Slippery Interface -Mechanism and Physical Properties-

Jun Yamamoto[1,2], Hirotsugu Kikuchi[3,2], Takeaki Araki[1,2], Isa-Nishiyama[4,2] and Kiyoshi Minoura[5,2]

junyama@scphys.kyoto-u.ac.jp
[1]Department of Physics, Graduate School of Science, Kyoto University, Kyoto, Japan
[2]JST-CREST, Saitama, Japan
[3]Institute of Materials Chemistry and Engineering, Kyushu University, Fukuoka, Japan
[4]DIC Corporation, Saitama, Japan
[5]Sharp Corporation, Nara, Japan
Keywords: Slipper interface, weak anchoring, liquid crystal display, low voltage, bright mode efficiency.

ABSTRACT

We have invented the new principle to produce the slippery interfaces on the glass or plastic substrates. Anchoring energy and viscosity of surface director can be evaluated from the motion of the surface director under rotational magnetic field. Poly-ethylene Glycol (PEG)-Gel surface shows "weak and lubricated" slippery interface which is good character for the new mode of liquid crystal display (LCD).

1 SLIPPERY INTERFACES

Slippery interfaces are created by the disorder effect. We designed and realized several models of self-organized slippery interfaces. For example, the localized impurities on the interface between liquid crystal and polymer thin films can weaken LC order near the interfaces. Then, the anchoring effect should be weakened, and molecular motion is greatly lubricated by the slippery interfaces.

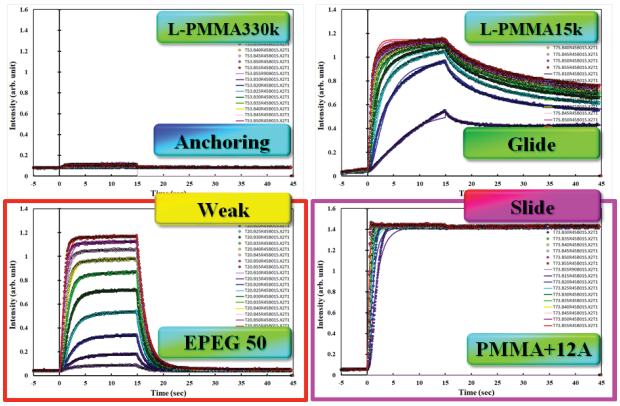

Fig.1 Four types of anchoring condition. "Weak" and "Slide" state are newly categorized by the movement of the surface director under electric field

We succeeded in controlling four types of interface states by the movement of the surface director representing the orientation of the liquid crystal molecules on the glass substrate surface. The first is the anchoring state, the liquid crystal molecules are strongly fixed on the glass plate. The second is glide state, when cutting the electric field, the surface director cannot return to the original position. Glide state relates to the burning problem. The new "Weak" state, despite the surface director is rotated greatly, it returns to the initial position completely at the time of electric field Off. Finally, in the new "Slip" state, the surface director rotates as large as the Weak state and stops completely at that moment when the electric field is shut off. That is, the surface director does not restore at all after cutting the electric field.

2 ANCHORING ENERGY AND SURFACE VISCOSITY

We characterize the slippery interface by measuring the dynamics of the surface director ns under rotational magnetic field. We analyze magnetic field dependence of the response of surface director $\boldsymbol{n}_s$ as indicated in Fig.2. We evaluate the temperature dependence of the anchoring energy W and viscosity of surface director γ_s (Fig.3). Slippery behaviors can be explained based on states of the polymer thin films and should be dependent on the rotational motion of the LC molecules on the polymer thin films swollen by the LC molecules themselves.

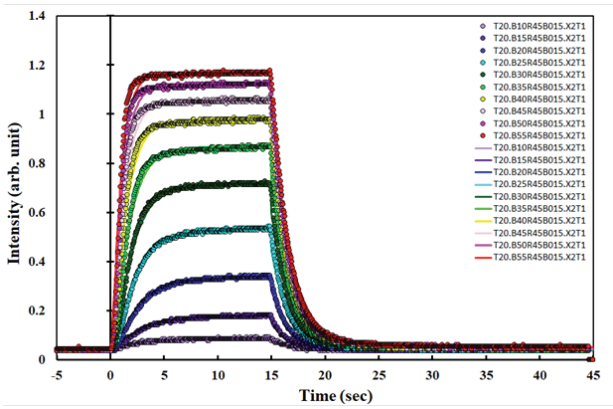

Fig.2 Response of the transmitted light intensity of the IPS-Nematic cell against switching on/off of the magnetic field on the slippery PEG-Gel films under Morgan limit. Colors represent the magnetic field dependences.

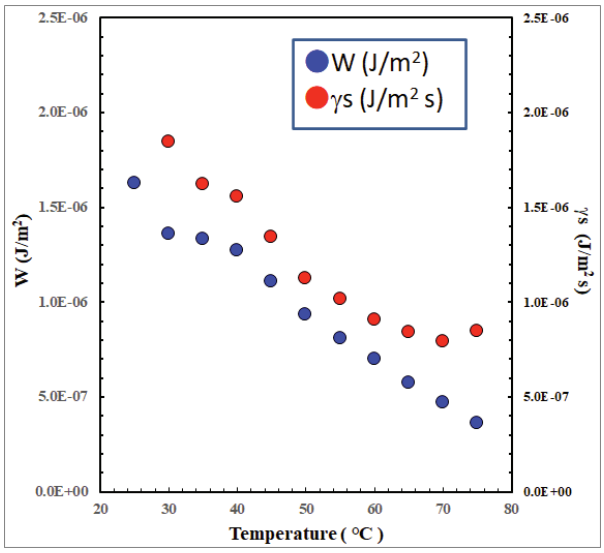

Fig.3 Temperature dependence of anchoring energy W and surface viscosity γs on the slippery PEG-Gel films.

3 LOW VOLTAGE DRIVEN NEW LCD MODE

We made a combination LCD cell which consist of the strong anchoring surface of polyimide for one of the inner surfaces of the glass substrates and used the slippery interface for the other. New LCD mode appears in this combination LCD cell. Recovering force on the switching off process can be assisted by the twist distortion of bulk nematic in addition to the restoring motion of the surface director driven by the weak anchoring interface. The mode shows several good performances, such as reduction of the driving voltage due to slippery interface in comparison with current modes in nematic LCD. (1) Mode efficiency greatly enhance near 100%, nevertheless current strong anchoring modes only show 70~80%. This is because the large rotation of liquid crystal molecules on the surface near the IPS electrode. (2) Driving voltage can be reduced about 50%. (3) If Δn is large enough, we can accelerate response time twice as faster than original one keeping same driving voltage by reduction of cell thickness.

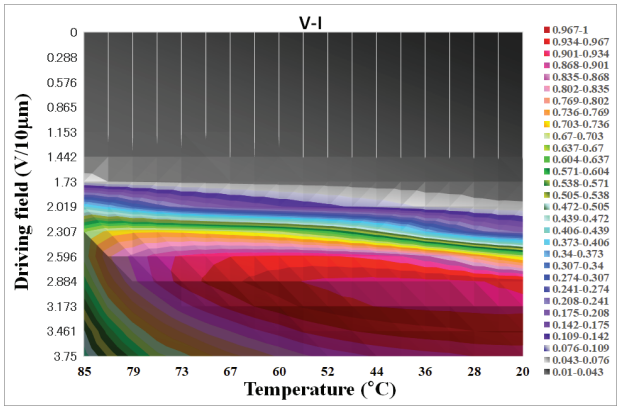

Fig.4 Temperature dependence of the mode efficiency for the slippery PEG-Gel/PI combination nematic LCD cell.

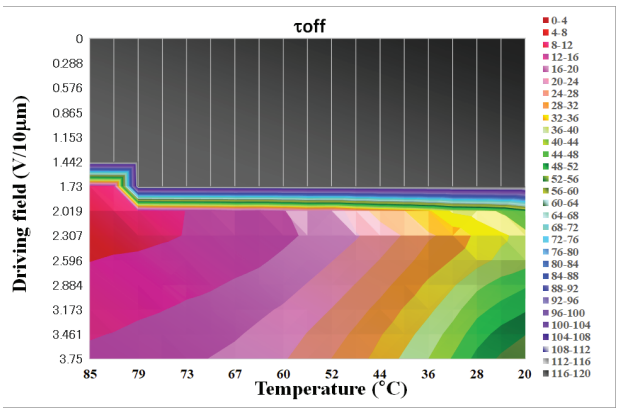

Fig.5 Temperature dependence of the switching off time for the slippery PEG-Gel/PI combination nematic LCD cell.

4 SLIPPERY FERROELECTRIC SMECTIC C* (SMC*) PHASES

We applied the slippery interfaces to the homeotropic ferroelectric SmC* liquid crystals for the DH-FLC mode in the in-plane switching cell and succeeded in reducing to reduce the driving voltage drastically keeping the ultra-fast response. Figure 5 shows the performance of SmC* on the slippery interface. SmC* on the slippery interface can be driven by low driving voltage <~1.0V/μm. The response time for the fast component does not decelerate and keeps the same speed as that of the original material (<100 μsec).

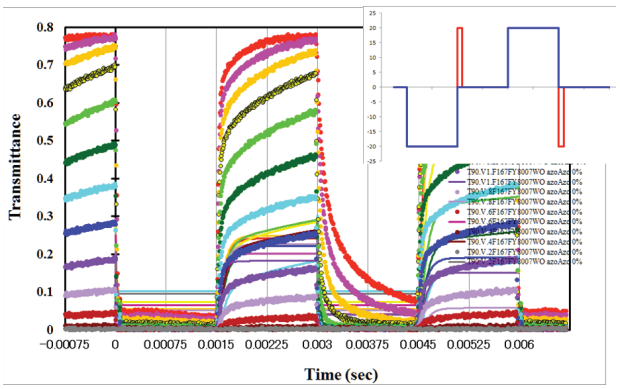

Fig.5 Reduction of driving voltage for ultra-fast DH-FLC mode of SmC* on the slippery interface.

5 CONCLUSIONS We have invented the new principle to produce the slippery interfaces on the glass or plastic substrates. Poly-ethylene Glycol (PEG)-Gel surface shows “weak and lubricated” slippery interface which is good character for the new mode of liquid crystal display (LCD). We can arbitrary control the anchoring energy ***W*** by changing the network density of the PEG-Gel.

ACKNOWLEDGEMENT This work was supported by JST-CREST (Grant Number JPMJCR1424).