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Photolithographic Patterning of Electrically Conducting Polypyrrole Film

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Photolithographic Patterning of Electrically Conducting Polypyrrole Film

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The micro-patterns of electrically conducting polypyrrole (PPy) with line width as low as 30 μm have been successfully achieved using a photolithographic method. PPy as a conducting pattern was chemically polymerized within the poly (vinyl alcohol) (PVA) matrix layer where ferric *p*-toluenesulfonate as an oxidant was embedded in a designed architecture. Surface resistivity and transmittance at 600 nm of PPy regions were in the range of $10^3 \sim 10^5$ Ω/□ and 50% ~ 90%, respectively. The resistances of PPy patterns were in the range of $10^4 \sim 10^6$ Ω, which is lower than that of PVA region by about 10^{10} times.

Keywords Electrically conducting polypyrrole; Micro-patterning; Photolithography

INTRODUCTION

Electrically conducting polypyrrole (PPy) has been considered as a promising material for many applications because of high electrical

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conductivity, ease of synthesis, and good environmental stability. However, PPy is, in general, insoluble and infusible and thus hardly deformable or shapeable, having limited its practical application [1,2].

In this study, we report a new route to fabricate patterns of electrically conducting polymers on an electrically insulating substrate using a photolithographic method and investigated properties of the patterns.

EXPERIMENTAL

Oxidant-incorporated PVA layers were prepared on glass substrates by spin-coating aqueous solution of ferric *p*-toluenesulfonate (FTS) and PVA. They were exposed to UV (365 nm) with the intensity of 10 mW/cm^2 for 5 ~ 10 minutes through a photomask. We observed a dramatic reduction of absorption peak at 350 nm of the UV-exposed region in the oxidant layer, indicative of the photodegradation of FTS upon UV irradiation [3]. The patterned oxidant film was then exposed to pyrrole vapor, resulting in polymerization of pyrrole only on the unirradiated area.

RESULTS AND DISCUSSION

As shown in Figure 1, surface resistivity and transmittance at 600 nm of PPy films with the thickness of 0.5 ~ 1 μm were in the range of 10^3 ~ 10^5 Ω/□ and 50% ~ 90%, respectively. Both the surface resistivity and the transmittance decreased with the increase of the oxidant concentration in FTS/PVA layers. It indicates that the polymerization of pyrrole occurred homogeneously within the oxidant layers and thus the PPy content in the matrix film increased with the increasing oxidant concentration.

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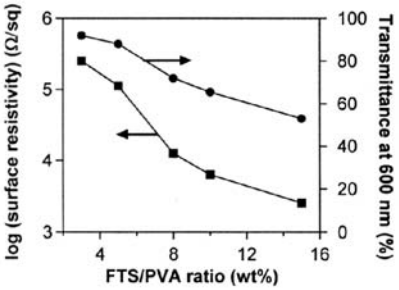

FIGURE 1. Surface resistivity and transmittance of PPy films as a function of the oxidant concentration.

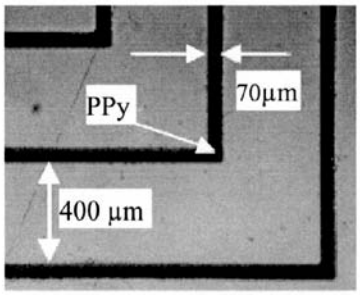

FIGURE 2. Optical microscopic image of PPy patterns.

Figure 2 shows the optical microscopic image of PPy patterns prepared using a photomask with the line width of 70 μm. It can be observed that a good-quality pattern of PPy was achieved by the polymerization of pyrrole only on the unirradiated area. In fact, we have successfully obtained patterns with line width as low as 30 μm. Since the resistivity of PVA region is higher than that of PPy layer by about 10^{10} times, we believe the intervening PVA region is able to work as an insulating barrier.

Table 1 shows the resistances of PPy patterns with the line dimension of 80 μm × 1 cm as a function of oxidant concentration. The decrease in the resistance with the increasing oxidant concentration must results from not only increase of PPy content within PVA matrix but also thickening of the conducting pattern.

TABLE 1. Resistances of PPy patterns as a function of the oxidant concentration

FTS/PVA weight ratio	3	5	8	10
Resistance (Ω)	4.23×10^{6}	3.23×10^{6}	6.72×10^{5}	2.15×10^{5}

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As shown in Figure 3, the UV-irradiated area shows smooth surface morphology, while the UV-unirradiated area shows the rougher surface with protrusions due to the polymerization of pyrrole. We also observed that the thickness of the oxidant film was increased by 5% ~ 10% as a result of the incorporation of PPy.

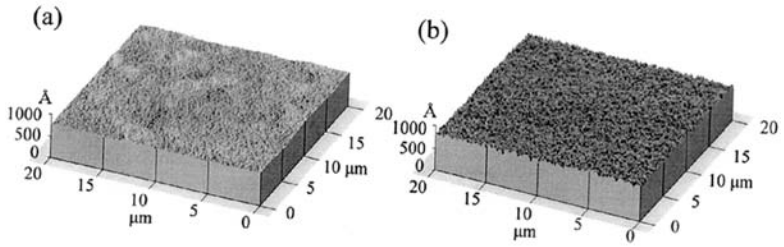

FIGURE 3. AFM image of the surface of (a) UV-irradiated area and (b) UV-unirradiated area after the polymerization of pyrrole.

CONCLUSIONS

We successfully achieved the micro-patterns of electrically conducting PPy with the line width as low as 30 μm using a photolithographic method. The electrical resistivity of the patterned PPy would be readily controlled in the range of $10^3 \sim 10^5$ Ω/□ with the oxidant concentration in the matrix layer. We were also able to obtain electrically conducting patterns of poly (3,4-ethylenedioxythiophene) (PEDOT) applying the same photolithographic method described above.

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