Electron contribution to heat propagation in nanolayered PEDOT:PSS

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Abstract

In this work we investigate the effect of electrical conductivity on thermal conductivity in conductive poly(3,4-ethylenedioxythiophene):poly(styrene sulfonate) (PEDOT:PSS) layer-by-layer (LbL) thin films. We have used infrared radiometry and thermoreflectance to obtain thermal conductivity. As a result of the temperature-dependent studies, we suggest that electrons have a significant effect on thermal conductivity.

Sample preparation

Glass substrates (5×5 mm) were cleaned using acetone and isopropanol via spin coating (3500 rpm, 30 s each), then dried with air. Polymer solution was deposited and spin-coated (3500 rpm, 30 s). Samples were dried on a hot plate at 110 °C for 15 minutes. A second polymer layer was applied using the same procedure.

Molecular structure of the Material

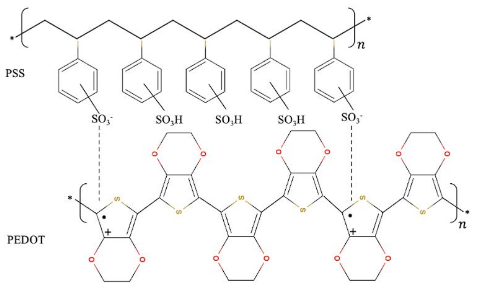

Figure 1. Molecular structure of PEDOT:PSS

Methods and Measurements

Conductivity Measurement Based on Van de Pauw Configuration:

Square samples with 4 contacts on the edges were prepared (Figure 2). Hall measurements under Van der Pauw configuration used to measure resistivity ($\rho = R.d$) of the studied samples which R is sheet resistance and d is thin film thickness. Ultimately, electrical conductivity obtained by $\sigma = 1/\rho$. The current was applied from contacts 1 to 3 and the Hall voltage was gained between contacts 2 and 4. For the temperature sweep, the sample was placed in a closed cycle cryostat with an applied magnetic field of 0.28 T.

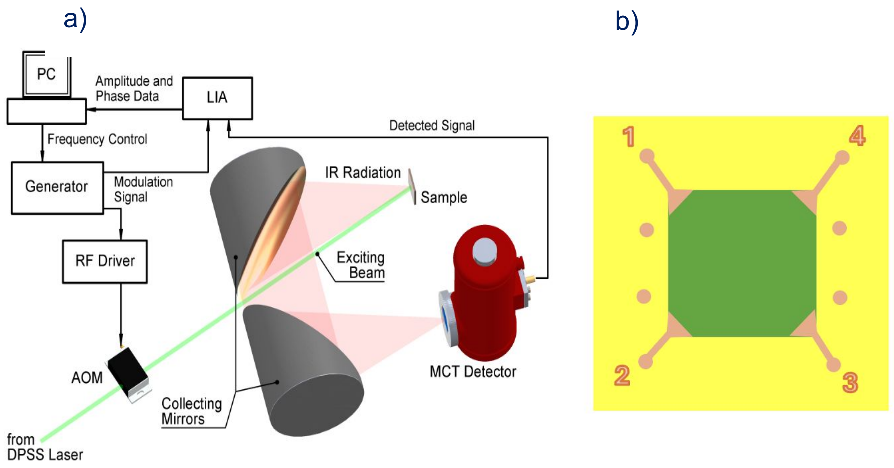

Figure 2. a) PTR setup, b) Van der Pauw configuration for 4-probe resistivity measurements

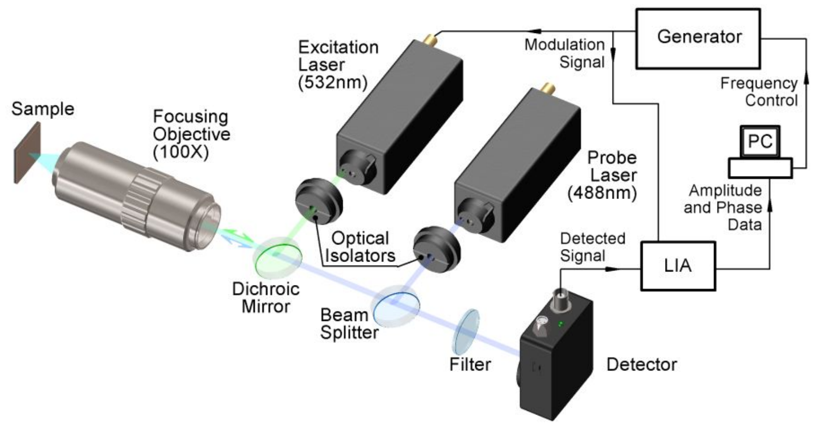

Figure 3. a) FDTR setup

Results

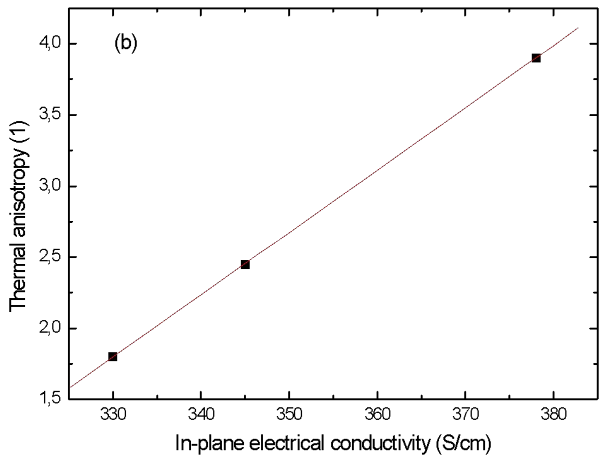

Figure 4. Thermal anisotropy of PEDOT:PSS thin films as a function of temperature.

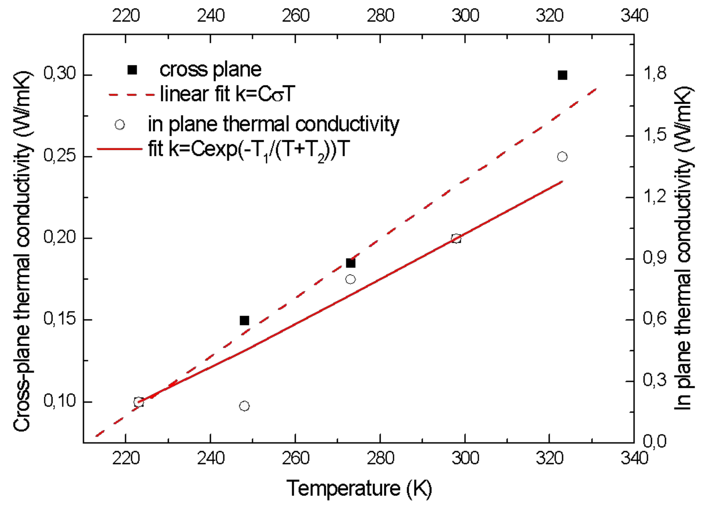

Figure 5. Temperature dependence of in-plane and cross-plane thermal conductivity for PEDOT:PSS thin films with 500 nm thickness.

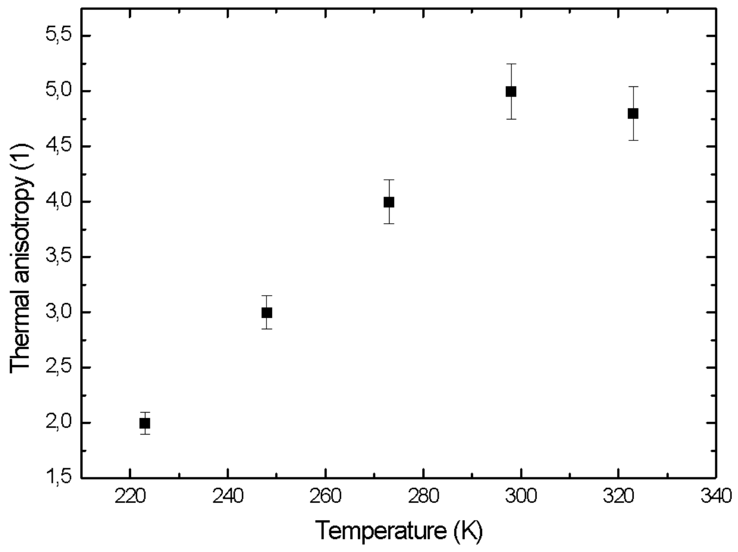

Figure 6. Temperature dependence of thermal anisotropy for PEDOT:PSS thin films with 500 nm thicknesses. .

Conclusion:

1. Thermal anisotropy increases linearly as a function of in-plane electrical conductivity.
2. Cross-plane thermal conductivity increases from 0.1 to 0.3 W/mK in the temperature range from -50 to 50 C.
3. In-plane thermal conductivity increases from 0.2 to 1.4 W/mK in the temperature range from -50 to 50 C.
4. The temperature-dependent increase in thermal anisotropy was attributed to heat conduction by the electronic component, described by K= LσT.

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