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Measurement of Surface States in Au/Polyimide/Au Junction

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We studied Au/polyimide(PI)/Au junctions with the number of deposited polyimide(PI) Langmuir-Blodgett(LB) layers of 31 41, and measured the current-voltage of these junctions. Then we estimated the distribution of the density of characteristics surface states in PI LB film. This result supports the conclusion of our previous study, which was obtained om surface potential measurement.

Keywords: Langmuir-Blodgett; polyimide; MIM

INTRODUCTION

In the Langmuir-Boldgett(LB) technique, a monolayer on the water surface is transferred on to a substrate, which is raised and dipped through the surface, and one can obtain multilayers in which constituent molecules periodically are arranged in layer. The LB technique has attracted considerable interest in the fabrication of electrical and electronic device, *e.g.* metal-insulator-metal(MIM) and metal-insulator-semiconductor (MIS) junctions. Many researchers have investigated the electrical properties of monolayer and multilayer films.[1-6]
In the present paper, we give a pressure stimulation into organic thin films and detect the induced displacement current. Also, we fabricated MIM junctions with the structure of an Au/ PI/Au by the conventional LB technique.

BASIC CONSIDERATION OF MEASUREMENT

We consider a single monolayer on a water surface. Charge Q is induced on Electrode 1, and it is given by

$$Q = -N\frac{\mu_z}{d} + \frac{\varepsilon_r\varepsilon_0(V-\Phi_s)S}{d} \quad (1)$$

Here d is the distance between the electrode and the water surface, N is the number of molecules under Electrode 1, μ_z is the average vertical component of the dipole moment of a molecule, ε_r is the relative dielectric constant of monolayers on a water surface, ε_0 is the dielectric constant of vacuum, Φ_s is the surface potential of the water, S is the area of Electrode 1. The displacement current I flow through the sensitive ammeter only when induced charge Q on Electrode 1 is changed by the application of surface pressures. Therefore, the

reorganization of molecules can be detected with high sensitivity. Since the charge Q originates from constituent polar molecules distributed on the water surface and a potential difference between the surface of the water and Electrode 1, the current I is given by

$$I = -\frac{dQ}{dt} = (\frac{\mu_z}{d})\frac{dN}{dt} + (\frac{N}{d})\frac{d\mu_z}{dt} + (\frac{\varepsilon_r \varepsilon_0 S}{d})\frac{d\Phi_s}{dt} \quad (2)$$

and, Capacity C is given by[7]

$$C = \varepsilon_0 \frac{\varepsilon_r S}{d} \quad (3)$$

EXPERIMENT

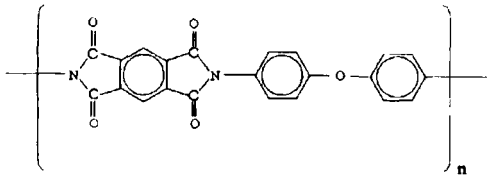

FIGURE 1. Structure of polyimide monomer.

Chemical structure of PI monomer is shows in Fig. 1. Ultrathin films of disilane-containing polyimide were prepared. PI solution with a mixture of N, N-dimethyl-n-octadecylamine(C_{18}DMA) and kapton(2:1), are prepared at a concentration of 0.333[*mmol/l*] in benzene.[8]. The substrate was a glass-slide cut to 13×38×1mm. After the substrate was subjected to ultrasonification in distilled water, three junctions were fabricated on each substrate as follows. The resulting Au/PI/Au junction was a sample. The number of deposited PI layers was between 31 and 41. DC biasing voltage V was applied to the sample, and current I across the sample was measured in a short-circuit condition at a room temperature. Current I flowing the circuit was measured by an electrometer. (model 6517 Keithley Instruments, Inc.)

RESULT AND DISCUSSION

Fig. 2 shows a typical example of the current generated from PI molecules during the compression with a constant barrier velocity in the area per molecule ranging from 320 $Å^2$ to 55$Å^2$. Surface pressure-area isotherm is also shown in the figure. Current was found to be initiated at A=310$Å^2$, although the surface pressure change was not detectable. A current peak appears in the range of molecular area A between 320 $Å^2$ and 185$Å^2$ (Range 1) by monolayer compression. The PI monolayer was transferred to substrates at a constant surface pressure of 13[mN/m]. The transfer rate was 5[mm/min]; Y-type deposition was carried out with a transfer ratio of close to unity.[9]

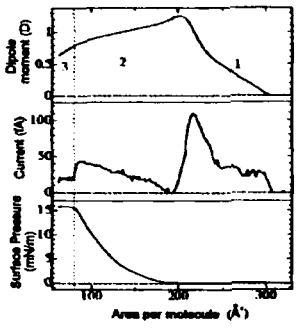

FIGURE 2. Result of barrier Compress.

Fig. 3 shows I-V characteristics of an Au/PI/Au junction with 31, 35 and 41 layers of PI LB film. The I-V characteristic was observed when the number of deposited PI layers was a linear relationship.

$$U = \frac{1}{2}CV^2 \qquad (4)$$

$$u = \varepsilon_0 \frac{\varepsilon_r V^2}{2d^2} \qquad (5)$$

Here U is a capacity energy, and u is an energy density.

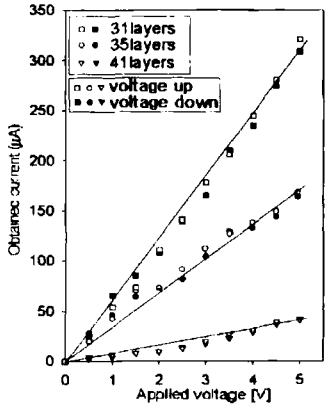

FIGURE 3. I-V characteristics of Au/PI/Au structure.

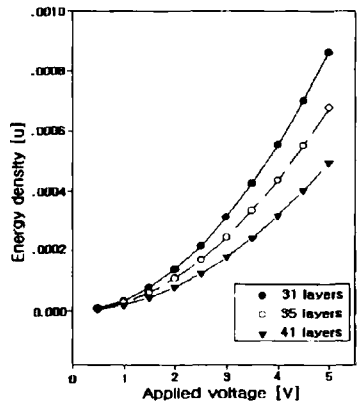

FIGURE 4. Relation of energy density and supply voltage.

Fig. 4 shows the relationship between the supply voltage and energy density by Eq. (4), (5). We are known that the resistance for the number of accumulated layers and the energy density for input voltage show desired results, and the insulation properties of a thin film is better as the distance between electrodes is larger.

CONCLUSION

We give pressure stimulation into organic thin films and detect the induced a displacement current, then manufacture a device under the accumulation condition that the state surface pressure is 13[mN/m]. In processing of a device manufacture, we can see the process is good from the change of a surface pressure for organic thin films and transfer ratio of area per molecule.

The structure of manufactured device is Au/polyimide(PI)/Au, the number of accumulated layers is 31, 35 and 41. The I-V characteristic of the device is measured from 0 to +5[V]. The maximum value of measured current is increased as the numbers of accumulated layers are decreased. The energy density for input voltage show desired results, and the insulation properties of a thin film is better as the distance between electrodes is larger.

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