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A Facile, Fast, and Low-Cost Method for Fabrication of Micro/Nano-Textured Superhydrophobic Surfaces

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Abstract

Alkyl ketene dimer (AKD) is frequently used in paper industry as an inexpensive sizing agent. The formation of a porous structure after curing the solidified AKD for four days results in superhydrophobicity. We utilized, a facile and low-cost method to turn AKD's surface superhydrophobic in < 10 min. We fabricated superhydrophobic coatings by dipping glass and paper substrates in molten AKD at 40°C for 3 min and then treating them with ethanol after solidification. Moreover, the advancing and receding contact angles significantly increased from 92.9±3.0 and 78.4±4.7° to 158.7±1.4 and 156.8±0.9°, respectively. This increase in superhydrophobicity is due to the formation of porous, entangled irregular micro/nano textures that create air cushions on the surface resulting in droplet state transition from Wenzel to Cassie.

Method

Isothermally heating AKD at 40°C for 3 min → Dip-coating the sample in molten AKD → Treating the solidified AKD with ethanol

The samples were characterized by X-ray diffraction (XRD), Scanning electron microscopy (SEM), Fourier transform-infrared spectroscopy (FT-IR), X-ray photoelectron spectroscopy (XPS), and Confocal laser scanning microscopy (CLSM). In addition, in order to measure the mean diameter and fraction of pores on the surface of AKD coatings, the SEM images were analyzed with an image-processing software (ImageJ 1.52a). Also, advancing and receding contact angles were measured for 9 randomly-chosen spots on each sample with the liquid increase/decrease method by using a drop shape analyzer (DSA25E, Krüss, Germany)

Role of ethanol treatment

The role of ethanol is to dissolve the smooth structures containing monomers and help nano-patterns to separate and stand out. This promotes the increase of pores fraction, which is beneficial for improving the superhydrophobic properties of the surface. Based on the FT-IR results, it was seen that neither ethanol treatment nor long curing process of AKD has a noticeable impact on the functional groups of the as-solidified AKD. Furthermore, XPS results also were entirely in agreement with FT-IR results and revealed that there are no noticeable changes in the chemical bonds in this process.

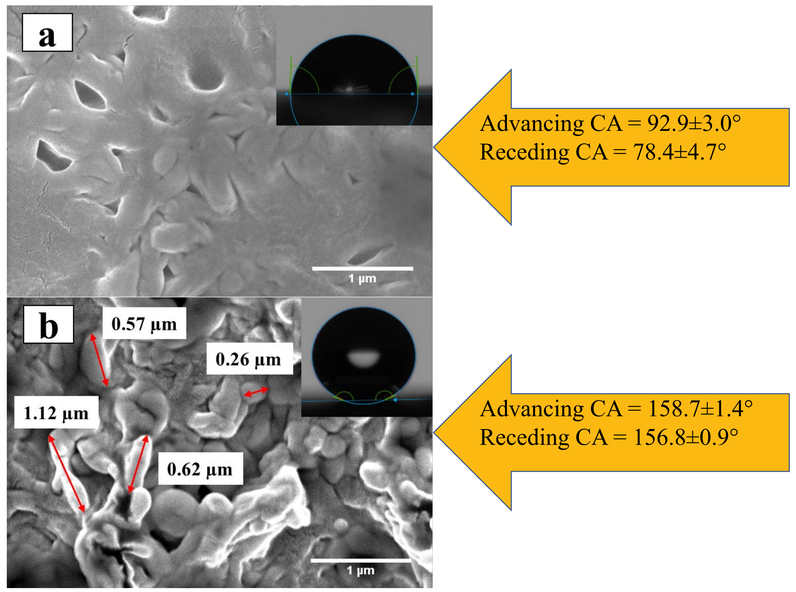

Figure 1. SEM images of AKD coatings prepared from a 40°C melt, isothermally heated for 3 min: (a) with no post-solidification modifications, and (b) solid coating was treated with ethanol. Insets: water droplet on the sample.

Impact of heating time and temperature of the melt

We increased the temperature of the melt from 40 to 70°C (held isotherm for 3 min) and treated the sample with ethanol after solidification. It is seen that the advancing and receding contact angles are 160.5±1.1 and 158.5±1.5°, respectively; therefore, the molten AKD's temperature plays an important role in the wettability of the samples. In order to make the sample with the highest dynamic contact angles, we optimized the values of AKD's melt temperature, melt isothermal holding time, and ethanol treatment.

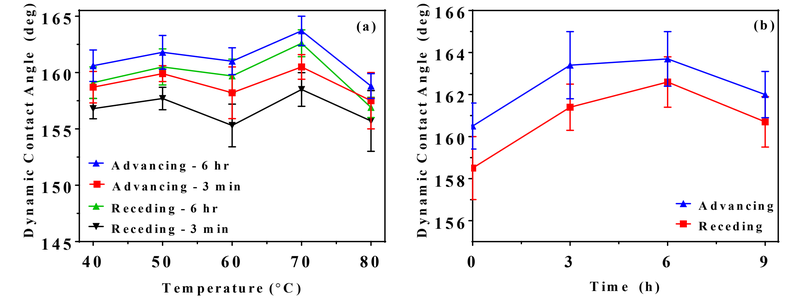

Figure 2. Advancing and receding contact angles of ethanol-treated solidified AKD from: (a) isothermally heated melt at 40 to 80°C for 3 min and 6 h, and (b) isothermally heated melt at 70°C for 3 min, 3 h, 6 h and 9 h.

Flexibility of our facile method

Besides ethanol, this technique was also demonstrated to be working with some other organic solvents such as methanol and isopropanol. In addition to glass, our method seems to also work for other substrates including paper.

References

A.R. Esmaeili, N. Mir, R. Mohammadi, A Facile, Fast, and Low-Cost Method for Fabrication of Micro/Nano-Textured Superhydrophobic Surfaces, J. Colloid Interface Sci. (2020). https://doi.org/https://doi.org/10.1016/j.jcis.2020.04.027.