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P7-1

Fabrication and Electrical Properties of Dendrimer LB Films Base on Metal Complex

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1. Introduction

Currently, device miniaturization and highly integrated circuit design is of major interest for the development of electronic devices. Various studies have been conducted to develop new materials and processing techniques [1]. A research area, which has obtained increasing interest during the last decade concerns improvement of the macromolecular properties by changing the macromolecular architecture. One of the most peculiar characteristics of dendritic macromolecules is their controlled molecular structure and orientation, which means that they have a practical application in achieving a highly organized molecular arrangement [2]. It is obvious that any molecular device to have uniform and well-defined properties must consist from molecules, which is arranged in a well-ordered configuration. Also, the monolayers and Langumuir-Blodgett (LB) film of dendrimers have been studied extensively [3, 4].

In this paper, we attempted to fabricate a G4-48PyP dendrimer Langmuir-Blodgett films containing 48 pyridinepropaneol functional end group that could form a complex structure with metal ions. We investigated the surface activity of dendrimer films at air-water interface. The electrical properties of the ultra-thin dendrimer LB films were investigated by studying the current-voltage (I-V) characteristics of metal/dendrimer LB films/metal (MIM) structure. Thus, the investigation of the electrical properties of LB films of G4-48PyP is important for their potential use in molecular electronic nanodevices.

2. Experimentals

The dendrimer containing 48 pyridinepropanol was synthesised by the use of siloxanetetramer (2,4,6,8-tetramethyl-2,4,6,8-tetravinylcyclotrtrasiloxane,($(CH_2=CH)MeSiO)_4$) as the core molecule, hydrosilation with $HSiMe_nCl_{3-n}$ and alcoholysis with allylalcohol. By the two alternative processes, hydrosilation and alcoholysis, the dendrimer carried out up to the fourth generation with 48-Cl on the periphery. And then, G4P-48-Cl dendrimer was terminated with 4-pyridinepropanol. Final compound, G4-48PyP has 48-pyridinepropanol on the outermost periphery of dendrimer (Fig. 1). As the pyridinepropanol functional group has the property of Lewis base on nitrogen atom, it formed complex with metal ions easily. The LB films were transferred onto slide glass for measurement of electrical properties. For the electrical properties of the LB films, an upper aluminium(Al) electrode was deposited on the film surface by using the vacuum evaporation method to form a Al/dendrimer LB films/Al sandwich structure. A DC power supply and a HP 3458A Multimeter were used to measure the I-V characteristics.

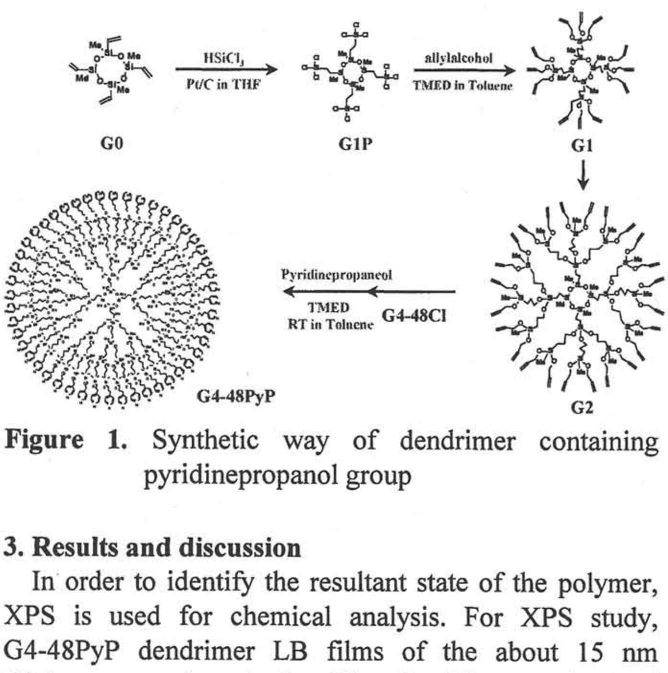

Figure 1. Synthetic way of dendrimer containing pyridinepropanol group

3. Results and discussion

In order to identify the resultant state of the polymer, XPS is used for chemical analysis. For XPS study, G4-48PyP dendrimer LB films of the about 15 nm thickness were deposited on Si wafer. We were observed in the XPS data for Fe complex dendrimer. Therefore the functional end group of dendrimer is combined with Fe^{2+} ions. Also, Fe^{2+} ion is contributed to cross-linking or branching reaction between dendrimers.

The electrical properties of dendrimer LB films were investigated by measuring the leakage current I versus applied voltage V, which is shown in Fig. 2. The I-V characteristics show the symmetry. In the forward bias direction, there is a suppression of the current up to about 1.0 V after which the current starts to increase. The forward currents follow approximately an exponential trend. The devices fabricated with Fe^{2+} ions had larger current values than pure G4-48PyP dendrimer. The calculated conductivity σ values of pure G4-48PyP dendrimer and its complexes with Fe^{2+} ions are 9.56×10^{-16} and 1.46×10^{-14} S/cm, respectively. And those phenomena can be explained through the effect of metal ions. In conclusion, it is demonstrated that the metal ion around G4-48PyP dendrimer can contribute to make formation of network structure among dendrimers and it result from the change of electrical properties.

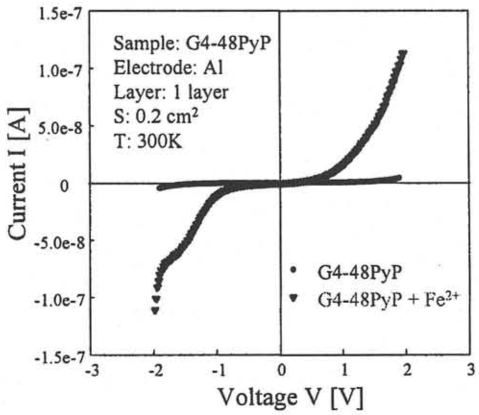

Figure 2. I-V characteristics for LB film of pure G4-48PyP dendrimer and its complex with Fe^{2+} ions

The current density-voltage (J-V) behavior of Schottky barrier devices is usually assumed to follow the standard thermionic emission theory for conduction across the junction [5]. The current increases exponentially in the forward bias region. In applying this theory to the present system, the current assumed to be controlled by the transfer of carriers across the interface of the Al/dendrimer monolayer, and the drift and diffusion of carriers within the depletion region are assumed to be unimportant. In the Fig. 3, linear relations are observed for the devices fabricated with pure G4-48PyP dendrimer and its complexes with Fe^{2+} ions, which suggest the formation of a Schottky barrier. The calculated barrier height ϕ_b values of pure G4-48PyP dendrimer and its complexes with Fe^{2+} ions are 1.18 and 1.10 eV, respectively. Generally, ϕ_b is proportional to the bandgap (E_g) of the semiconductor. The material with the smaller E_g has a higher conductivity under the same conditions. The conductivity of its complex with Fe^{2+} ions had larger than that of pure G4-48PyP according to the experimental results. It is demonstrated the effect of complex with metal ions.

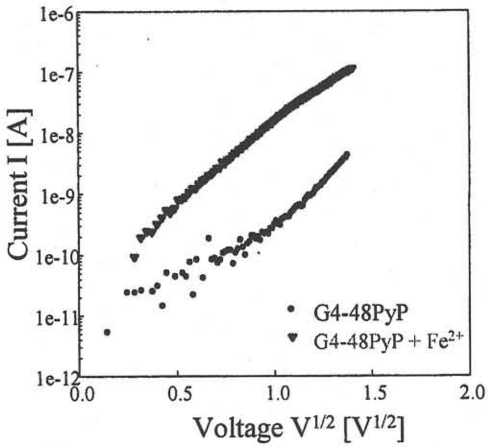

Figure 3. Schottky plot for LB film of pure G4-48PyP dendrimer and its complex with Fe^{2+} ions

4. Conclusions

We attempted to fabricate a ultra-thin dendrimer LB films containing 48 pyridinepropanol end group. That could form a complex structure with metal ions. In this study, the samples for electrical measurement were fabricated to two types, that is, pure G4-48PyP dendrimer and its complex with Fe^{2+} ions. The calculated conductivity σ values of pure G4-48PyP dendrimer and its complexes with Fe^{2+} ions are 9.56×10^{-16} and 1.46×10^{-14} S/cm, respectively. And the calculated barrier height ϕ_b values of pure G4-48PyP dendrimer and its complexes with Fe^{2+} ions are 1.18 and 1.10 eV, respectively. In conclusion, it is demonstrated that the metal ion around G4-48PyP dendrimer can contribute to make formation of network structure among dendrimers and it result from the change of electrical properties.

Acknowledgments

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