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Reliability of liquid crystal cell and immiscibility between dual-curable adhesives and liquid crystal

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ABSTRACT

The dual-curable adhesive used to attach thin film transistors (TFTs) to color filters in the construction process of liquid crystal display (LCD) panels requires fast curing by UV irradiation and strong bond strength after thermal-curing. In addition, it is necessary to consider the immiscibility of the dual-curable adhesives with the liquid crystal, because they come directly into contact with the liquid crystal without curing process in the large LCD panel production. In this study, dual-curable adhesives based on partially acrylated epoxy acrylate oligomers were prepared and investigated with nematic liquid crystals using gas chromatography (GC), polarized optical microscopy and the measurement of the transmittance of the liquid crystal.

As the concentration of C=C bonds was increased, the immiscibility was enhanced due to the fast curing rate of the partially acrylated epoxy acrylate oligomers and reduced visual contamination was observed in the polarized optical microscope images. Moreover, the transmittance of the liquid crystal cells was not changed before and after the dual-curing of the adhesives and was maintained for 100 h.

1. Introduction

Since liquid crystals were first discovered by Reinitzer and Lehmann more than 100 years ago, there have been many studies on their display applications [1]. Liquid crystals are very useful for constructing a variety of electro-optical devices owing to their large optical anisotropy which is easily controlled by an external electric field or geometrical modulations.

There are various types of commercialized display such as cathode ray tubes (CRTs), plasma display panels, vacuum fluorescent displays, light-emitting diodes, electroluminescent displays, field-emission displays and LCDs [2]. Among them, LCDs are widely used for flat panel displays as a substitute for CRTs all around the world [3]. Moreover, liquid crystals are applied to many optical processing devices [4,5] and adapted for biophysical devices.

Recently, with the increasing demand for mobile devices in the digital multimedia broadcasting and ubiquitous environments, all organic displays in which all of the elements such as the substrates, integrated circuits, and electrodes are made of organic materials, have attracted much attention, since thin, lightweight, and bendable displays have several advantages including their low power consumption and simple fabrication processes [6].

Liquid crystals are important in several key areas of flat panel displays and fiber-optic communications, since their large optical anisotropy can be electrically and/or geometrically controlled in a simple way. The majority of the specific electro-optical effects of liquid crystals depend on the anisotropy of their electrical and optical properties. The basis of these effects is the reorientation of the director, which

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is described as the average axis of preferred orientation of the liquid crystal molecules, in the macroscopic volume of the materials under the influence of an externally applied field [7,8]. Also, in many application areas, the reliability of the liquid crystal devices comes to be more important, since the physical properties of the liquid crystals depend on the heat, pressure, electromagnetic field, and irradiation of light. The liquid crystal devices should be explored under a variety of environmental conditions such as outdoor and humid conditions for practical applications [9,10]. Particularly, the temperature dependence of the optical properties of the liquid crystal displays is the most important factor determining their reliability [11].

It is important to increase the aperture efficiency of the LCD panel in order to acquire a low power consumption and high luminance LCD. For this purpose, it is necessary to accurately adhere the TFT substrate and the color filter substrate and to reduce the overlap margin in order to compensate for the positional deviation [12]. Also, the production methods used for LCD panels evolve as their size increases. In the case of small LCD panels, the adhesive frame was made by putting the dual-curable adhesive on the surface of the TFT and then covering the color filter. Next, this adhesive frame was cured by a UV- and thermal-curing process. Finally, the liquid crystal was injected into the gap using capillary action in a vacuum environment. However, as the panel size is increased, the time required to inject the liquid crystal increases. Therefore, the one-drop filling (ODF) method was developed. In this method, the adhesive frame is made by putting dual-curable adhesive on the surface of the TFT and then the exact amount of liquid crystal is poured into the frame without any curing process of the adhesive. Next, the color filter is placed over the frame and the adhesive is cured by UV irradiation and thermal heating. Therefore, for the application of various electro-optical control and display devices, the immiscibility between the liquid crystal and adhesives must be considered. Many studies have been conducted on the phase behavior, morphological properties, polymerization kinetics, and electro-optical properties of liquid crystal [13–16]. However, there were no related researches to immiscibility between liquid crystal and adhesives.

The goal of this work, therefore, is to evaluate the immiscibility between the dual-curable adhesives used for the ODF method and the liquid crystal during the UV- and thermal-curing process. Their immiscibility is investigated using gas chromatography, transmittance measurements, and polarized microscopy.

Table 1
Blend ratio of dual-curable adhesives.

Epoxy acrylate oligomer	50.3 wt%
TMPTA	21.5 wt%
Photoinitiators	7.2 wt%
Latent curing agent (LCA)	10.1 wt%
Curing acceleration agent	1.0 wt%
SiO_2	10.0 wt%

2. Experimental

2.1. Materials

In order to synthesize the partially acrylated epoxy acrylate oligomers, a diglycidyl ether of bisphenol A (DGEBA) type epoxy resin (KER 828, epoxy group content: 5260–5420 mmol/kg) was kindly supplied by Kumho P&B Chemicals, South Korea. Acrylic acid (Junsei Chemical, Japan) and triphenylphosphine (TPP, Fluka, Switzerland) were used. Also, to prepare the dual-curable adhesives, the trifunctional monomer, trimethylolpropane triacrylate (TMPTA), and two types of photoinitiators, hydroxy cyclohexyl phenyl ketone (Micure CP-4) and hydroxyl dimethyl acetophenone (Micure HP-8), were kindly provided by Miwon Commercial, South Korea. As the thermal-curing agent, a mixture of dicyandiamide type latent curing agent (Amicure® CG-1400, Air Product) and curing acceleration agent (Sunmide LH-2102) was used. Also, hydrophobic fumed silica filler (Aerosil® R 974, Degussa) was used. All

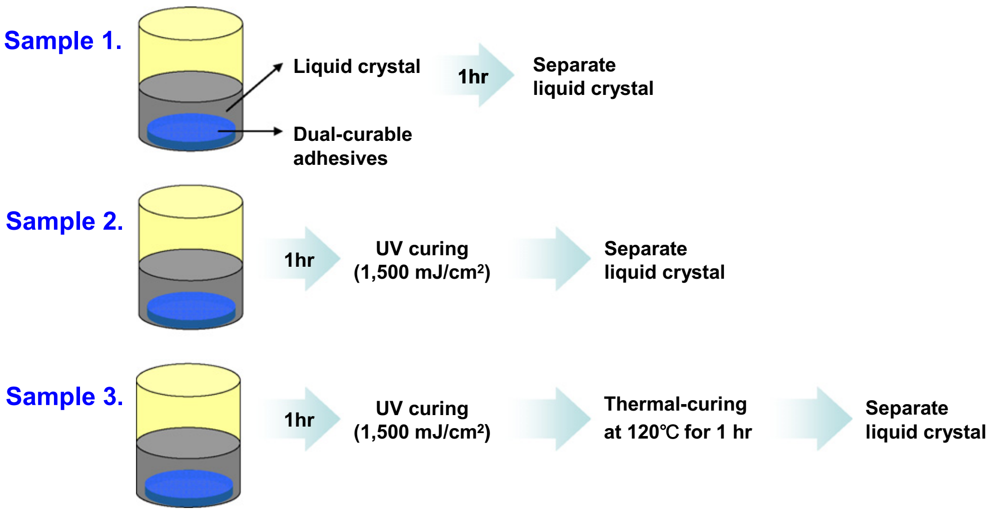

Fig. 1. Schematic diagram of sample preparation procedure of the liquid crystals designed to measure their immiscibility with the adhesive.