Electronic Properties of Silk / Molecular Conductor Hybrids

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Introduction

Recent advances in oxidative growth techniques are valuable for the development of all-organic devices. Conventional electrochemistry typically results in single crystals with mm sizes. Using the oxidative approach, a film-like large array of linked single crystals can be formed on polymeric substrates. This allows the fabrication of large-area all organic devices in a simple manner. Here we report methods of integrating molecular conductors onto silk substrates. The electrical conductivity of the hybrid bilayer film is highly dependent on strain and humidity levels. Furthermore, various phases of molecular conductors can be grown to produce semiconducting or metallic networks.

Experimental

The silk bilayer film is fabricated by transferring the molecular conductor film from a parent polycarbonate substrate onto a target polymerized silk film. The strain- and humidity-dependent conductivity measurements were carried out using a commercial strain stage and environmental chamber in 4-contact configurations. Temperature dependent conductivity measurements were performed in SCM 1 Millikelvin facility at NHMFL.

Results and Discussion

The electromechanical measurements reveal a gauge factor of ~ 9. The high gauge factor, coupled with the swelling properties of the silk substrate, allows reliable relative humidity (RH) monitoring. The humidity response is completely reproducible under slow RH changes. The electronic properties of the bilayer film can be tuned from being a semiconductor into a metal by varying the phase of the crystallites network.

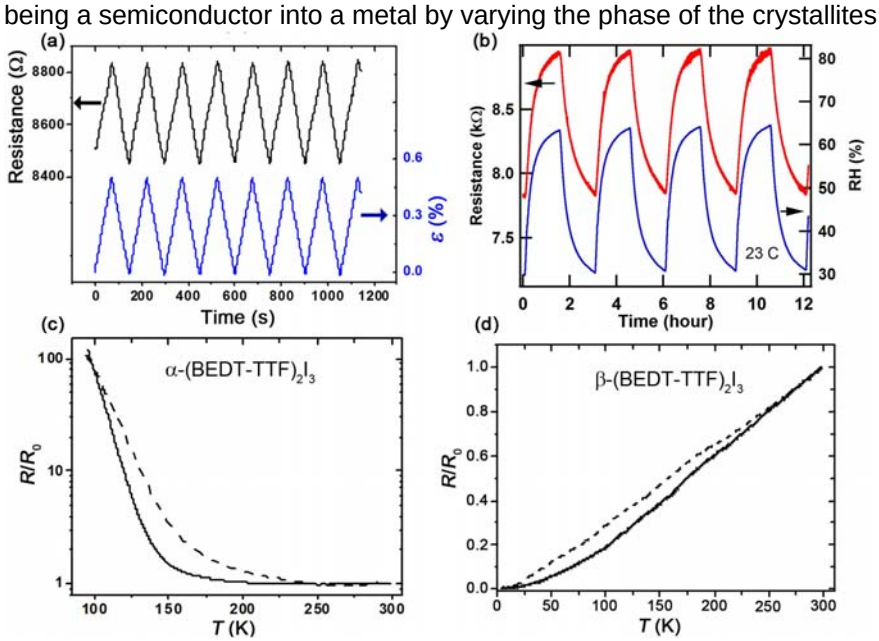

Figure 1. Electrical properties of $(BEDT\text{-}TTF)_2I_3$ / silk bilayer films. (a) Strain- and (b) humidity- dependent resistance of silk bilayer films. The humidity dependence is not observed in the pristine polycarbonate bilayer films. Temperature dependent resistance of α- and β- phased $(BEDT\text{-}TTF)_2I_3$ / silk bilayer films, showing a semiconducting and metallic behavior, respectively.

Conclusions

We have developed a simple method of fabricating silk / molecular conductor hybrids that exhibit high piezoelectric effects, humidity sensitivity, and phase-tunable electrical characteristics. Attempts to fabricate superconducting films on silk substrates are currently being explored.

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