A Study on the Electrical Physical Properties of Organic Thin Films for Manufacture in Power Device

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Monolayers of lipids on a water surface have attracted much interest as models of biological membranes, but also as precursors of multilayer systems promising many technical applications. Until now, many methodologies have been developed in order to gain a better understanding of the relationship between the structure and function of the monolayers. Maxwell displacement current (MDC) measurement has been employed to study the dielectric property of Langmuir-films. MDC flowing across monolayers is analyzed using a rod-like molecular model. A linear relationship between the monolayer compression speed α and the molecular area A_m. Compression speed α was about 30, 40, and 50 mm/min. Langmuir-Blodgett(LB) layers of Arachidic acid deposited by LB method were deposited onto slide glass as Y-type film. The structure of manufactured device is Au/Arachidic acid/Al, the number of accumulated layers are 9~21. Also, we then examined of the Metal-Insulator-Metal(MIM) device by means of I-V. The I-V characteristics of the device are measured from -3 to +3 V. The insulation property of a thin film is better as the distance between electrodes is larger.

Keywords : Maxwell displacement current (MDC), Langmuir-films, MIM device

1. 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.. Many researchers have investigated the electrical properties of monolayer and multiplayer films[1,2].

Before grasp electrical and electronic properties, that observe surface structure of LB film and grasp the properties is important.

Insoluble monolayers on water surface exhibit various phases, and they are interesting as two-dimensional and interfacial system in the fields of physics, chemistry and electronics.

In this paper, we give pressure stimulation into organic thin films and then manufacture a device under the accumulation condition that the state surface pressure is 2, 10, 30 mN/m(gas state, liquid state, and solid state). The physicochemical properties of the LB films on the surface of pure water are studied by AFM[3]. Also, we then examined of the Metal-Insulator-Metal(MIM) device by means of I-V.

2. ANALYSIS

Figure 1 shows a model of a floating monolayer on a water surface. For simplicity, we confine our discussion to monolayers in the isotropic polar orientational phase. Briefly, the monolayer consists of rodlike polar molecules with a length l. Each molecule has a permanent electric dipole moment μ in the direction along the molecular long axis, and it stands at a tilt angle θ away from the normal direction to the water surface. The motion of rodlike polar molecules is restricted within $0<\theta<\theta_A$, where $\theta_A = \sin^{-1}\sqrt{A/A_0}$ $(A_0 = \pi l^2)$.

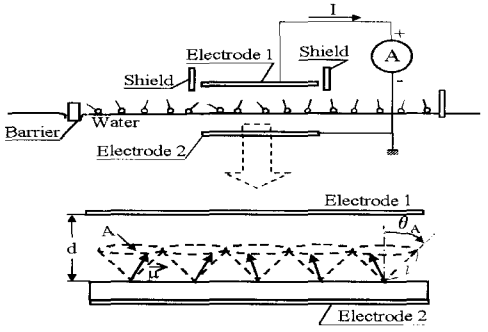


Fig. 1. Molecular model on the water surface.

Here A is the molecular area and A_0 is the critical molecular area. The monolayer film is sandwiched between electrodes 1 and 2.

Electrode 1 is suspended in the air parallel to and at a distance d from the water surface. The orientational order parameter S (t) of the organic monolayers on electrode 2 is given by

$$S(t) = \int_{\theta}^{\theta_A} \cos\theta f(\cos\theta, t) \sin\theta d\theta \tag{1}$$

Here $f(\cos\theta, t)$ denotes the orientational distribution function at $t=t$.

Assuming that the orientational motion of molecules satisfies the Debye-Brownian motion equation, we obtain the following rate equation.

$$\frac{d}{dt}(S(t) - S_{eq}) = -\frac{S(t) - S_{eq}}{\tau} + \frac{1 - <\cos^2\theta>}{\xi} RU(t) \tag{2}$$

Here $\tau$is the dielectric relaxation time of monolayer films, and given by

$$\tau = \frac{\xi}{kT} \frac{<(\cos\theta - <\cos\theta>)^2>}{1 - <\cos^2\theta>} \tag{3}$$

Where < > represents the thermal average, k is the Boltzmann constant, ξ is the frictional constant of monolayer, R is the external stimulation, and $U(t)$ is a step function.

In the MDC measurement, monolayers are compressed at a monolayer compression speed of α from the molecular area $A = A_i$. Electronic charges are induced on electrode 1 due to the presence of polar molecules on the water surface, and the magnitude of these electronic charges by monolayer compression. As a result, MDC flows through an ammeter. MDC is expressed as

$$MDC = I = -K \frac{d}{dA} \left(\frac{S}{A} - \frac{S_{eq}}{A_i} \right) \tag{4}$$

with $K = \frac{\alpha\mu}{d} B$. Here B is the working area of electrode 1. Therefore the following relation is easily obtained by integrating the MDC with respect to the molecular area

$$\frac{S}{A} - \frac{S_{eq}}{A_i} = -\frac{1}{K} \int_{A_i}^{A} I dA \tag{5}$$

Substituting Eq. (5) into Eq. (4), the following equation is obtained

$$I = \frac{1}{\tau\alpha} \int_{A_i}^{A} I dA + K \frac{S_f}{\tau\alpha} - \frac{1}{A} \int_{A_i}^{A} I dA \tag{6}$$

assuming $S_{eq}(A_i) = 0$. It should be noted here that rod-like polar molecules lie on water surface at the molecular area $A > A_0$, due to the Coulomb attractive force working between polar molecules and the water surface. That is $S_{eq}(A_i) = 0$ for $A > A_0$. Usually in the MDC measurement, the monolayer compression starts at $A = A_i > A_0$. At the molecular area $A = A_m$ MDC reaches maximum, therefore $dI/dA = 0$ at $A = A_m$. The dielectric relaxation time τ(A) of monolayers can be determined as a function of the molecular area[4].

3. EXPERIMENT

Chemical structure of a AZ-G4 monomer shows in Fig. 2. Monolayers of arachidic acid were spread from dilute chloroform solutions (0.5 *mmol*) onto the surface of pure water. The working area of electrode 1 was 45.6 cm^2. The distance d between electrode 1 and the water surface was 1 mm. The displacement current I was measured by an electrometer (Keithley 6517).

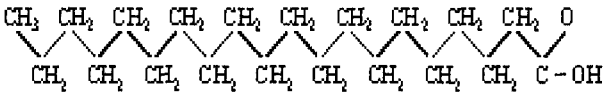


Fig. 2. Molecule structures of arachidic acid.

Arachidic acid was spread on pure water(pH 6.0, 18.2 MΩ cm) and maintained at 20 °C. After a monolayer was rested for 5 minutes, the monolayer was compressed at a compression speed of 30, 40, 50 mm/min. MDCs were measured during monolayer compression.

The AFM observations have been done with an AFM(Digital Instrument Nano Scope III) along with estimation of surface roughness.

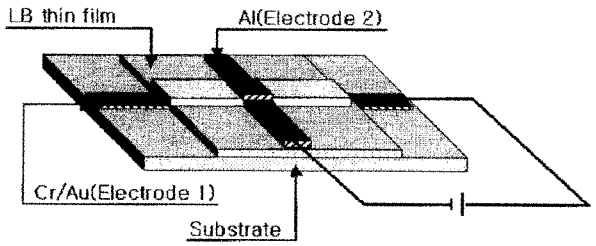
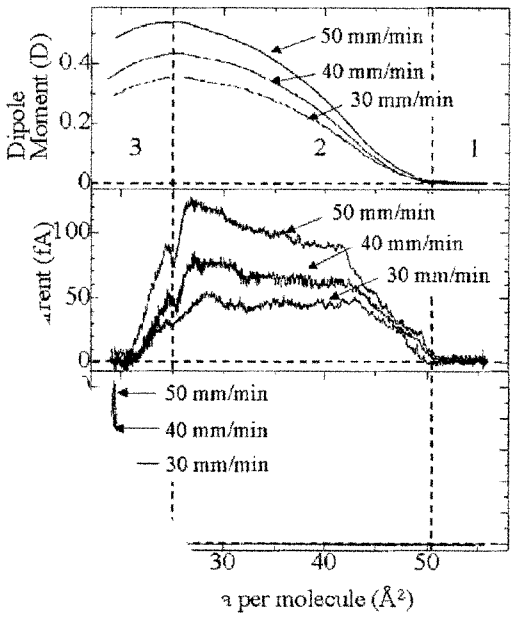


Fig. 3. Structure of MIM.

LB layers of Arachidic acid deposited by LB method were deposited onto slide glass as Y-type film. The structure of manufactured device is Au/Arachidic acid/Al, the number of accumulated layers are 9~21. Also, we then examined of the Metal-Insulator-Metal(MIM) device by means of I-V. The I-V characteristics of the device are measured from -3 to +3 V.

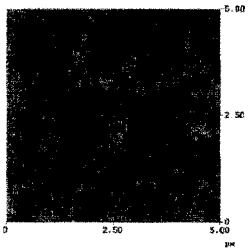
4. RESULT AND DISCUSSION

Figure 4 shows a typical example of MDCs, where MDCs were initiated to flow at the molecular area $A=A_0$, due to the phase transition from the isotropic planar alignment phase on water surface (Range 1) to the polar orientational isotropic phase (Range 2). MDC peaks appear in the range of molecular area A between 51 and 25 $Å^2$(Range 2) by monolayer compression. We plotted the vertical component $m_z(=\mu S)$ of the dipole moment of monolayers determined by Eq. (5), assuming $S_{eq}(A_i)=0$.

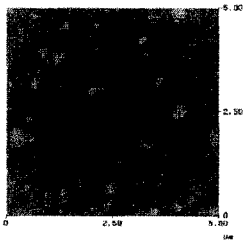


ier compress.

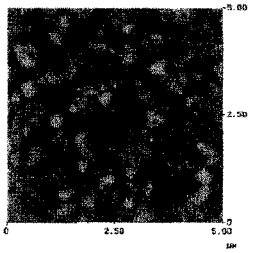
Figure 5 shows a surface mor
acid films obtained with the AFM
consists of 5 μm. The stable images ar
strong interaction between the monolay
substrate. We are unable to obtain molecu
images of the films but did see a ma
between images of the bare substrate and tho
network structure film deposited onto it. Form
prevent when gas phase state and liquid pha
measure but could know organic matter that mol
form equal and stable film when molecules were distributed evenly, and accumulated in solid state only.



(a) 2 mN/m



(b) 10 mN/m



(c) 30 mN/m

Fig. 5. AFM image by surface pressure.

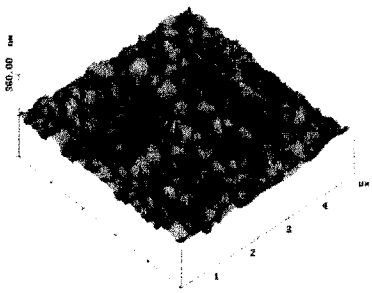


Fig. 6. AFM image.

Figure 6 shows roughness result of LB film surface that deposition by solid state. Distinction of molecule border side was not clear, and could know that roughness appears greatly. Also, Image of LB film could know that is displaying very big and irregular form.

Figure 7 shows Y-type 21layer when do deposition for surface pressure and area per molecule by time measure. Compressed 30 mN/m that is deposition condition and surface pressure is regulated minutely approaching to deposition condition, dipper can see as board doing up, down stroke action that molecules are changed. Could know organic molecular film changed well in board seeing that decrease from of possession area per molecule shows lineally on water surface.

Figure 8 is I-V characteristics that approve voltage to Cr-Au/Arachidic acid/Al device that deposition each 9, 13, 17, 21 layers and is detected. we then examined of the Metal-Insulator-Metal(MIM) device by means of I-V. The I-V characteristic of the device is measured from -3 to +3 V. In figure, current about voltage, deposition number of layer is much, could know that appear as size of current that happen in equal apply voltage is small. Also, deposition layer is small, increased with exponential function, if thickness great, curved line expressed direct ohmic characteristics. This is the insulation property of a thin film is better as the distance between electrodes is larger.

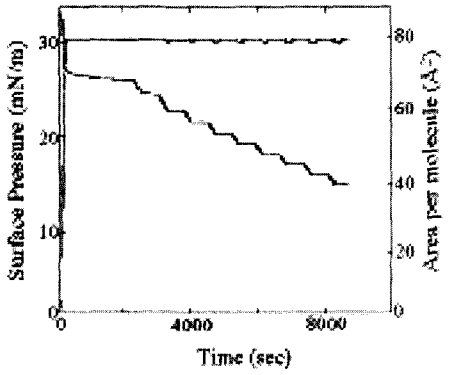


Fig. 7. Deposition of transfer ratio.

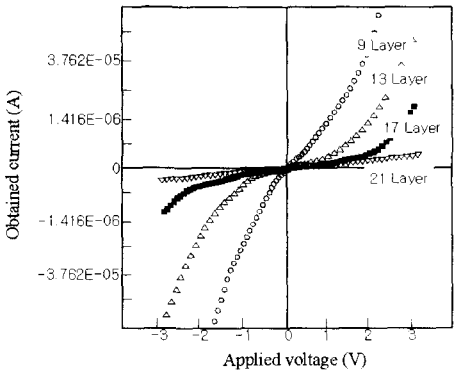


Fig. 8. I-V characteristics.

4. EQUATIONS

The LB films during barrier compression with the initial rise in surface pressure. The surface pressure change was generated at A=24 $Å^2$ and see gas state(56-24 $Å^2$), liquid state(24-20 $Å^2$), solid state(20-19 $Å^2$). We give pressure stimulation into organic thin films and then manufacture a device under the accumulation condition that the state surface pressure is 2, 10, 30 mN/m(gas state, liquid state, solid state).

The stable images are probably due to a strong interaction between the monolayer film and glass substrate. Formation that prevent when gas phase state and liquid phase state measure but could know organic matter that molecules form equal and stable film when molecules were not distributed evenly, and accumulated in solid state only.

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