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## Uniaxial Stretching of Polypyrrole Cast Film

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Uniaxial stretching of polypyrrole (PPy) cast film significantly improved the electrical conductivity and break strength of the film in the stretching direction. The electrostatic effect of nitrogen atoms in pyrrole rings was also increased from 44% to 56% by stretching without change in the doping level. These phenomena indicate that stretching can induce more extended conformation of PPy molecules in the cast film.

### Keywords

Soluble polypyrrole; Cast film; Uniaxial stretching;  
Extended conformation

## INTRODUCTION

Chemically prepared polypyrrole (PPy) doped with dodecylbenzene sulfonic acid (DBSA) is soluble in organic solvents [1], while most conducting polymers are insoluble. Free-standing film can be cast

from the solution and stretched up to 150% elongation. This work reports the changes in electrical and mechanical properties of the PPy cast film induced by mechanical stretching of the film.

## EXPERIMENTAL

Soluble PPy was synthesized by the chemical oxidation as reported earlier using DBSA as a dopant source [1]. PPy-DBSA powder was dissolved in chloroform containing a certain amount of extra DBSA. Free-standing films with thickness of 100  $\mu\text{m}$  were prepared by casting the solution onto a glass plate. The polymer free-standing films (10 cm X 2 cm) were uniaxially stretched at a rate of 2 mm/minute in an oven maintained at 80  $^{\circ}\text{C}$ , and then the extra DBSA was removed from the film by washing with methanol. Electrical conductivity of the film was measured with van der Pauw's four probe method.

## RESULTS AND DISCUSSION

As shown in Figure 1, the break strength (21 MPa) of an unstretched PPy film increased upto 70 MPa as the elongation increased, which is higher than that of polystyrene (c.a. 50 MPa) commercially used.

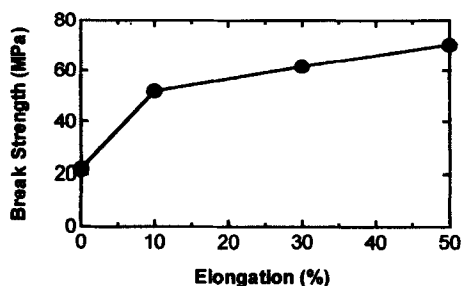


FIGURE 1. Break strength of stretched PPy cast films.

The elongation at break also increased with the elongation compared to that (0.7%) of unstretched PPy film, but did not exceed 3% owing to the very brittle nature of PPy molecule.

Figure 2 shows the ratio of the conductivity of stretched PPy film to that of unstretched film as a function of the elongation, where the conductivity of an unstretched PPy film ( $\sigma_0$ ) was 2.0 S/cm. It was observed that the electrical conductivity ( $\sigma_{||}$ ) in the stretch direction linearly increased upto by 2.5 times with the elongation, while the conductivity ( $\sigma_{\perp}$ ) in the perpendicular direction slightly decreased to a limited value. Such a linear increase in conductivity along stretch direction was also reported for other conducting polymer film such as polyacetylene [2]. It is obvious that the enhanced mechanical and electrical properties along the stretch direction resulted from the conformational change of PPy chains.

As shown in Figure 3, logarithmic conductivity parallel or perpendicular to the stretch direction of stretched PPy film showed linear relationship with  $T^{-1/2}$ , implying the conduction mechanism follows quasi-1D hopping in both directions.

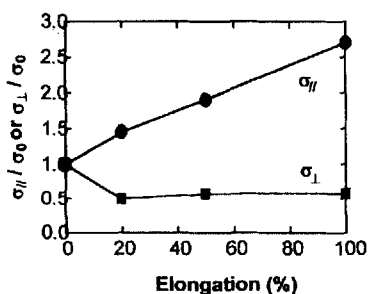


FIGURE 2. Conductivity of stretched PPy free standing films.

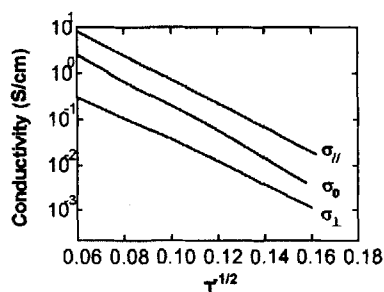


FIGURE 3. Dependence of conductivity on temperature.

XPS N1s analysis reveals that the electrostatic effect of nitrogen atoms in pyrrole rings increased from 44% to 56% by the 100% stretching, even though the dopant content in PPy-DBSA did not change at 24% as estimated by elemental analysis.

Increase in the conductivity, the break strength, and the electrostatic effect confirms that the mechanical stretching of PPy free-standing films can induce the conformational extension of PPy chains to increase the charge delocalization.

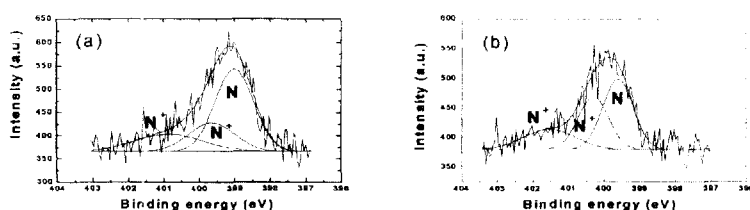


FIGURE 4. XPS N1s spectra of (a) an unstretched and (b) 100% stretched PPy cast films.

## CONCLUSIONS

Uniaxial stretching of PPy cast films induced the conformational extension of PPy molecules. In the directions both parallel and perpendicular to stretch direction, the conduction occurs following the quasi-1D hopping.

## Acknowledgment

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## References

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- [2] Y. Cao, P. Smith, and A. J. Heeger, *Synth. Met.*, **41-43**, 181 (1991).