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# Transparent and Conductive Composite of Poly(3,4-Ethylenedioxythiophene) and Silica Sol-Gel Materials

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# Transparent and Conductive Composite of Poly(3,4-Ethylenedioxythiophene) and Silica Sol-Gel Materials

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A novel transparent and electrically conductive polymer composite has been prepared by using conductive poly(3,4-ethylenedioxythiophene) (PEDOT) and inorganic silica network. In this composite, a conducting PEDOT was incorporated in order to impart the excellent conductivity and the transparency, and an inorganic silica network provided good mechanical properties. In order to achieve the facile composite formation, PEDOT was polymerized during the silica network formation through the *in-situ* sol-gel process. The resulting transparent and conductive film exhibited ~200 S/cm conductivity, more than 80% transparency, and 9H pencil hardness.

*Keywords:* transparent conductive composite; PEDOT; silica; in-situ sol-gel process

## INTRODUCTION

Conducting polymers exhibit the excellent electrical properties, however, common usage of these materials has been restricted due to the lack of processability.[1] Various techniques, such as soluble conducting polymer formation using functional dopants[2] and blend or composite formation,[3,4] have been introduced to enhance the processability. The composite formation is one of the simplest ways to overcome the processing difficulty. An another drawback of conducting polymer is the limitaion of optical transparency.

Most conducting polymers, such as polypyrrole, polyacetylene, are dark black in doped state. A new conducting polymer poly(3,4-ethylenedioxythiophene) (PEDOT ), which was recently introduced by Bayer, exhibited much improved optical transparency in oxidized state[5]. In this paper, we report a novel process for transparent and conductive polymer composite film formation using PEDOT and inorganic silica network by the *in-situ* sol-gel process.

## EXPERIMENTAL

The silica sol was prepared by dissolving 10 g of tetraethylorthosilicate (TEOS) into the cosolvent of 4 g of $H_2O$ and 86 g of isopropanol. Nitric acid was added for hydrolysis catalyst and the solution pH is adjusted to be 1.5. In the composite film formation, a suitable amount of EDOT and ferric toluene sulfonate (FTS) oxidant were added into silica sol, and the mixed solution was spin cast and finally baked in convection oven for 1 hr at 130 °C for complete gellation. The resulting film was washed with *n*-butanol and deionized water to remove residual oxidants. Electrical conductivity was measured by a conventional four probe method using Keithley 236 source measure unit.

## RESULTS AND DISCUSSIONS

The electrical conductivity of the composite film is monitored as a function of reaction time. The conductivity increases linearly for initial 30 min and reaches at constant level as shown in figure 1. The increase in the conductivity is conceivable due to the PEDOT formation. So, it can be seen that the optimum reaction time for PEDOT formation is at least 30 min. The reaction time and temperature are also important for silica gel formation.

After gellation at 130℃ for 30 min, a silica hard coating with >9H pencil hardness is successfully obtained. The effect of dopants on the electrical conductivity has been also examined, however remarkable change is not observed.

A thin film of PEDOT in oxidized state is transparent with sky-blue tint, however it still absorbs visible light with the wavelength of greater than 500 nm. So, the content of PEDOT in the composite is a key factor to adjust the electrical and optical properties. As shown in Figure 2, the increase in the PEDOT content results in the increase in conductivity as well as the decrease in the optical transparency. In this experiment, the optimum weight ratio of PEDOT/silica seems to be 0.6.

In the composite formation, a silica hard coating is formed by dehydration reaction at 130 °C. For complete gellation, higher temperature is favored, however it can also degrade PEDOT. It is observed that the highest temperature for PEDOT formation is180 °C, as shown in figure 3.

The optoelectronic property of the film is examined using *in-situ* UV-Vis spectroscopy during the potentiometric redox process. It is observed that as the oxidation level increases, an absorption band at 600 nm decrease and a broad absorption band at >1000 nm increases, as shown in Figure 4. So, as the film oxidized, an absorption in the visible region decreases and that at near IR region increases which results in the enhanced optical transparency.

**Acknoledgements**

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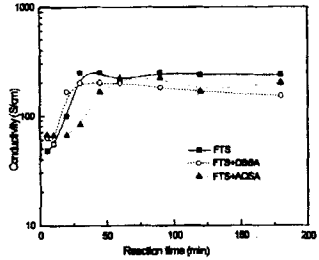


**Figure 1. Conductivity vs. Reaction time**

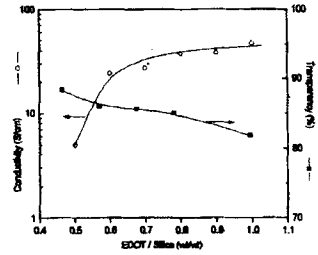

**Figure 2.Conductivity &Transpareny vs. EDOT content**

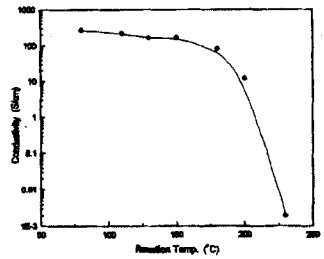

**Figure 3. Conductivity vs. Reaction Temp.**

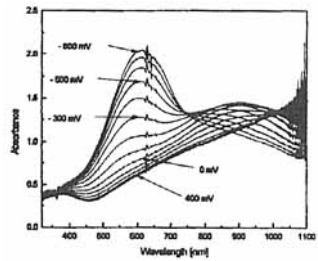


**Figure 4. UV-Vis spectra during redox process**

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