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Preparation of MIM(Metal-Insulator-Metal) Non-linear Device Using Electropolymerized Poly-N-methylpyrrole

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The MIM cell of ITO(indium tin oxide)/polymer/ITO type was prepared by sandwiching electrochemically polymerized poly-N-methylpyrrole(PMPy) film for the insulator between sputtered ITO layers of the cell. When using undoped polymer layer, the two-terminal device shows non-linear and symmetric current-voltage(I-V) curve, where the current changes 5 orders between the voltage of 0 V and ±15 V, respectively.

It has reported that the use of MIM switching devices allows for larger and/or high resolution liquid crystal (LC) displays.[1] Devices are fabricated in industrial process by thin film techniques, where tantalum oxide (Ta_2O_5) layer, as an insulator of MIM, is usually formed by partially anodizing a sputtered tantalum layer. The application of organic insulating layers has already been tried to a Schottky diode (metal/polymer),[2] an organic heterojunction (polymer/polymer),[3] a FET,[4] a microelectrochemical diode,[5] a MIM device using a LB(Langmuir-Blodgett) film,[6] and so on. However, the MIM device using electropolymerized insulating layer has not been realized. In this letter, we attempt the electropolymerized polymer film for the insulator of the MIM cell, since the technique of electro-polymerization has the merit of forming insulating thin films easily and also simplifying the preparation of MIM cells. Therefore, it can be accelerated by this switching device that larger area LC display is industrially realized. A schematic representation of the MIM device experiments is shown in Fig. 1. The holes for the deposited polymer layer with various areas, 100, 300, 500, 700, 1000 μm in diameter were prepared by photolithographic technique on the 0.4 μm thick ITO layer. The PMPy(poly-N-methylpyrrole) film was galvanostatically polymerized on the ITO electrode in propylene carbonate (PC) solution containing 0.2 mol dm^{-3} N-methylpyrrole and 0.2 mol dm^{-3} $LiClO_4$ under the condition of drawing as low current density as possible. The PMPy film was electro-chemically undoped at -1.2 V vs. Ag/Ag^+ for 5 minutes to become the insulating state. After the PMPy film was rinsed in acetone and dried in vacuum condition, the 600 Å

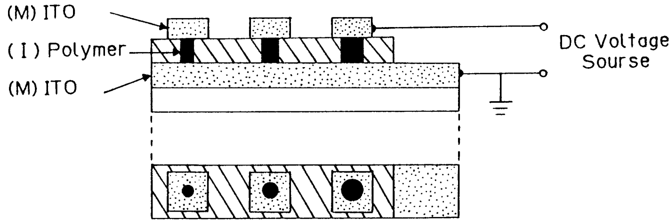

Fig. 1. Schematic representation for the MIM device experiments.

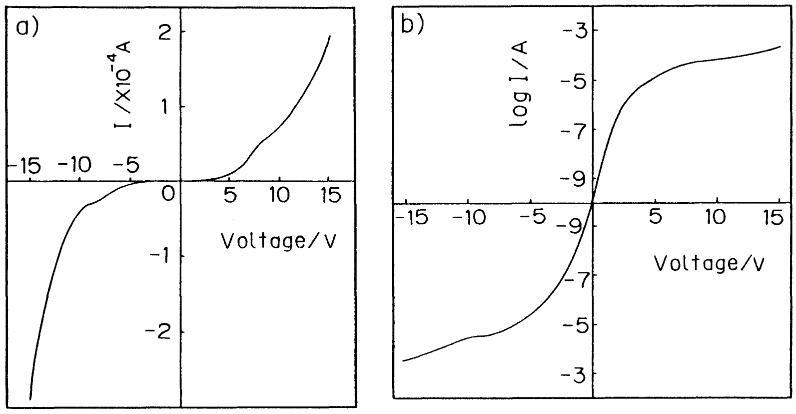

Fig. 2. I-V(a) and logI-V(b) characteristics of ITO/PMPy(undoped)/ITO cell.

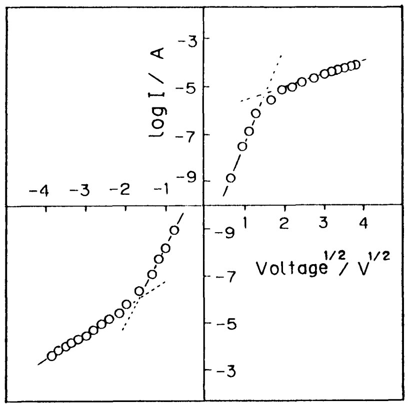

Fig. 3. LogI-$V^{1/2}$ characteristics of ITO/PMPy undoped)/ITO cell.

thick ITO was sputtered on it and patterned by etching.

Figure 2 shows the representative current-voltage (I-V) characteristics of the ITO/PMPy/ITO cell. The current is shown in I(a) and logI(b) units. The diameter and thickness of the PMPy film are 300 µm and 1 µm, respectively. The current increases steeply from ±3 V and it shows symmetrical shape in Fig. 2(a). It is demonstrated that the current gives 5 orders changes from 10^{-9} to 10^{-4} amperes symmetrically between 0 V and ±15 V in Fig. 2(b). The excellent reproducibility was given in the region between ±15 V. While in cases of the larger area than 500 µm in diameter or the thinner than 1 µm in thickness, the high reproducibility and such current changes were not obtained for the PMPy film usage in this MIM system.

Figure 3 shows the logI-$V^{1/2}$ plots, giving the straight lines but the slopes clearly change at ca. ±4 V region. At the higher electric field region, the conduction mechanism might be the Poole-Frenkel effect through the bulky PMPy film,[7] and at the lower field region another mechanism should be considered.

Consequently, the high potential of the MIM device using electropolymerized layer at undoped state is demonstrated by the symmetrical non-linear I-V response. This suggests another application of functional organic thin films.

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