

Fabrication and evaluation of fluoropolymer porous membranes simulating skeleton flower petals

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<introduction>

At present, attention is being paid to materials that can change from transparent to opaque. A practical example is a public toilet in Shibuya Park, which was installed in 2020, and a possible application are greenhouses that autonomously control room temperature depending on the weather (Fig.1). These bring various advantages from the artistic viewpoint, for crime prevention, autonomous operation and combine this with low installation and maintenance cost. However, the present windows use liquid crystalline panels that require electric energy, are costly, and face durability problems. We focused on a biomimetic approach to produce a reversible dimming of windows, based on the petals of the skeleton flower, which is a plant that changes petal transparency and opaqueness depending on the weather. (Fig.1) The petals of skeleton flower, which is an alpine plant, are white when dry (Fig. 2 (a)), but become transparent when the petals get wet due to fog or rain (Fig. 2 (b)). This phenomenon is thought to be caused by light scattering at air pockets inside the petals. When the petals are moistened by fog or rain, the petals become transparent, that means light scattering is reduced. It is thought that this effect is due to the air pockets in the petals being filled with water. However, this phenomenon was difficult to reproduce in the laboratory because the surface tension of water is high. Therefore, by mixing Polysorbate 20 (Tween 20) (Fig.3 (c)) the surface tension of water is reduced, and the petals of skeleton flower were made transparent also in the laboratory. In the same way, we succeeded in making the petals of cherry blossoms and oxeye daisy, which are difficult to be transparent in nature, transparent.

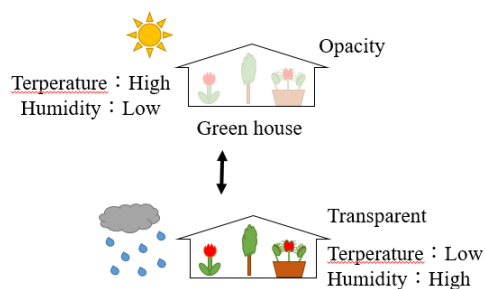


Fig.1 Greenhouses that change from transparent to opaque depending on the weather

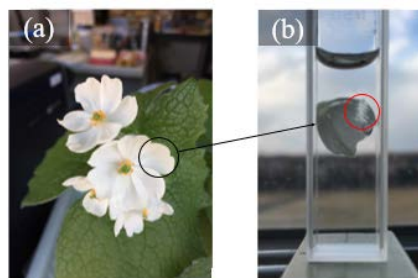


Fig.2 Photograph of (a) dry (b) wet flower petals

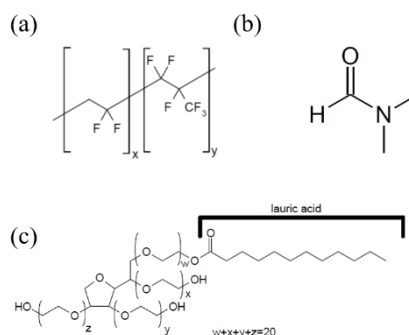


Fig.3 Chemical structure of (a)PVDF-co-HFP、
 (b) DMF、(c)Polysorbate 20 (Tween20)

This petal mechanism is mimicked by the fluoropolymer poly (vinylidene difluoride-co-hexafluoropropylene) (PVDF-co-HFP) (Fig.3 (a)). A fluoropolymer was chosen, because it has a refractive index similar to water, is chemically and mechanically stable.

<Experiment>

PVDF-co-HFP was dissolved in N, N-dimethylformamide (DMF) (Fig.3 (b)) to prepare a 0.06 g / mL PVDF-co-HFP and DMF solution. After dropping the prepared solution on a slide glass, spin coating was performed at 600 rpm for 30 seconds using a spin coater. Next, the slide glass was submerged in pure water at 60 ° C., and a white film formed on the slide glass or released from the slide glass within 1 minute, so that it could be taken out and dried.

<Results and Discussion>

FE-SEM images of the front surface (Fig. 4 (a)), back surface (Fig. 4 (b)) and cross section (Fig. 4 (c)) of the dried porous film. Many air pockets (holes) of various sizes can be seen on the front and back sides, and in the cross section. Figure 5 shows the transparency in the visible region when dry and wet. The transmittance is low when dry and high when wet. Light scattering occurs due to the internal holes, resulting in low transmittance on the dry film. However, when the Tween 20 aqueous solution is dropped on the film surface, the pores are filled with the aqueous solution and light scattering does not occur, so that the transmittance is considered to be high. Fig. 6 shows the results of measuring the transmittance of the prepared skeleton flower petal mimicry structure over time. (The wavelength used was 560 nm, which is considered to be easy for humans to see.) The transmittance is high immediately after wetting, but the transmittance drops sharply in about 50 minutes, and after 10 minutes, the same transmittance as in drying. It is considered that the reason for this is that the Tween 20 aqueous solution existing inside evaporates, air accumulates inside the pores, and the difference in refractive index from the polymer increases, causing light scattering. From the above results, it was also found that it has a reversible property of becoming transparent when moistened and opaque when dried.

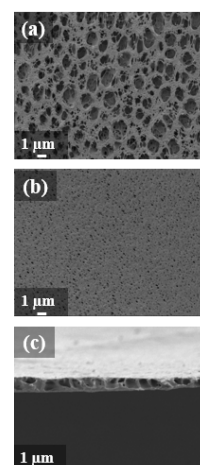


Fig.4 FE-SEM images of a PVDF film
 (a) upper surface (b) lower surface (c)
 cross section

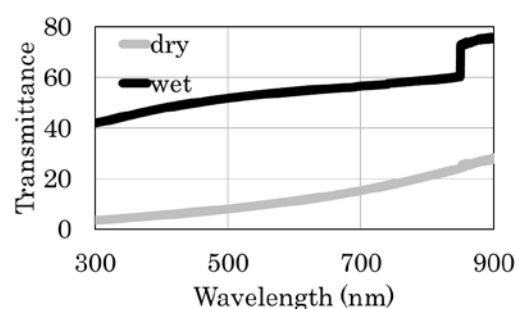


Fig5. Transmission spectra of
 dry and wet PVDF films

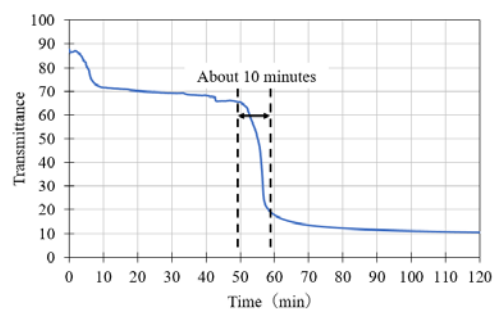


Fig6. Permeability of the skeleton flower
 petal structure over time