High transmission light diffusers from anodized aluminium oxide and nanoimprint lithography

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We report a high transmission polymethylmethacrylate (PMMA) light diffuser with low-cost and large-area nanoscale-patterning[1]. In this work, the anodized aluminium oxide (AAO) and nanoimprint lithography (NIL) techniques were successfully used to fabricate PMMA light diffusers with different periods, and the transmittance properties were investigated as well. The NIL stamps were first fabricated by the process of AAO resulting in self-ordering arrays with approximately hexagonally periodic surface microstructures, and then pressed together with the PMMA substrates after heating. The inverse microstructures of NIL stamps were shows on the surface of PMMA substrates after de-molding. The periods of NIL stamps primarily depend on the electrolyte pH and the anodic applied-potential during anodization. Therefore the stamp with the small period was anodized in $H_2C_2O_4$ (oxalic acid solution), named Oxalic. The stamp with the medium period was anodized in H_3PO_4 (phosphoric acid solution), named Phosphoric. The stamp with the large period was anodized in $C_6H_8O_7$ (citric acid solution), named Citric[2].

2D images and cross sections of three NIL stamps were measured by atomic force microscopy (AFM) and shown in Figure 1(a-c). The disorder increases when increasing the period The center-to-center distance of Oxalic, Phosphoric and Citric stamps for the specific periods are 324 nm, 430 nm and 693 nm, respectively, and the depths of the dimples are 155 nm, 207 nm and 355 nm, respectively. Roughly, the depth of the dimples is close to being the same as the half length of the center-to-center distances.

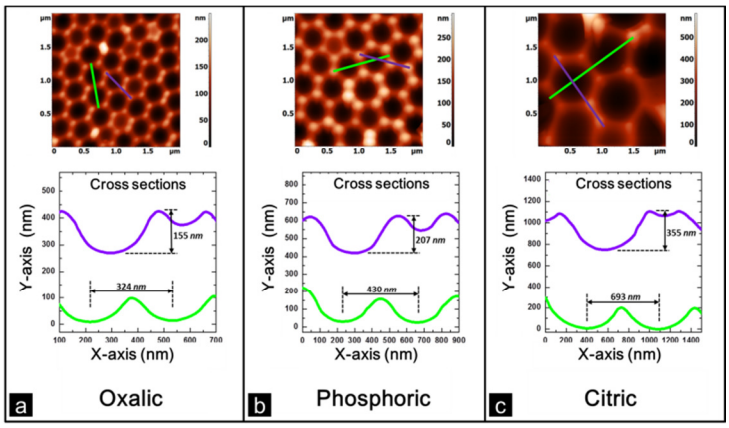

Figure 1 2D images and cross sections of three nanoimprint lithography (NIL) stamps with the small, medium and large periods.

After the process of NIL, the PMMA light diffusers with the small, medium and large periods were obtained. Total transmittance have been characterized by UV/Vis spectroscopy

(PerkinElmer Lambda 1050) with an integrating sphere, where the incident angle was set at normal incidence, and the diffused transmittance was obtained by introducing an opening in the integrating sphere removing the light of specular transmission away from the sphere. The morphology of light diffuser, Phosphoric, was measured by AFM and shown in Figure 2(a) as example. It is clear to see that the surface microstructure shows the inverse geometry of the Phosphoric NIL stamp.

Total and diffused transmittances of all PMMA light diffusers were shown in Figure 2(b). All light diffusers shows relative high total transmittance, > 80%, when the wavelengths are over 375nm. The total transmittance decreases when increasing the period of the surface microstructures, but the tendency of diffused transmittance is opposite. The surface microstructures with a large period of around 700 nm can diffusely transmit near-infrared (NIR) light more effectively than the other samples with shorter average periods of 320 nm and 430 nm. Around 25% of the incident light for wavelengths between 300 nm and 800 nm were diffusely transmitted through at the Citric light diffuser, and the light was diffusely transmitted into a large range of angles away from the surface normal. Therefore, the Citric light diffuser shows interesting for many application such as enhancing the light trapping for thin-film solar cells.

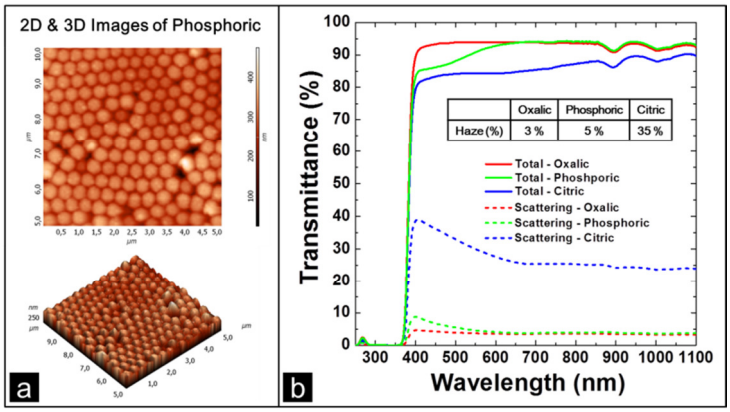

Figure 1 (a) The 2D and 3D images of Phosphoric light diffuser. (b) Total and diffused transmittances of all PMMA light diffusers were shown in Figure 2(b).

References.

[1] S. Y. Chou, P. R. Krauss, and P. J. Renstrom, *J. Vac. Sci. Technol. B* **14**(6) (1996)
[2] Y. C. Tsao, T. Søndergaard, E. Skovsen, L. Gurevich, K. Pedersen, and T. Garm Pedersen, *Opt. Express.* **21**, A84 (2013).