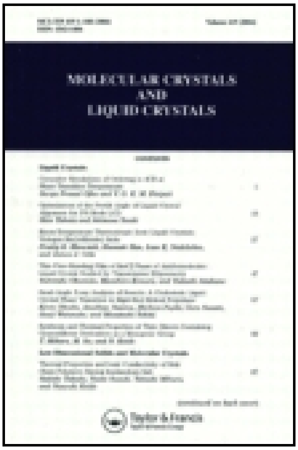

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Formation of Polypyrrole Fine Wires by "Electropolymerization LB Technique"

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FORMATION OF POLYPYRROLE FINE WIRES BY "ELECTROPOLYMERIZATION LB TECHNIQUE"

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Abstract Electrically conducting wire of 0.5μm width and of 50μm length was formed over the electrically insulation gap formed on the ITO substrate by "electropolymeriation LB technique"; the combination of elctropolymerization of conducting polymer and the deposition of Langmuir-Blodgett films. The conductivity of the wire was estimated to be about 200S/cm from the I-V characteristics and the value was not inferior to the reported conductivity of the electrochemically polymerized polypyrrole film.

INTRODUCTION

Forming electrodes on ultra-thin organic films or connecting other components to it often poses significant problems when developing products that utilize these materials. Especially, for fabrication of devices using Langmuir-Blodgett (LB) films, it is very important to develop electrodes[1] or wires which do not cause damage to the LB films. A damage free method which allows the formation of electrodes or provides reliable means of attaching wires to ultra-thin organic film is essential for the development of molecular electronic devices.

We proposed a new method for forming wires in LB films [2] : during transference of Langmuir film containing pyrrole (Py) to a substrate, the Py monomers electropolymerized under application of a voltage. We call this method " electro-polymerization LB technique". This method is the combination of LB film formation and electropolymerization of conducting polymer. In this study, a voltage was applied for three different lengths of time. The results were that highly conductive polypyrrole (PPy) wires were formed across an insulation gap using the proposed technique.

EXPERIMENTAL

The experimental setup of the two electrode system for the fine wire formation on a LB trough is shown in Fig.1. A Pt plate was used as the counter electrode. The distance between the counter electrode and the LB film substrate (working electrode) was10mm and the counter electrode was inserted into the water subphase at a slant.

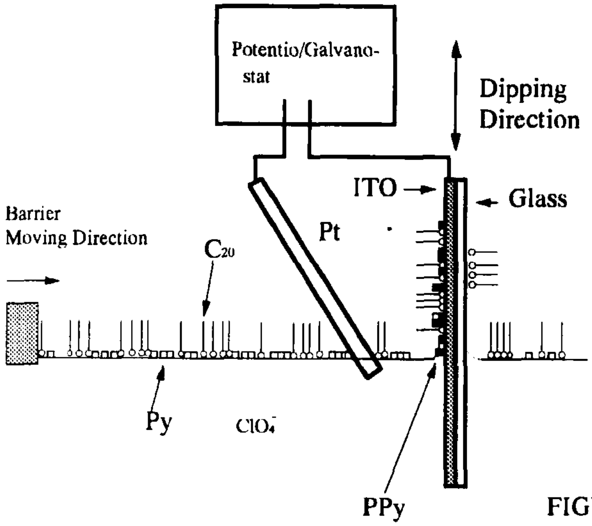

FIGURE 1 The experimental setup for the "electropolymerization LB technique".

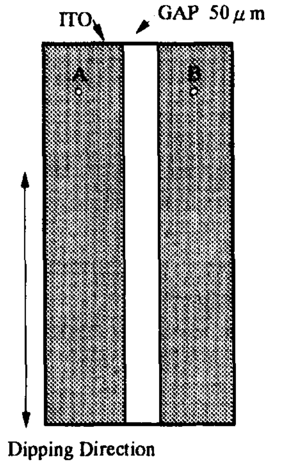

FIGURE 2 A diagram of an ITO substrate with an insulating gap of about 50μm created using photo-lithography.

The electrical resistivity of the water used for the subphase was 18 MΩcm.

The spreading solution was a benzene solution which contained 10% ethanol, 5mM arachidic acid (C_{20}) and 150mM Py. Furthermore, 75mM lithium percholate ($LiClO_4$) was added to the solution as a supporting electrolyte for electrochemical polymerization of Py and as a dopant for PPy.

The applied voltage for the electropolymerization was 7 volt. For the LB film substrate, we used the special patterned ITO substrate by photolithography as a working electrode which is shown in Fig.2. In this figure, the electrically insulation gap in the center of the substrate was 50μm width and the 2mm length.

For the electropolymerization, we did not applying voltage while the substrate is moving, then stop the movement at every bottom position and continue polymerization for 10 minutes.The velocity of the dipper of the substrate was 10mm/min.

RESULTS & DISCUSSIONS

The micrograph of the conducting wire formed by the "electropolymerization LB technique" was shown in Fig.3. This micrographs shows that fine wire of the PPy was formed over the insulation gap like bridges. In this figure, the wires which stopped growth part of the way were also shown in the same photograph. The extent of the position which the wires were formed was almost limited within 200μm every time, which is the width from the left to the right of this micrograph. Since the thickness of the Pt counter electrode was 100μm, it is considered that the Py monomers were gathered around the width of the electric field produced by the electrodes. It was certain that the bridge like PPy wires were formed within the extent every time, however, the precise positions of the wires could not be decided. We consider that the position of the wire which reached on the other side was the place where the enough Py monomers were supplied during electropolymerization.

A filed emission scanning electron microscope (FESEM) image of one of the wires ,which is shown in Fig.2 as "A", is shown in Fig.4. As is seen in Fig.3,the PPy wire was formed from an aggregation of lumps of PPy which were grown intermittently.

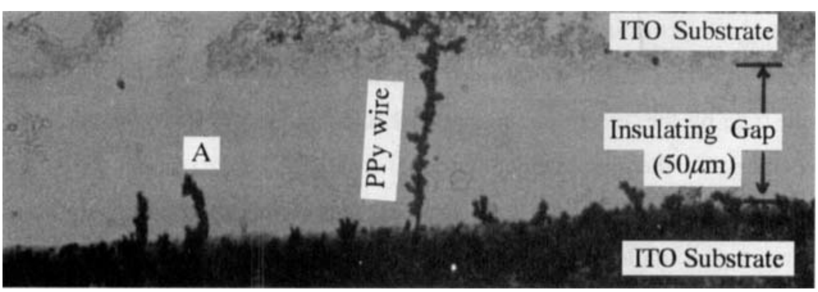

FIGURE 3 Micrograph of the conducting polymer PPy wires formed by electropolymerization LB technique.

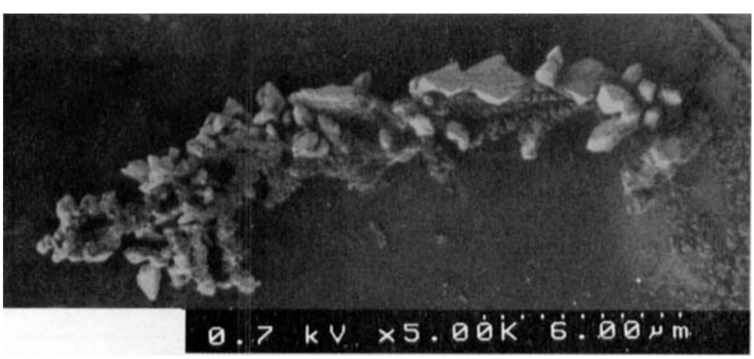

FIGURE 4 FESEM image of one of the wires shown in Fig.3 as "A".

I-V characteristics of the wires of conducting polymer PPy were shown in Fig.5 .It was found that the longer the polymerization time, the higher the electrical conductivity of the poly-Py wire. The electrical conductivity was 200S/cm. Though the value falls behind the value of 10^5S/cm,which was reported for the poly-acetylene film[3], it is typical for the reported value, 100-500S/cm, of the electropolymerized poly-Py film[4].

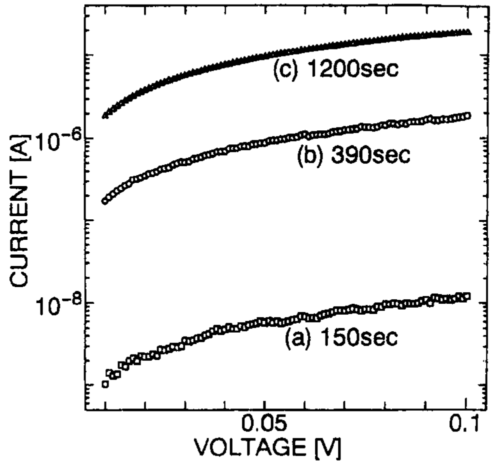

FIGURE 5 I-V characteristics of the wires formed by electropolymerization LB technique.

CONCLUSION

From this study,we concluded as follows. (1). Electrically conducting PPy wire of 0.5 μm width and of 50μm length was formed over the electrically insulation gap formed on the ITO substrate by the "electropolymeriation LB technique". (2)The conductivity of the wire is dependent on the time of electropolymerization.(3).The maximum conductivity of the wire was estimated to be about 200S/cm. (4). This technique is promising for wiring or integrating organic molecular devices since it can be utilize at room temperature ,under the normal pressure and can produce damage-free electrodes for ultra-thin organic films.

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