— Communication —

LCD Driving Characteristics of MIM Diode Using Electropolymerized Polypyrrole Thin Film as an Insulator

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Received July 1, 1991; Accepted September 12, 1991

1 INTRODUCTION

An MIM type non-linear resistance device is used as a switching device for active matrix LCD of the high display quality¹⁾. So far, the Ta/TaO_x/Metal structure is known as for this device¹⁻³⁾. And an MIM device using organic insulating film prepared by LB (Langmuir-Blodgett) technique is studied by Maeda *et al*⁴⁾.

We have reported an electropolymerized thin organic film that is applicable to an insulator for the MIM device⁵⁻⁷⁾. Electropolymerization can easily form an organic thin film and can produce a large-size LCD at a low cost. Especially, the polypyrrole(PPy) film electropolymerized in the alkali solution (e.g. pH12) has high resistance (10¹⁰ ohm cm) in as-prepared conditions, and the MIM device which uses this PPy film as an insulator shows non-linear and symmetrical I-V characteristics stably as is previously reported^{6,7)}.

In this report, we describe the results of the multiplexing drive simulation of TN-LC cell connected to the MIM device on the basis of the basic results of Refs. 6 and 7, and discuss the possibility of active-matrix LCD driven by this MIM device.

2 EXPERIMENT

The MIM device consisted of the ITO/PPy/ITO structure. The fabrication process was similar to the previous experiments^{5,6)}. A 1 μm thick photo-

resist film (OMR-83, Tokyo Ohka Kogyo Co., Ltd.) was formed over the ITO/glass electrode, and 300 μm diameter contact holes for the deposited PPy were prepared by photolithographic technique. PPy films were electropolymerized in aqueous solution containing 0.25M Py and 0.01M NaOH at the constant potential of 1.5V vs. Ag/AgCl for 60 minutes. The film thickness of the PPy film was 0.1 μm. PPy films were first rinsed in water, next dried in atmosphere for 24 hours, and then dried at 160°C for 60 minutes. Then sputtered ITO films were formed on the each PPy film having a 2mm × 3mm area.

Figure 1a) shows the schematic measurement circuit of the TN-LC cell switching behavior by this MIM device. The TN-LC cell had an area of 5 mm × 5 mm and a capacitance of 135 pF. The MIM device had a capacitance of 155 pF. Figure 1b) shows MIM-LC driving waveforms applied to on-state and off-state LC cell. Driving voltage is defined as on-state waveform pulse voltage (V_a). Typical transmittance (T) - V_a characteristics were investigated at a frame frequency of 32 Hz, duty ratio T_g/T_f = 1/64 or 1/256, and bias ratio V_b/V_a = 1/4. The V_b was fluctuated in the actual multiplexing driven LCD, however, in this experiment V_b was at a constant level for simple evaluation.

In an MIM driven LCD, in order to get high contrast ratio between on-off waveforms, large C_{LC}/C_{MIM} ratio (e.g. 10) is better²⁾. For example in an MIM-LCD using TaO_x as MIM's insulator, the C_{LC}/C_{MIM} ratio was 3.5. In this experiment, this ratio had not been optimized (C_{LC}/C_{MIM} = 0.9) because the MIM of larger area was easy to construct and evaluate the performance properties.

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Key Words: MIM, Polypyrrole, Active Matrix LCD, Electropolymerization

Fig. 1 MIM-LC driving circuit diagram and waveforms.

3 RESULTS AND DISCUSSION

As is already reported^{5,6)}, this MIM device has a symmetrical non-linear I-V characteristic, and has threshold voltages at $\pm 5V$ ⁶⁾.

Figure 2 shows a T- V_a characteristics of TN-LC cell with and without the MIM device at duty ratio 1/64. Without MIM, there is scarcely a difference of T- V_a curves between on-off waveforms, so that multiplexing drive is impossible. With an MIM device, threshold voltages of the LC cell are obviously different between on-off waveforms. And the T- V_a curve at on-waveform improves steeper than that without the MIM because the charge on the on-state LC cell is maintained by the switching effect of MIM device. Therefore the contrast ratio between on-off waveforms at the same V_a became obviously high. When a condenser was inserted into the circuit instead of the MIM device, T- V_a curves improved weak slope and threshold voltages of the LC cell were scarcely different between on-off waveforms. It explains that this MIM diode actually works as a

Fig. 2 T- V_a characteristics of TN-LC cell with and without MIM diode at 1/64 duty ratio.

switching device, and that does not work as a voltage divider by the capacitance of the MIM device.

Figure 3 shows T- V_a characteristics of LC cell driven at 1/256 duty ratio. By the switching effect of the MIM device, a sufficient contrast was obtained even at 1/256 duty ratio. Because actual pocket TVs with MIM-LCD are operated at 1/256 duty ratio³⁾, the MIM is able to be used for a pocket TV.

Maximum contrast ratios were about 17 at 1/64 duty ratio and 8 at 1/256 duty ratio. In this experimental, capacitance ratio of C_{LC}/C_{MIM} had not been optimized, so that higher contrast ratio would become possible by making C_{MIM} smaller, i.e. using smaller size MIM device.

Fig. 3 T- V_a characteristics of TN-LC cell with and without MIM diode at 1/256 duty ratio.

In conclusion, the MIM device of ITO/PPy/ITO construction works as the switching device for active matrix LCD of at least 1/256 duty ratio.

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