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Characterization of an acrylic pressure-sensitive adhesive blended with hydrophilic monomer exposed to hygrothermal aging: Assigning cloud point resistance as an optically clear adhesive for a touch screen panel

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ABSTRACT

Optically clear adhesive (OCA) is a key material for assembling a touch screen panels (TSP). TSPs are now applied to many devices; therefore, their preparation and adhesion performance examination including durability can be beneficial work. Cloud point resistance means that a material does not have a hazy appearance under any environment, especially under sudden temperature and humidity changes. It is a critical property for an OCA because it is directly related to image display on a TSP. A hydrophilic component needs to be incorporated to the OCA, and 2-hydroxyethyl acrylate (HEA) was selected as the monomeric hydrophilic component. The change in adhesion performance under hygrothermal aging conditions was investigated. The aging behavior was also monitored using infrared (IR) and Raman spectra and chemiluminescence (CL) analysis. The HEA-containing pressure-sensitive adhesive (PSA) exhibited a good cloud point resistance and adhesion performance along with stable adhesion properties during aging. This consequence is considered suitable behavior for the prepared PSA as an OCA.

1. Introduction

A capacitive-type touch screen panel (TSP) has been employed in many recent electronic devices, and Fig. 1 shows its structure [1]. It is very important to utilize an adhesive to assemble a TSP. The adhesives used inside the TSP structure are called optically clear adhesives (OCAs) because the high transparency of the cured adhesive is critical. The cured adhesive is a tacky film shape like a pressure-sensitive adhesive (PSA).

The advantage of using an OCA is not only just a simple way to fabricate TSPs but also the realization of a clear and bright image on the screen. When the space between each component layer is filled by OCA, the difference in the refractive index between layers decreases compared with that only filled with air because the polymer has a similar refractive index to glass or other films that are used as a substrate. The similar refractive index allows the straight progress of light without loss; therefore, more light can reach the user's eye from the display module in the TSP.

Acrylic polymers are good candidates for an OCA because general acrylic polymers have excellent transparency when they were cured thermally or by UV. If an acrylic polymer is used as the OCA, the transparency can be fulfilled easily as a first qualification. The required properties of the OCA are appropriate adhesion strength, durability, and corrosion resistance besides transparency. Above all, the cloud point resistance must be satisfied.

Cloud point resistance refers to not having a hazy appearance under any condition. The reason and solution of cloud point resistance are illustrated in Fig. 2. The cloud state can take place because of unequally dispersed moisture. The wavelength of this localized moisture differs from the light wavelength, leading to haze on a film. However, moisture can exist as small droplets or as a continuous solubilized phase in the PSA matrix by incorporating a hydrophilic component. Then, the PSA film can maintain its transparent state [2].

In view of the above description, a hydrophilic component is vital in the OCA preparation. A patent has been applied for [2], but a paper has not yet been published on this topic. A hydrophilic PSA has been designed using poly(ethylene glycol) and poly(*N*-vinyl caprolactam), and its properties have also been tested [3], although that work did not focused on the OCA application. Apart from this case, hydrophilic PSAs are mainly employed in medical applications such as a transdermal patch for a drug delivery system [4–7], biosensing [8], biodegradable PSAs [9], and paper recycling-friendly PSAs contained in a mixture of recycled-fiber sources [10].

On that account, the hydrophilic component to be added to acrylic PSA was studied in this research for OCA applications. Its basic properties and durability were examined. Usually, the durability of the PSA is estimated by the hygrothermal aging test, which is a common accelerated

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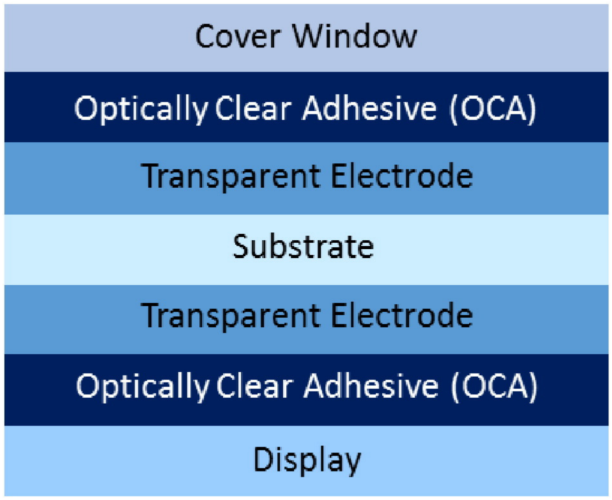

Fig. 1. Capacitive-type TSP structure which is representative of TSP driving method and OCA application [1].

aging test. An acrylic OCA was prepared by the UV irradiation of an acrylic monomer blend, and several properties needed in an OCA such as visible light transmittance, tack, and peel strength were surveyed with the increasing hydrophilic component. The aging behavior was monitored to inspect what change occurred and how this change was connected to the adhesion property change.

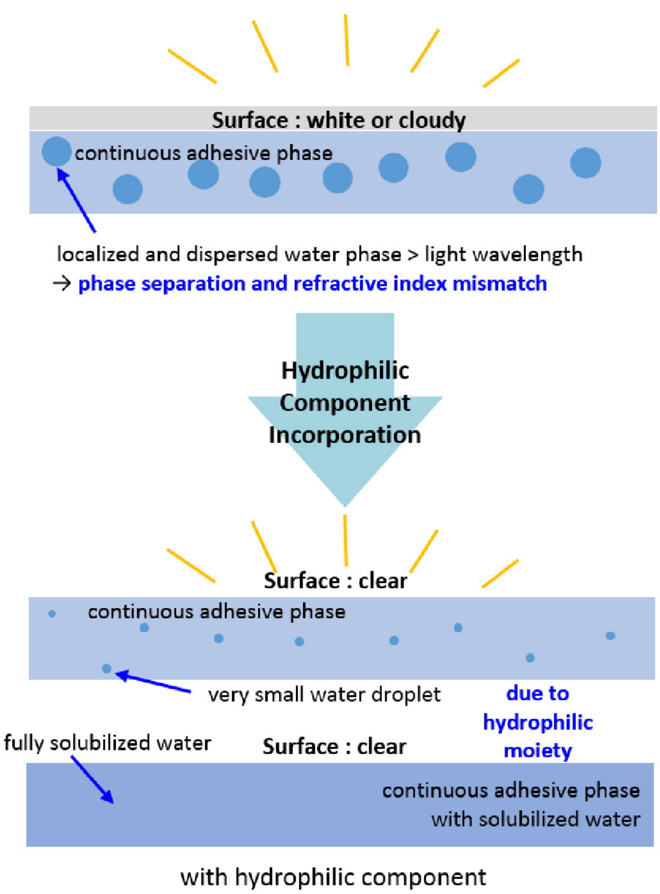

Fig. 2. Role of hydrophilic moiety in imparting cloud point resistance to OCA.

2. Experimental

2.1. Materials

2-Ethylhexyl acrylate (2-EHA, Samchun Chemicals, Republic of Korea), isobornyl acrylate (IBOA, Sigma Aldrich, USA), and *N*-vinyl caprolactam (NVC, Sigma Aldrich, USA) were used for preparing the basic monomer premix, which is base resin. 2-Hydroxyethyl acrylate (HEA, Samchun Chemicals, Republic of Korea) was blended into the partially polymerized monomer premix associated with the cloud point resistance property. The photoinitiator was α,α-dimethoxy-α-phenylacetophenone (Irgacure 651, BASF, Germany). 1,6-Hexanediol diacrylate (HDDA, Miwon Specialty Chemical, Republic of Korea) functioned as a crosslinking agent. All materials were used as received without further treatment.

2.2. Monomer premix preparation

The monomer premix was prepared by irradiating the 2-EHA, IBOA, and NVC monomer mixture with UV at an intensity of 40 mW/cm^2, as shown in Table 1. The monomer mixture was charged to a 300 mL round bottom flask with the photoinitiator. N_2 gas was used to purge the flask at a rate of 20 mL/min, and temperature was controlled to room temperature during the irradiation. After partial polymerization by UV, the viscosity of the monomer premix was 870 cP, as measured by a Brookfield viscometer using spindle No. 4 under 750 RPM at room temperature.

2.3. Coating and curing

Various amounts of HEA (2, 5, 10, 20 phr) were blended into the monomer premix using a paste mixer (DAEWHA Tech., Republic of Korea). The prepared mixture was coated on PET film at a thickness of 175 μm for the peel strength and visible light transmittance measurement and a thickness of 500 μm on the release film for the other experiments. The coated mixture was cured by conveyor belt type UV curing equipment with a 1000 mJ/cm^2 UV dose to form the PSA film.

2.4. Gel fraction

To measure the curing degree according to the blended amount of HEA, the gel fraction of the cured PSA film was calculated from the following equation.

$$\text{Gel fraction } (\%) = (W_1/W_0) \times 100$$

where W_0 is the initial weight of the sample, and W_1 is the solvent-extracted weight of the sample [11].

The cured PSA film was soaked in toluene at 50 °C for 24 h. After the toluene was extracted from the film, it was dried at 50 °C for 24 h to remove residual solvent. The dried PSA film weight which is constant after the drying was obtained, and the gel fraction was calculated.

2.5. Aging condition

The aging condition was 50 °C and 80%RH for investigating property changes and cloud point resistance of the prepared PSA as an OCA. All

Table 1
Formulation for cloud point resistant OCA.

	#1	#2	#3	#4	#5
	Base resin (2-EHA: 60 wt.%, IBOA: 20 wt.%, NVC: 20 wt.%)				
HDDA (phr)	0.1	0.1	0.1	0.1	0.1
Photoinitiator (phr)	0.15	0.15	0.15	0.15	0.15
2-HEA (phr)	0	2	5	10	20