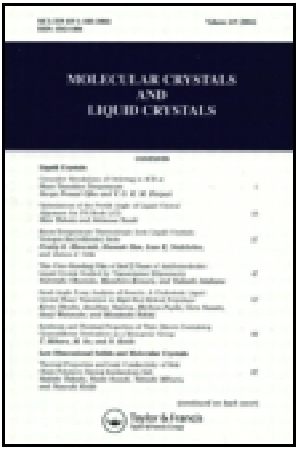

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Investigation on Monomers for a New Polymer-LC Dispersed Structure

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We presented bright full color reflective LCDs called IRIS (Internal Reflection Inverted Scattering), which utilize an unique polymer-LC composite system. In this paper, we discussed the dependency on LCs and monomer materials for the reflectivity. For these experiments, we synthesized a series of new terphenylmethacrylate monomers incorporating substituents. The monomers have sufficient stability and good solubility. We found the liquid crystalline characteristic of monomers strongly affects the scattering properties. Investigating a UV polymerization process and LC materials as well as monomers, the composite system provides sufficient durability for active-matrix LCDs.

Keywords: reflective LCD; polymer; terphenylmethacrylate; durability

INTRODUCTION

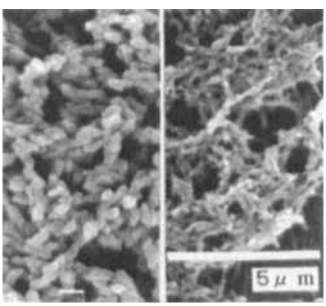
With very low power consumption, reflective full color displays are in strong demand for mobile application, PDAs, PCs and cell-phones etc. At the last SID'97, we presented bright reflective color LCDs using IRIS[1) 2)], Internal Reflection Inverted Scattering, a kind of PDLC technology and operates as a reverse mode.

In particular IRIS is an excellent solution to meet the needs for mobile application, especially outdoors and in sunlight, where high durability in conjunction with good image quality is a necessity. IRIS is a solution to meet these requirements because it does not need any polarizer and any photo-initiator in photo-polymerization.

In this paper, we will describe the unique polymer-LC composite structures of IRIS, which depend on monomers, LC materials and a polymerization UV process. Furthermore, we will describe image quality that depends on the polymer-LC composite structures.

The structure plays an important role in controlling scattering property, and its oriented grain shape differs from previous work by Hikmet[3]. The anisotropic networks studied by Hikmet have problems in terms of active-matrix driving ability because of their high driving voltage.

POLYMER STRUCTURE AND ELECTRO-OPTICAL RESPONSE



(a) (b)

Fig. 1 SEM photographs of the polymer structure

Among PDLC systems, IRIS has a unique polymer structure, which shows oriented polymer grains literally dispersed in liquid crystal. Figure 1 (a) and (b) show SEM photographs of the polymer structure of IRIS.

In Fig. 1 (a) the polymer structures look like the grains are being gathered. The grains overlap with grains located nearby, and thus the grains are connected three-dimensionally. The polymer structure shown in Figure 1 (b) seems to be a gel-network without the grains. The structure is highly dependent on the photo-polymerization condition and monomer and LC materials. These variations of the polymer structures strongly affect electro-optical responses such as driving voltage and scattering property.

Figure 2 represents typical electro-optical responses of IRIS corresponding with Fig. 1 (a) and (b). The gel network, case (b), shows weak scattering and relatively high driving voltage. In contrast, (a) shows good scattering properties and moderate driving voltage.

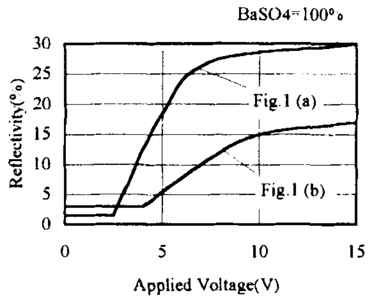


Fig. 2 Elector-optical response

Accordingly, being of a polymer grain structure plays an important role in scattering characteristics and reverse mode operation. The oriented polymer grain LCD is characterized with strong front scattering and weak back-scattering as compared with normal type PDLC. By using an inner reflector in LCDs for folding light, the strong front scattering can be utilized effectively. Accordingly, bright color images can be rendered even when using RGB color filters.

MONOMERS AND LC MATERIALS

Monomers and LC materials affect the polymer-LC structure normally. Investigating a number of monomers and LC materials, we found a relationship between the maximum reflectivity and optical anisotropy (Δn) shown in Fig. 3. Clearly the Δn of a liquid crystal mixture is a major parameter for the strength of scattering.

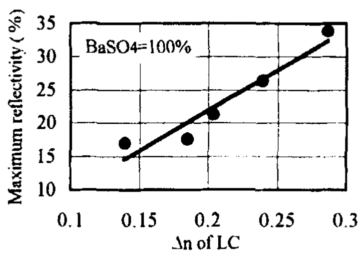


Fig. 3 Relationship between Δn of LC and maximum reflectivity

Additionally, we have studied effects of various monomer materials. Figure 4 shows various threshold voltage and reflectivity data plotted as a parameter of LC.'s Δn. Each data corresponds to various monomer materials. As explained in Fig.4, this results in Δn must be a dominant parameter even in the use of any monomer.

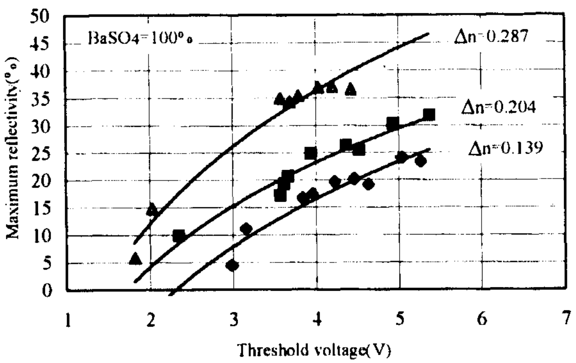


Fig. 4 Relationship between threshold voltage and maximum reflectivity

Though both a threshold voltage and a maximum reflectivity are changed by both kinds of liquid crystal and monomer used, there is a correlation in every liquid crystal, and the relations of the curve shown in the graph consist of the change of liquid crystal. This curve depends on the kinds of liquid crystal used, and a curve moves in the upper left direction as much as the liquid crystal of high Δn is used. It is necessary to choose the material of the upper left

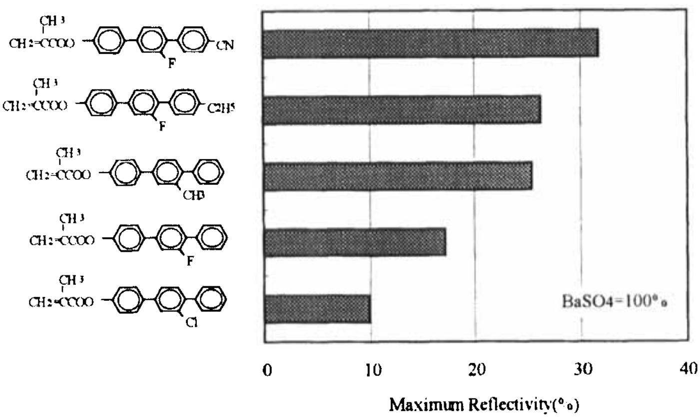


Fig. 5 Maximum reflectivity for some monomers

direction in the graph because of the low driving voltage and high reflectivity. To investigate the effect of the monomer materials, we have also focused on the liquid crystaline characteristics of monomers. Figure 5 shows the maximum reflectivity of a terphenylmethacrylate system as a function of liquid crystalline character. In Fig. 5, it was clear that maximum reflectivity depends on the kind of the substituent. The monomer with substituent liquid crystalline character has a higher maximum reflectivity. Gray[5)] studied the relationship between the substituent and variation of liquid crystalline character. According to Gray's, the monomers located on the right side in Fig. 5 have the high liquid crystalline character.

We selected monomers to obtain a desirable monomer's molecular structure in consideration of the followings.

1. Having sufficient stability against electrical fields, heat and light after polymerization.
2. UV polymerization process is smoothly completed even without a photo-initiator.
3. Having good solubility in liquid crystal mixtures without reducing the liquid crystalline character of the mixtures.
4. The synthetic scheme is simple.

The first point and the second point are necessary to produce highly durable LCDs. The third point is indispensable in order to get the oriented polymer, which decides the characteristics of IRIS. Finally, the fourth point has to be achieved considering the productivity and cost of monomers. We decided that the mesogen structure satisfying these requirements is terphenyl derivatives having no spacer and using methacrylate as the reactive group. Polymerization progressed smoothly by using methacrylate as the reactive group.

We considered that terphenyl derivative core without a central bonding group would have thermal stability, light durability and high liquid crystalline character. Monomers without a spacer result in the simplification of the synthetic process. We considered that terphenyl derivatives with a lateral group have good solubility in liquid crystal mixtures. Figure 6 shows the synthetic scheme of the terphenyl.

To investigate solubility, the monomer of 5% was dissolved in a liquid crystal mixture based on biphenyl and terphenyl liquid crystals. We settled a value of 5% the border for solubility because around 5wt% the scattering shows optimal in every experimental result. The terphenyl derivative without a lateral group was not completely dissolved in the mixture. Thus the solubility was improved by introducing a lateral group. The crystallization of monomers shown in Fig.5 did not occur for 100 hours in a liquid crystal mixture.

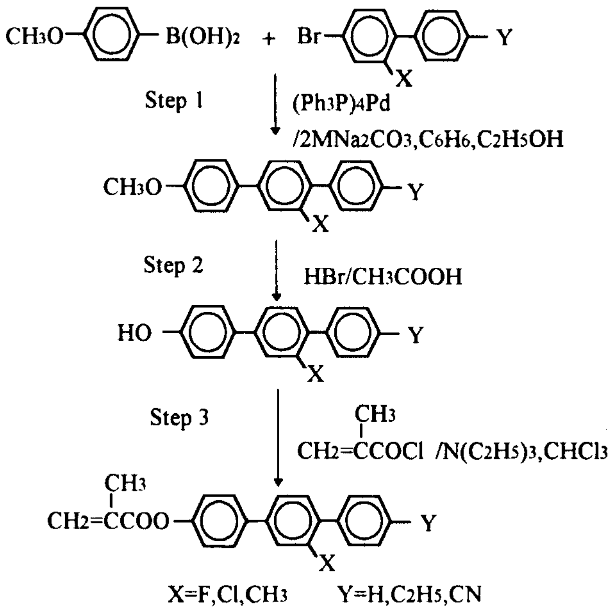


Fig. 6 Synthetic scheme of the terphenyl derivatives

POLYMERIZATION UV PROCESS

Polymerization conditions also strongly affect the polymer structure. It is possible that the IRIS panel can be driven at low voltage by active-matrix by choosing UV intensity and temperature at the process. UV conditions such as temperature and intensity inevitably affect the polymer-LC structures of grain shape and size. Polymer separation speed during the polymerization UV process affects polymer structure as well.

DURABILITY

Monomers and LC materials, and UV process are essential factors in achieving high durability such as high temperature storage, sunlight irradiation, etc. In particular, the monomer essentially decides them.

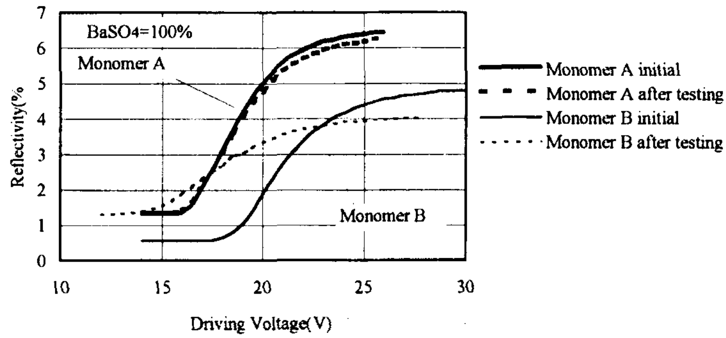


Fig. 7 Change elector-optical response

A difference in the durability of the IRIS using two kinds of different monomers is shown in Fig. 7. The LCDs are driven by active-matrix. X axis in Fig. 7 is driving voltage in the whole system. There is almost no difference between the initial characteristic and after driving it for 120 hours in the high temperature and high humidity environment when monomer A was used. On the other hand, when monomer B was used, there are drastic changes after driving it for 120 hours in the high temperature and high humidity environment.

By using stable LC materials and reactive diacrylate monomers without a photo-initiator, the IRIS panel can achieve at active-matrix applications, keeping the holding ratio an almost sufficient value.

In addition, the polymer-LC system provides high temperature durability, in particular, it provides more than 150 °C storage and less image sticking. Typical TN-LCDs which have polarizers cannot be used at more than 150 °C because of degradation of their polarizer.

Under strong sunlight irradiation, IRIS system shows better sunlight durability, because IRIS does not require any absorber in front, such as a polarizer

SUMMARY

We have synthesized a series of new terphenylmethacrylate monomers having sufficient stability and good solubility for an oriented polymer grain-LC system. We were able to utilize this system for scattering displaying mode called IRIS by investigating monomer and LC materials and UV polymerization process. Its front scattering characteristics caused by polymer shape is suitable for reflective color LCDs with internal reflection structure. For active-matrix applications, IRIS polymer-LC system provides sufficient driving characteristics, such as applying voltage and holding ratio. In addition IRIS, through its polymer structure, makes for highly durable displays suitable for outdoor use and high temperature storage durability, enabling it to be put in a car in summer.

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