAl2O4. Second, in the VIS region between approximately 460 and 600 nm, an overshoot exists, the peak of which is between the peak of the overshoot of the CoAl2O4 curve and that of the Cromophtal Orange curve. Third, in the NIR region, the curve of the orange-gray coating is similar in shape to those of TiO2 and Cromophtal Orange because of their greater weight contents relative to CoAl2O4 in the coating composition. Additionally, over the entire solar spectrum, the spectral reflectance of the superhydrophobic solar reflective orange-gray coating is much higher than that of the concrete.

3.5. Estimated cooling effect of the coating

For horizontal and low sloped opaque surfaces under the sun and thermally insulated underneath, the equilibrium surface temperature \( T_s \) may be evaluated from the following equation [20]:

\[
(1 - R)I = \sigma(T_s^4 - T_f^4) + h_c(T_s - T_{sky})
\]

where \( R \) is the solar reflectance of the surfaces; \( I \), the total isolation on the surfaces, W/m²; \( \epsilon \), the thermal emittance or emissivity of the surfaces; \( \sigma \), the Stefan-Boltzmann constant, \( 5.6685 \times 10^{-8} \) W m⁻² K⁻⁴; \( T_s \), the equilibrium surface temperature, K; \( T_{sky} \), the effective sky temperature, K; \( h_c \), the convection coefficient, W m⁻² K⁻¹; \( T_{sky} \), the ambient air temperature [20–22].

Therefore, the surface temperature of a coating on a typical clear summer sunny day can be estimated from its solar reflectance and thermal emittance using the online solar reflectance index calculator (Supporting information) based on Eq. (1) under the following conditions specified by ASTM E1980-01 (Standard practice for calculating solar reflectance index of horizontal and low sloped opaque surfaces):

- insolation = 1000 W m⁻²
- sky temperature = 300 K
- ambient air temperature = 310 K
- convection coefficient (medium wind) = 12 W m⁻² K⁻¹

The measured thermal emittances of the orange-gray coating and concrete are 0.88 and 0.95, respectively. As shown in Table 1, the solar reflectances of the cool coating and concrete are 0.815 and 0.356, respectively.

The estimated surface temperatures of concrete and the coating are 66.9 and 43.9 °C, respectively, yielding a cooling effect of 23 °C relative to concrete on a typical clear summer sunny day. This pronounced cooling effect necessarily results in lower heat conduction into buildings, significantly reducing the cooling energy consumption in summer [1].

3.6. Prediction of long-term durability of the coating

The superhydrophobicity of artificial superhydrophobic surfaces, like that of plants, is easily destroyed by rain [17] and mechanical abrasion [17,25] under exposure to outdoor conditions. With respect to the effect of UV on the artificial superhydrophobicity, while some studies showed that UV radiation in sunlight can decompose organic low SFE materials on the superhydrophobic surface and thereby reduce the robustness of superhydrophobicity [26,27], others reported that UV-induced wettability changes in oxides of certain transition metals, such as titanium dioxide (TiO2) and zinc oxide (ZnO) are completely reversible. The originally hydrophobic TiO2 and ZnO turned hydrophilic when irradiated with UV light and they recovered the initial hydrophobicity after removing the UV light [17,28–30]. Therefore, for practical application of the superhydrophobic self-cleaning cool orange-gray coating, it is of industrial importance to evaluate its long-term performance and make it regenerative and easily repairable [31].

After 400 h of artificial accelerated weathering, the samples were naturally dried under standard laboratory conditions ((23 ± 2) °C, RH (50 ± 5)% for 5 days. Subsequently, the WCA and spectral reflectance of the weathered samples were measured again and the representative spectral reflectance curves of the weathered solar reflective orange-gray coating with the greatest spectral reflectance attenuation is shown in Fig. 6. For comparison, the spectral reflectance curve of the above weathered sample after surface roughening using 180-grit emery paper is shown in Fig. 6. The spectral reflectances of the sample in the initial state, weathered state and after surface roughening again are summarized in Table 2.

Although the samples were free of blistering, peeling, cracking, chalking, and color change/fading, they had an average WCA of (72.4 ± 9.6)° and completely lost their superhydrophobicity. Moreover, the spectral reflectance curve of the weathered sample was slightly

![Fig. 5. Optical properties. Spectral reflectance curves for the superhydrophobic solar reflective orange-gray coating over a white basecoat, pigments used to fabricate the coating and concrete.](image)

![Fig. 6. Comparison of spectral reflectance curves of the orange-gray coating in its initial, weathered and surface roughened states.](image)

Table 1

<table>
<thead>
<tr>
<th>Sample</th>
<th>Solar</th>
<th>UV</th>
<th>VIS</th>
<th>NIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orange-gray coating</td>
<td>0.815</td>
<td>0.094</td>
<td>0.834</td>
<td>0.846</td>
</tr>
<tr>
<td>Concrete</td>
<td>0.356</td>
<td>0.253</td>
<td>0.351</td>
<td>0.371</td>
</tr>
</tbody>
</table>

![Fig. 6. Comparison of spectral reflectance curves of the orange-gray coating in its initial, weathered and surface roughened states.](image)
lower than that of the initial sample, with a greater reduction occurring in the shorter NIR and VIS regions (Fig. 6 and Table 2), which agrees well with a report by Santamouris et al. [32]. Because the spectral reflectance of a coating is mainly determined by the pigments and the Cromphotal Orange is the unique organic pigment among the solar reflective pigments used in this work, the unexpected increase in UV reflectance is most likely ascribed to UV degradation of the unique organic Cromphotal Orange. In addition, it is very interesting to note that the spectral curves of the orange-gray coating in the initial state, weathered state and after surface roughening again showed weak scattering blow 500 nm. As shown in Fig. 4b and indicated in a previous work, although the median particle size of titanium dioxide rutile used in this work is 280 nm [33], there are also large global features because of local aggregation of pigment particles. According to Mie scattering theory, the wavelength ($\lambda$) that is most efficiently scattered by titanium dioxide rutile of diameter D is given as follows [33]:

$$\lambda = \frac{D}{0.42}$$  \hspace{1cm} (2)

Clearly, to scatter a wavelength most efficiently, the particle size of titanium dioxide rutile should be slightly smaller than the half-wavelength. Consequently, to scatter the wavelength below 500 nm, the particle size of titanium dioxide rutile should be smaller than 250 nm. It is not the case in this work. Therefore, there is little scattering below 500 nm.

As mentioned above, more than 90% of the initial solar reflectance attenuation is attributed to soiling [2-4,32]; therefore, 5.9% of the initial solar reflectance attenuation should be ascribed to a change in the physical structure and chemical composition of the coating surface [34], as there was no particulate accumulation during the tests. The reaction product formed via the reaction between octyltriethoxysilane [34], as there was no particulate accumulation during the tests. The physical structure and chemical composition of the coating surface in this work is 280 nm [33], there are also large global features because of local aggregation of pigment particles. According to Mie scattering theory, the wavelength ($\lambda$) that is most efficiently scattered by titanium dioxide rutile of diameter D is given as follows [33]:

$$\lambda = \frac{D}{0.42}$$  \hspace{1cm} (2)

Comparison of the spectral and solar reflectance values of the representative solar reflective orange-gray coating in its initial, weathered and surface roughened states.

<table>
<thead>
<tr>
<th>Samples</th>
<th>Solar (%)</th>
<th>UV (%)</th>
<th>VIS (%)</th>
<th>NIR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before weathering</td>
<td>0.815</td>
<td>0.094</td>
<td>0.834</td>
<td>0.846</td>
</tr>
<tr>
<td>After weathering</td>
<td>0.767</td>
<td>0.197</td>
<td>0.762</td>
<td>0.816</td>
</tr>
<tr>
<td>Weathered sample after surface roughening</td>
<td>0.790</td>
<td>0.213</td>
<td>0.800</td>
<td>0.828</td>
</tr>
</tbody>
</table>

4. Discussion

Undoubtedly, the most effective and economic way for light-colored solar reflective coatings to remain their high solar reflectance is to endow these coatings with self-cleaning function. However, as mentioned above, although both superhydrophobic self-cleaning coatings and solar reflective coatings have been individually the subject of extensive scientific investigation during the past several decades, to the best of our knowledge, in all of the published literature available thus far, there appears to be no paper that described superhydrophobic self-cleaning solar reflective coatings.

Of particular relevance to this work, two research groups studied the hydrophobic paint coatings [7,35]. In the first previous study [7], Zhou et al. created a self-cleaning paint by adding 30 wt% of poly-gorskite (Pal) modified by amino silicon oil and aminopropytriethoxysilane to a commercial traditional paint. Although the modified Pal had a WCA of 154°, the paint coating with a WCA bigger than 140° was not superhydrophobic most likely because the coating surface had not sufficient roughness. Using a combined oxygen/argon plasma pretreatment and a fluoroalkyl silane final treatment, West et al. [35] successfully fabricated a highly filled superhydrophobic polyurethane paint coating surface. However, fluoroalkyl silane is more expensive than octyltrithiolsilane used in this work and the surface roughening using oxygen/argon plasma pretreatment is more complicated than that using appropriate emery papers.

In addition to plasma pretreatment, various techniques, including sol-gel technique [36] and layer-by-layer deposition technique [37], among others, have been developed to create appropriate film coating surface roughness. Although these fabrication methods are not complicated and expensive, they are not appropriate for the large-scale production and practical applications of artificial superhydrophobic coatings.

Final treatment of coating surfaces using emery papers to achieve the desired finish is a common procedure in paint industry. As shown above, grinding the coating surface with sufficient low SFE using suitable emery papers could generate randomly distributed micro-grooves with appropriate widths and expose the micro- and nano-particles on the coating surfaces. Both factors together imparted the superhydrophobic self-cleaning property to the coating surfaces. From the standpoint of practical applications, grinding process can be at least used in prefabricated wall products.

Although the low SFE and enhanced surface roughness are essential to fabricate superhydrophobic coating surfaces [10], extremely low SFE is not necessary to achieve the desired superhydrophobicity [38,39]. Instead, the suitable roughness of a surface is integral in promoting hydrophobic surfaces [8,17]. It is widely accepted that a superhydrophobic self-cleaning coating surface can be generated by introducing either micro-scale surface roughness or nano-scale surface roughness, or a combination of both [17,37,38], and that the spatial distribution of the texture motif on a superhydrophobic self-cleaning coating surface can be isotropic or anisotropic [17,40].

To study the effects of the surface roughening on the optical properties of the solar reflective orange-gray coating, the spectral reflectance curves of the coating before and after surface roughening using 180-grit emery paper are presented in Fig. 9 and the calculated spectral and solar reflectances are compared in Table 3. The grinding depth of the coating was approximately 25 µm. As indicated in Fig. 9, after grinding the coating surface, the spectral reflectance curve of the coating was slightly shifted upward over the entire solar spectrum. As shown in Table 3, the spectral reflectances of the coating after surface roughening in UV, VIS and NIR regions were slightly higher than those

$$\text{Weathered sample after surface roughening}$$

$$\lambda = \frac{D}{0.42}$$  \hspace{1cm} (2)
of the coating before surface roughening. Accordingly, the coating after surface roughening had a slightly higher solar reflectance than that of the coating before surface roughening. Essentially, the solar reflective orange-gray coating is a partially NIR-transmitting coating. Its solar reflectance is intimately related to the white basecoat. The NIR and solar reflectances of cool non-white coatings were found to decrease as the topcoat thickens [41]. Therefore, grinding the coating surface enhanced the solar reflectance of the solar reflective orange-gray coating.

With respect to the durability of the superhydrophobic self-cleaning solar reflective orange-gray coating, the results presented above demonstrate that the superhydrophobicity of the coating had good resistance to acid, alkali and mechanical abrasion. Although the artificial accelerated weathering might completely destroy the superhydrophobicity of the coating and partially attenuated its solar reflectance, grinding the weathered coating using an appropriate emery paper could fully re-established the destroyed superhydrophobic self-cleaning property and partially restored the attenuated solar reflectance.

5. Conclusions

In summary, an industrially producible, widely applicable, and easily repairable superhydrophobic self-cleaning solar reflective orange-gray coating can be fabricated using commercially available materials and following a simple industrial procedure. Grinding the coating surfaces using an appropriate emery paper generates microgrooves and yields micro-scale roughness and nano-scale roughness. Both factors together impart a superhydrophobic self-cleaning property to the coating surfaces. The superhydrophobicity of the coating has good resistance to acid, alkali and mechanical abrasion.

Grinding the coating surfaces using an emery paper also enhances the solar reflectance of the coating. The cooling effect of the superhydrophobic coating relative to concrete is estimated to be 23 °C on a
typical clear summer sunny day.

Although the superhydrophobic self-cleaning property is destroyed and the solar reflectance is attenuated after artificial accelerated weathering, the destroyed superhydrophobicity can be fully reconstituted and the attenuated solar reflectance may be partially restored by grinding the coating surface using an appropriate emery paper.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.solmat.2017.09.014.

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