Simple-structure polymer network liquid crystals for thermoresponsive switchable windows

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Abstract—We fabricated thermoresponsive reversible optical attenuators that possess phase separation structures of highly oriented liquid crystals (LCs) and anisotropically polymerized reactive mesogens (RMs). The devices shown here are a promising candidate for applications to smart windows. They can efficiently switch, not only optical clarity, but also the amount of heat penetration through the devices. We show here the relationship between switching performance and optical inhomogeneous structure formed through photopolymerization induced phase separation (PPIPS) by UV light source. The devices allow excellent thermoresponsive controllability of light transmittance.

Keywords—PNLC; PPIPS; NI phase transition; meso-scale phase separation; thermoresponsive switchable windows

I. INTRODUCTION

Meso- (submicron- to micron-) scale phase separations of orientation-ordered liquid crystals (LCs) and anisotropically polymerized reactive mesogens (RMs), which form structures called polymer network liquid crystals (PNLCs), can efficiently control light waves by responses of the LC orientation orders to extrinsic stimuli (electric fields, light, temperature, etc.) [1]. Our research has focused on developing various thermoresponsive optical attenuators with simple PNLC structures [2,3]. The PNLC structures are simple to manufacture and handle, so that they are a promising candidate to be applied in various situations, in particular, to energy-saving switchable windows.

II. SAMPLE PREPARATION

The PNLCs were fabricated in a simple way, that is, by UV irradiation to raw mixtures of LC, RM, and photoinitiator sandwiched by rubbing-treated transparent substrates. In detail, the LC was a typical nematic one, that is, 4-cyano-4'-heptylbiphenyl or 7CB, which has a nematic-to-isotropic (NI) phase transition temperature of TN=42 °C. The RMs were the mixture mainly consisting of 6-[4'-cyano-[1,1'-biphenyl]-4-yl]oxy]hexyl acrylate. The photoinitiator was DMPAP. The transparent cells with the raw mixtures inside were exposed at room temperature by UV light with an intensity of 1 mW/cm².

III. RESULTS AND DISCUSSION

The PNLCs have high controllability of light transmittance by change of optical clarity states between transparence below TNI and haze above TNI. Figure 1 shows direct transmittance, an indicator of clarity, and hemispherical transmittance, an indicator of the amount of heat penetration, as a function of wavelength (λ) at temperatures of 20 °C and 50 °C. The direct transmittance changes between 79% and 1% at λ = 550 nm, as shown in Fig. 1(a). Solar transmittance, which corresponds to the amount of heat penetration into buildings through windowpanes, was estimated to be 89% at 20 °C and 70% at 50 °C from the hemispherical transmittance, as shown in Fig. 1(b).

Figure 1. Thermoresponsive transparent/opaque switchability. (a) Direct and (b) hemispherical transmittance spectra. Luminous efficacy and solar irradiance are shown by black and gray areas, respectively. The insets show the snapshots of a sample at different temperatures and the measurement setups.

IV. CONCLUSIONS

The PNLCs are efficiently switchable in optical clarity with the amount of heat penetration through the devices. The structure, which consists of meso-scale phase separations, is simple to manufacture and handle. The devices are a promising candidate for applications to thermoresponsive switchable windows for energy-saving buildings.