Study of Polymer Stabilized Continuous Director Rotation Mode

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Abstract

We have studied the Polymer Stabilized Continuous Director Rotation (PSCDR) mode to solve the thermal shock problem which is core and main problem in CDR mode. The cell filled 95wt. % R2301 FLC and 5wt. % UCL-001 polymer is applied a low DC voltage only near the phase transition temperature from cholesteric to chiral smectic C phase transition to get defect-free alignment. In the previous work, we also confirmed layer deformation induced by an applied DC field only near the phase transition temperature from Ch to SmC. Results of layer structure, and characteristics of electro-optical properties between CDR and PSCDR mode will be discussed in this paper. We are also in progress to finalize the layer structures compared between CDR and PSCDR mode by x-ray measurements.*

1. Introduction

Since Meyer has found FLC (Ferroelectric Liquid Crystal) from rod -shape liquid crystal with chiral molecular structure in 1975, many manufacturing companies have applied for practical application in display such as SSFLC (the surface stabilized ferroelectric liquid crystal display) and AFLC which have characteristics of fast response time and wide view angle. But, mass production of SSFLCD and AFLCD had been stopped because there were many serious problems to be solved for LCD application, such as due to difficulty of low contrast ratio caused by zig-zag defects, mechanical durability, and so on.

Alternatives FLC modes which are Twisted FLC, Deformed Helix FLC (DHF), Polymer stabilized FLC, V-Switching AFLC, polymer separated composite organic films (PSCOF) [1], and Continuous Director Rotation (CDR) [2,3] have been researched in many universities and institutes. Especially, CDR mode has been spotlighted because of easiness of continuous gray scale control and zig-zag defect free. Nevertheless, CDR mode could not be applied for production because there was a problem of thermal shock. But, we think that best candidate modes for future mass production will be PSCOF and PSCDR.

In this paper, we have studied the stability of thermal shock investigated by the dependence of dark state on thermal cyclic. We have also tried to solve the problem of thermal shock by polymer Network-Stabilized mono-stable method (PSCDR) used FLC which has Ch-SC* phase transition [4-6].

2. Experimental Details

In the bistable states, molecules in SmA* tends to align parallel to the rubbing direction when a transition from nematic phase to SmA* phase occurred, while the layer normal became parallel to the rubbing direction. Therefore, two domains with their layer normal directions tilted by $\pm\theta$ appeared which can make zig-zag defect due to chevron layer structures. In order to get mono-domain, defect-free cells, a low DC voltage has been applied for only near the phase transition temperature from cholesteric phase to SmC* phase. Because of the strong mono-stable orientation along the rubbing direction and the torque imposed on the directors by applied field, the director continuously rotates on a cone, so that continuous gray scale is possible.

We have used two ferroelectric liquid crystals and a polyimide as shown in Table 1.

Table 1. Characteristic of FLCs and PI.

Liquid Crystals	Materials	A08	R2301
	Ps	$10nC/cm^2$	$3.5nC/cm^2$
Alignment	Materials	AL3046	
	Pretilt Angle	3°	
	Rubbing	Anti-parallel	
UV	polarized UV		

All cells were made by applying weak DC voltage in the local region of phase transition from cholesteric phase to Smectic C* phase. Because FLCs don't have the Sm A phase, they have phase transition from Cholesteric phase to Smectic C* phase. Molecular in the bistable state in Sm C* tended to align to the rubbing direction at the transition. In this studies, we applied low negative DC voltage in ITO electrode of the cell, and then it made molecular to align same direction to rubbing direction. In this process, we gained mono domain which allowed the black state without defect in the unit cell. This was called CDR (Continuous Director Rotation) mode.

We have tried a preceding experiment with the number of four cases. (1) We have changed the applied voltage after fixed the region of ± 3℃ at the phase transition temperature. Simultaneously we have come down the temperature by 1℃ in one minute with applying voltage to the samples. (2) We have made PSCDR cell in the way of (1) after mixing the monomer UCL-001 in R2301 by selected rate. We change the optimized voltage (6V) after fixed into 5wt% a monomer rate. (3) We have irradiated a proper UV intensity ($1.5mw/cm^2$) for a proper time (10 minute) in room temperature. We have made it to align parallel to the rubbing direction at UV light irradiation. We thought that polarized UV light can align the monomer well to a rubbing direction than non polarized UV. (4) Finally, we have measured the EO Characteristics of texture, VT curve, and hysteresis so on.

After investigating electro-optical properties, we have tried making very thin glass cell (below 100 m thick cell) by glass etching used HF for x-ray scattering to fine layer structure in cell. This etching process is to minimize x-ray absorption from the glass cell. We have already checked the x-ray transmittance at arm zero depending on the thickness of beryllium, aluminum foil, and glass cell. We can find that the glass cell of 100 μm thickness produces a half intensity of that of a 1mm beryllium cell. We have executed x-ray scattering experiments at Kent State University in USA. The high resolution x-ray scattering experiment were done using an 18kW Regaku RU-300 rotating anode generator, with two perfect germanium monochromatic crystal and analyzer crystals, and a two-circle diffractometer using copper K_α radiation.

3. Results and discussions

In this study, we have used B08 and R2301 liquid crystal and AL3046 PI. Figure 1 showed dark state image texture taken by polarized microscope at room temperature in comparison before and after DC treatment.

1) CDR Mode

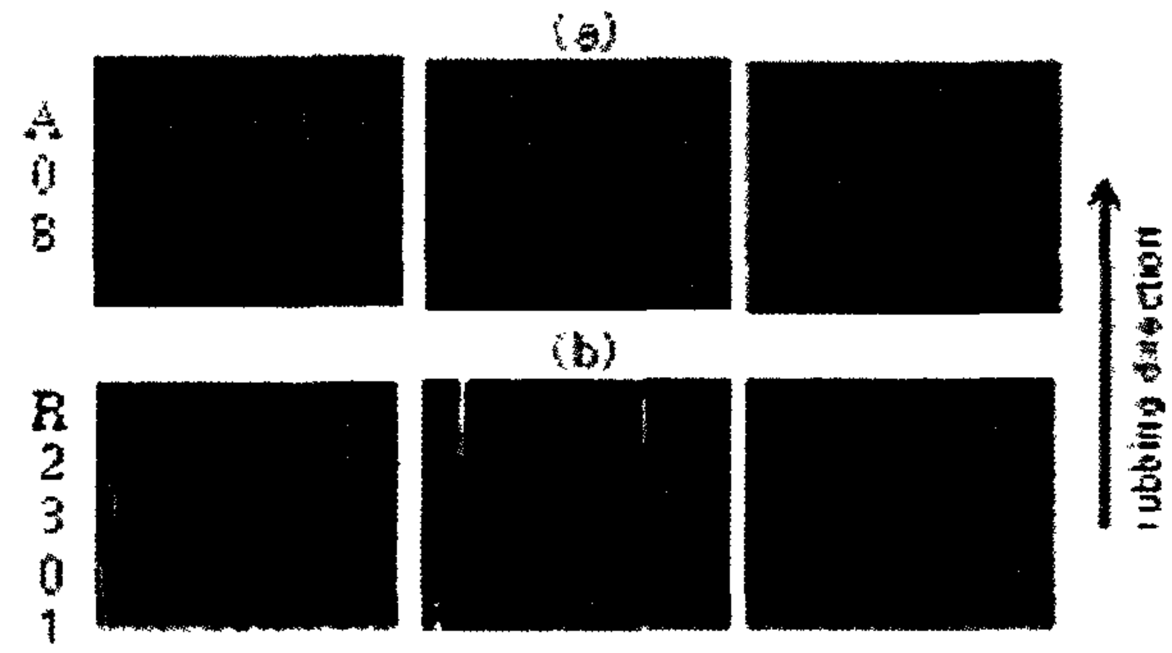

Fig. 1. Black state by applied negative DC voltage. (a) Before CDR, after CDR (DC 3V ±3℃-6min), and (DC 5V ± 3℃-6min) (b) Before CDR, after CDR (DC 6V ±3℃-6min) and (DC 8V ±3℃-6min).

As shown in Fig. 1, we obtained the better dark state for A08 applying DC 5V than applying DC 3V. In the case of the R2301, we obtained better dark state when we applied the DC voltage 8V. When we compared R2301 with A08, although the DC voltage is different, R2301 could get better dark state. And, both samples didn't show zig-zag defect after CDR treatment.

2) PSCDR Mode

The monomer UCL-001 (Merck) was used for PSCDR mode. We changed the rate of monomer to 3, 4, 5 wt% after fixed Voltage 6V to get best concentration. Figure 2 showed the texture of black state to get the optimized condition. As shown in the Fig. 2, the optimized combinations are the DC 6V/5wt% and DC 6V/4 wt%.

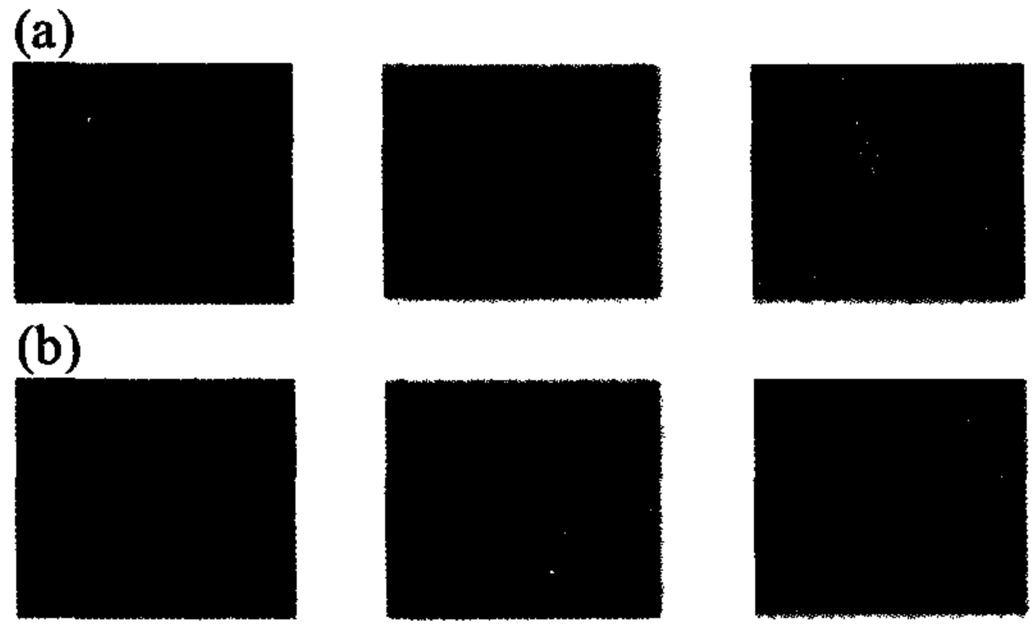

Fig. 2. The texture of PSCDR on monomer rate and applied voltage. (a) Changing the voltage to negative DC 5V, 6V, and 8V on 5 wt% monomer. (b) Changing monomer rate on 6 DC voltage.

3) The stability of Thermal Shock

To study the stability of thermal shock, the samples made by 5 wt% of UCL-001 and 95 wt% of R2301 were exposed with a polarized UV intensity (1.5mw/cm²) after applying negative DC 6V for making CDR.

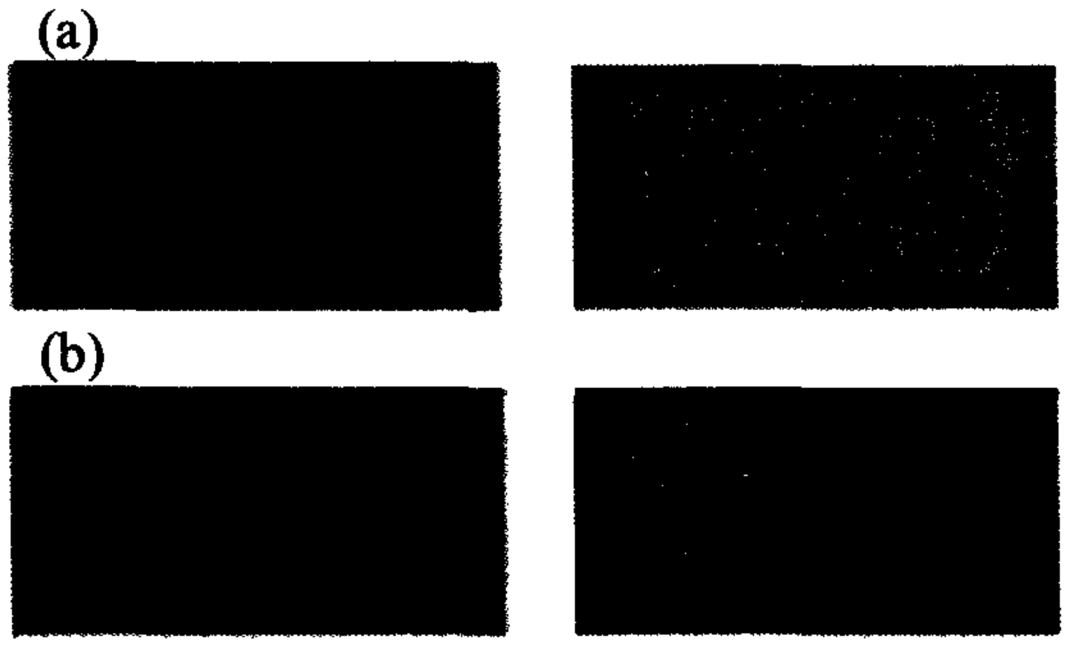

Fig. 3. Textures in thermal cyclic after increasing temperature to above 60℃ and then decreasing temperature to room temperature; (a) Un-polarized UV and (b) Polarized UV.

As shown in Fig. 3, we could find that the black state with irradiation polarized UV at room temperature was better than its state with un-polarized UV at the room temperature after making CDR mode. We could conclude that PSCDR mode with irradiation polarized UV was a solution for the thermal shock problem.

4) Optical Characteristics

We compared black state and transmittance between CDR mode and SSFLC mode. As shown in Fig. 4, the black state and transmittance in CDR mode shown an explicitly threshold voltage were much better than them in SSFLC mode.

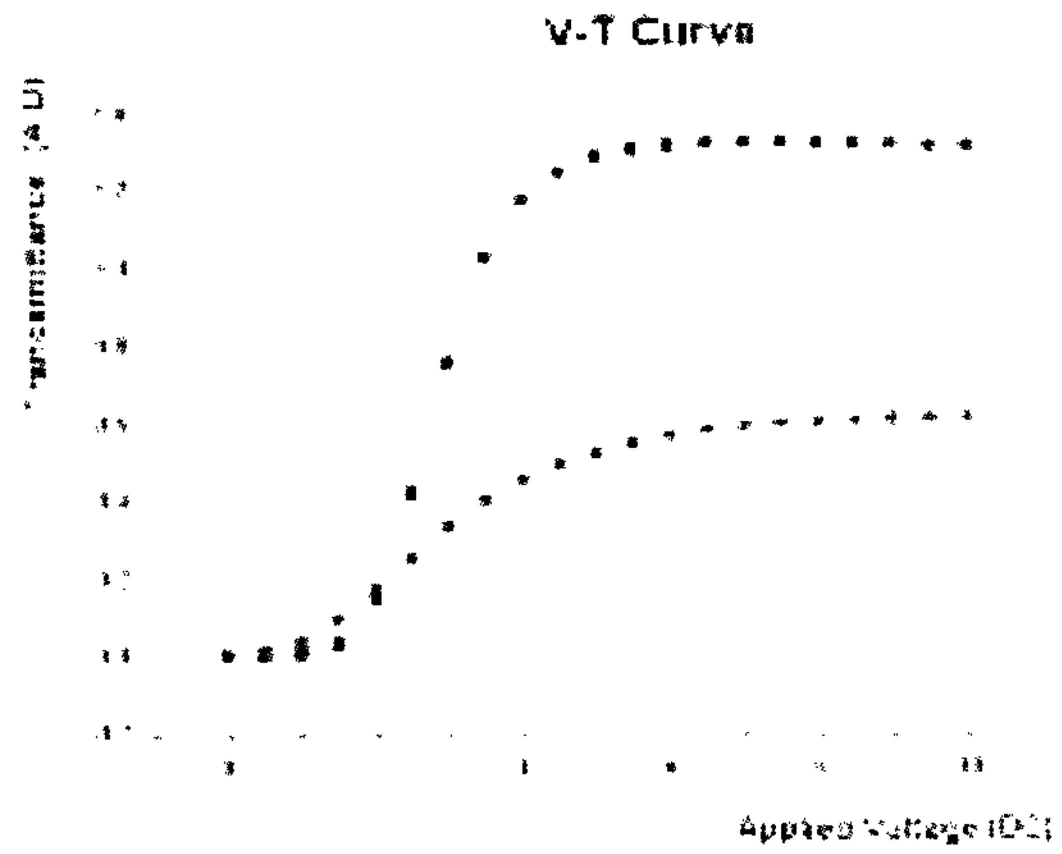

Fig. 4. Transmittance curve on voltage for CDR (black point) and non-CDR (red point) modes.

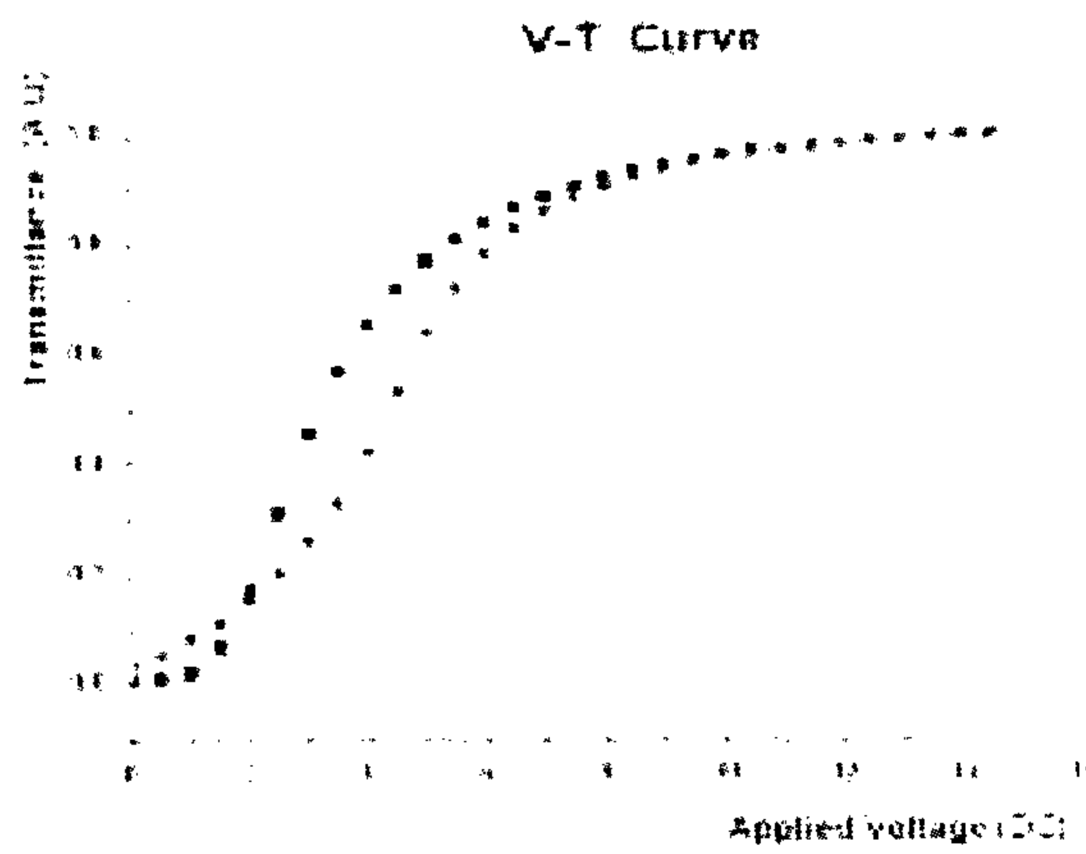

Fig. 5. VT Curve obtained in PSCDR mode with irradiation of the polarized UV (■) and the un-polarized UV (●).

Black state of PSCDS mode exposed polarized UV is much better than its black state exposed un-polarized UV as shown in Fig. 5. It meant that molecular aligned in the direction of polymer network. We thought that polymer network could be formed very well when we exposed polarized UV instead of un-polarized UV to PSCDR sample. We will prove if polymer network aligns in the rubbing direction by SEM picture.

5) Results of X-ray Scattering

All measurements were performed with a cooling sequence from high temperature to room temperature. Both substrates of cell were etched until 1.8μm for preventing absorption of x-ray beam. The cell was heated up to isotropic phase and cooled down to 61°C. And then we applied DC 5V from 61°C to 55°C for CDR treatment. Layer structure of regular cell without CDR treatment was chevron structure in SmC* phase as we expected. (We didn't include this result in this paper.) Figure 6 showed the bookshelf layer structure in cell with CDR treatment. Angle of bookshelf layer was exactly matched the angle of molecular tilt angle for compensating layer buckling. As we expected, there was no chevron layer structure in SmC* phase that the zig-zag defects didn't occurred. Just below temperature, 55.3°C, of DC treatment temperature, we could get a very sharp peak which meant that alignment of molecules was perfect. But, when temperature decreased, the peak was getting weak and broad even though the layer maintained the bookshelf structure. Alignment of molecules was getting worse and worse because of thermal shock problem which we wanted to solve by PSCDR mode.

4. Conclusion

We studied the PSCDR mode which could be a best mode to solve problems of mechanical and thermal shock for HDTV and plastic display application in future. We found that CDR mode didn't show up chevron layer structure, but had thermal shock problem by checking texture and x-ray results. PSCDR cell irradiated the polarized UV light showed stable results in black state when temperature decreased. We conclude that the PSCDR mode can be a best solution for future application. We are in progress to study layer structure.

5. Acknowledgement

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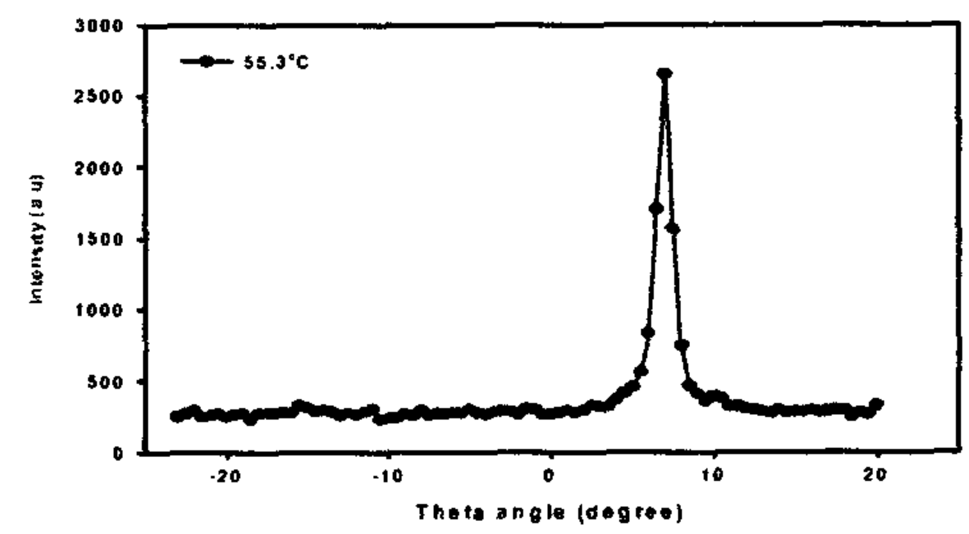
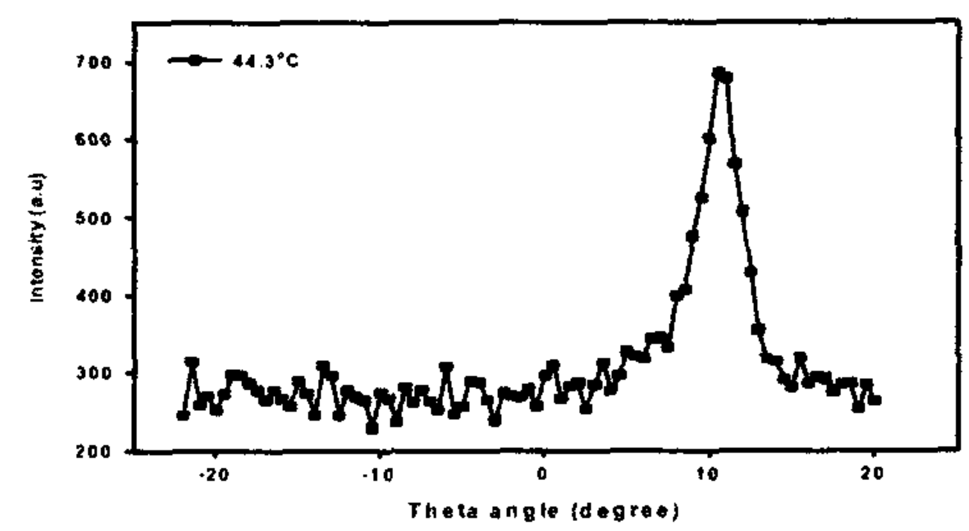
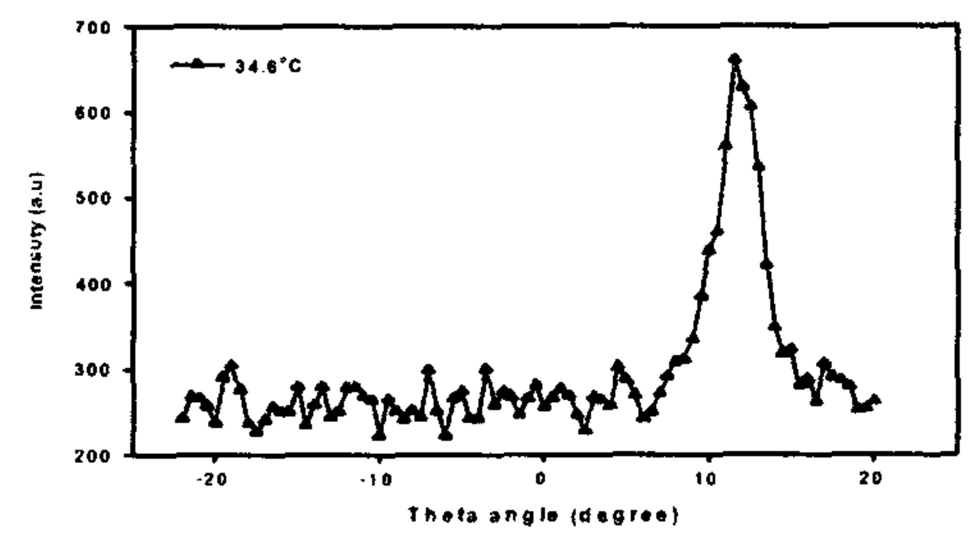


(a)



(b)



(c)

Fig. 6. Trend of rocking curves as a function of temperature (a) 55.3°C, (b) 44.3°C, (c) 34.6°C in CDR mode applied for DC treatment.

6. References

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