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Mechanism of Photorefractive Effect in Polymer Layered Nematic Liquid Crystal Systems

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The photorefractive (PR) effect in liquid crystals sandwiched between photoconductive polymer layers was first studied by Ono *et al.*[1-2] They reported that the PR effect vanished at steady state if there were not insulating layers because no charge trapping occurred in the photoconductive poly(*N*-vinylcarbazole) (PVK) layers.[1] However we observed a significant PR effect in the polymer layered liquid crystal (PLLC) system where a liquid crystal layer doped with fullerene is sandwiched between two photoconductive PVK layers. These contradicting results between Ono's and ours necessitated the systematic study for the verification of the PR mechanism in PLLC.

The basic structure of the samples used in this study consists of an ITO glass electrode - poly(vinyl alcohol) (PVA) layer - PVK layer - E7 liquid crystal - PVK layer - PVA layer - an ITO glass electrode. Fullerene (C_{60}) was used for charge generators, PVA for insulating layers, and PVK for charge-trapping layers (Fig. 1 (a)). The E7 nematic liquid crystal was purchased from Merck Ltd. The fullerene concentration in both the PVK and the liquid crystal layers was 0.05 wt. %. The PVK and PVA layers were spin-coated and the thickness of the layers was about 1 μm and the thickness of the liquid crystal layer was controlled by a spacer of 12 μm thickness.

A linearly polarized single mode He-Ne laser of 17 mW was used for two beam coupling and diffraction efficiency measurements as a light source. The intensity of two p-polarized writing beams was about 350 mW/cm^2 and the angle between the beams was 0.026 radian. The sample normal was tilted by 30 degrees from the acute angle bisector of the two beams. Fig. 1 (b) shows a typical asymmetric two beam coupling in the C_{60} doped E7 liquid crystal layer sandwiched between C_{60} doped PVK layers (sample 8 of Table 1), which confirms nonlocal photorefractive effect. The gain coefficient of the sample was 220 cm^{-1}.

The mechanism of the photorefractive effect in the PVK-layered PLLC was investigated by measuring the first-order Raman-Nath diffraction efficiency. The results of the steady state diffraction efficiency for the samples that consist of various combinations of PVK layers with or without C_{60}, PVA insulating layers, a E7 liquid crystal layer with or without C_{60} are summarized in Table 1. The maximum diffraction efficiency values are given in Table 1 and the applied voltages that yielded the maximum diffraction efficiency are given in parentheses.

Our study shows that the formation of the current paths along the bright sites of the interference pattern across the sample plays an important role for the photorefractive effect in the PVK layered liquid crystal systems. Our study also leads to the conclusion that the photoconductive PVK layers are the dominant charge trapping layers in the PLLC system while the insulating PVA layers are not.

Table 1. First-order Raman-Nath diffraction efficiency of PLLC.

	Constitution					Diffraction efficiency (%)
	Upper charge trapping layer	Upper insulating layer	Liquid crystal	Lower insulating layer	Lower charge trapping layer	
1	PVK		E7		PVK	0
2	PVK	PVA	E7	PVA	PVK	0
3			E7-C_{60}			0.24 (4 V)
4	PVK		E7-C_{60}		PVK	2.6 (40 V)
5	PVK	PVA	E7-C_{60}	PVA	PVK	-
6	PVK-C_{60}		E7		PVK-C_{60}	2.0 (40 V)
7	PVK-C_{60}	PVA	E7	PVA	PVK-C_{60}	0.69 (100 V)
8	PVK-C_{60}		E7-C_{60}		PVK-C_{60}	3.7 (8 V)
9	PVK-C_{60}	PVA	E7-C_{60}	PVA	PVK-C_{60}	1.2 (100 V)

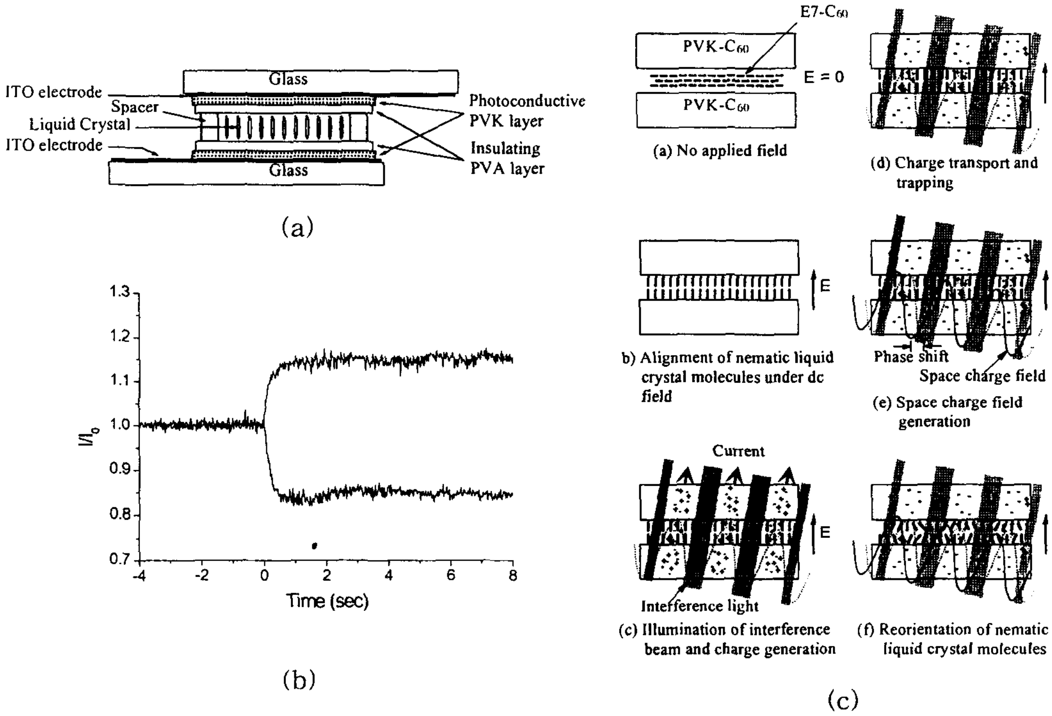

Fig. 1. (a) The basic structure of photorefractive liquid crystal samples. (b) Energy exchange between two writing beams. I_0 and I represent the intensities before and after two beam coupling, respectively. (c) Mechanism of photorefractive effect of a polymer layered liquid crystal, PVK-C_{60}/E7-C_{60}/PVK-C_{60}.

1. H. Ono and N. Kawatsuki, Appl. Phys. Lett **71**, 1162-1164 (1997).
2. H. Ono and N. Kawatsuki, Opt. Commun. **147**, 237-241 (1998).