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Electrical Properties for Insulation Layers of Phenolic Polymer Thin Films

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We have fabricated the crosslinked Langmuir-Blodgett (LB) films using amphiphilic phenol, p-hexadecoxyphenol (p-HP), which can form polyion complexation with formaldehyde at the air-water interface. The conductivities of p-HP LB films are as follows: heat-treatment of 1% formaldehyde subphase (3.76×10^{-15}~4.76×10^{-15} S/cm)<1% formaldehyde subphase (7.36×10^{-15}~8.34×10^{-15}S/cm)<pure water (1.33×10^{-14}~1.74×10^{-14}S/cm). Also, relative dielectric constants of p-HP LB films were reduced from 5.76~8.23 (pure water) to 2.47~2.73 (heat-treatment of 1% formaldehyde subphase).

Keywords: LB method; crosslinking; conductivity; dielectric constant

INTRODUCTION

As the present trend in microelectronics is to make devices and other components smaller in size, faster in response, and higher performances in output, the demand on both materials and the fabrication process becomes more crucial. Particularly, there is growing interest in the use of organic polymers either to supplement or to replace inorganic materials for insulation and passivation in terms of planarization, surface cracking, dielectric behavior, thermal stability, and reliability[1].

In this paper, we fabricated insulating thin films using amphiphilic phenol, p-hexadecoxyphenol(p-Hp), which can form polyion complexation with formaldehyde at the air-water interface. Also, the possibility for insulation layers of electronic devices was investigated from the conductivity and relative dielectric constant measurements.

EXPERIMENTAL

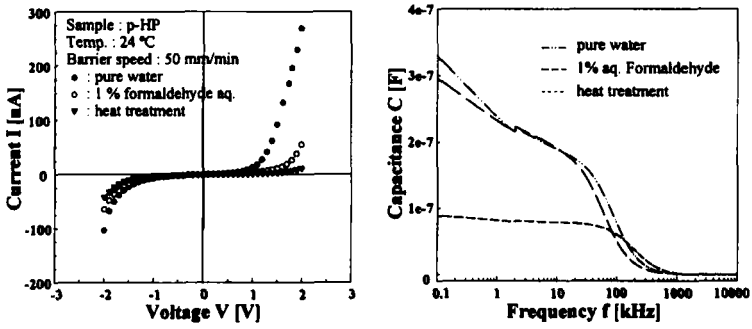
Thin films of p-HP, amphiphilic phenolic polymer, formed from phenol-formaldehyde resin of crosslinked structure from reaction with formaldehyde were prepared from LB method described in our previous works[2]. Metal/Insulator/Metal (MIM) structures were fabricated by evaporation under vacuum conditions (6×10^{-5} Torr) using aluminum as an electrode material and the current and capacitance were measured using a Keithley 6517 electrometer and an impedance analyzer (HP 4192 LF), respectively[3].

RESULTS AND DISCUSSION

Figure 1(a) shows current-voltage (I-V) characteristics of 2 layers LB films deposited in the pure water (PW) and 1% aqueous formaldehyde (1AF), and heat-treated 1AF LB films (H1AF). Heat treatment of LB films deposited in the 1AF worked for 24 hours in a vacuum in order to improve crosslinking reaction. The values of current in the same applied voltage was as follows: PW>1AF>H1AF.

Figure 1(b) shows the variation of capacitance with frequency measured for MIM structures with PW, 1AF, and H1AF at room temperature. The value of the capacitance gradually decreases with the increase in frequency and remains at an almost constant value at higher

frequency for all MIM structures.



(a) (b)

FIGURE 1. (a) current-voltage (I-V) characteristics and (b) capacitance-frequency (C-F) characteristics of p-HP LB films

Table 1 lists values of the conductivity and relative dielectric constant of p-HP LB films using capacitance for the low frequency (1~10kHz) in Figure 1. The reduction in the values of both the capacitance and relative dielectric constant observed after heat treatment is considered to be due to the change structure by a higher degree of crosslinking of the LB films.

TABLE 1. Conductivity and relative dielectric constant of p-HP LB films.

Condition	Conductivity	Relative dielectric constant
PW	1.33×10^{-14} ~ 1.74×10^{-14} S/cm	8.36 ~ 9.05
1AF	7.36×10^{-15} ~ 8.34×10^{-15} S/cm	7.76 ~ 8.23
H1AF	3.76×10^{-15} ~ 4.76×10^{-15} S/cm	2.47 ~ 2.73

CONCLUSION

In conclusion, we have provided evidence for the high insulating performance of phenol-formaldehyde thin films by the LB method. Conductivity of their LB films was as follows: pure water > 1 % aq. Formaldehyde > heat treatment, in the current-voltage (I-V) characteristics. It is demonstrated that insulation properties of crosslinked p-HP LB films were improved. In capacitance-frequency properties, the heat-treated p-HP LB films for crosslinking showed a low relative dielectric constant.

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