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Pentacene Thin Film Photoconductivity : Influence of the Electrode.

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Introduction

We have measured the photoconductivity action spectra for pentacene films on sapphire as a function of film thickness, using either gold or aluminum electrodes. The aim was to examine the influence of the electrode metal on the photo-generation of mobile charge carriers in organic semiconductor films.

Experimental

The apparatus is shown schematically in Figure 1. Pentacene (TCI) was sublimed in vacuum three times and once under 30 Pa N_2 gas flow before use. Single crystal sapphire [0001] substrates (Shinkosha) were first annealed at 1000 °C in air to expose atomically flat terraces, after which metal electrodes spaced 0.1 mm apart were prepared by vacuum deposition through a metal mask. Gold electrodes were 100 nm thick, with a 5 nm titanium adhesion layer. Aluminum electrodes were 35 nm thick. The substrates were degassed at 150 °C under UHV before use. Leakage currents (dark or photoconductance) were below 10 fA. Pentacene films were prepared by stepwise thermal deposition from a resistively heated crucible to a maximum film thickness of 100 nm. The substrate temperature was kept at 30 °C, and the deposition rate was constant at 2.0 ± 0.3 nm min^{-1}. After each deposition step the photocurrent was evaluated for wavelengths from 400 nm – 1180 nm, using a Bunkokeiki SM-25 monochromatic light source and a Keithley 6487 picoammeter-sourcemeter. The incident photon flux was 10^{19} photons m^{-2} and the applied bias was 10^5 V m^{-1}. Measurements were obtained at a repetition rate of approximately 0.1 Hz, with dark current subtraction performed for each data point.

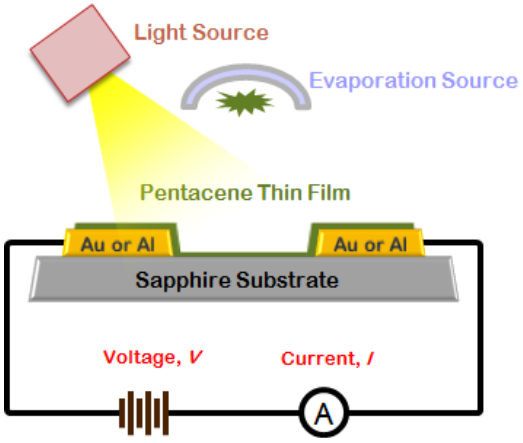

Figure 1. Diagram of the experimental apparatus for *in situ* photoconductance measurements.

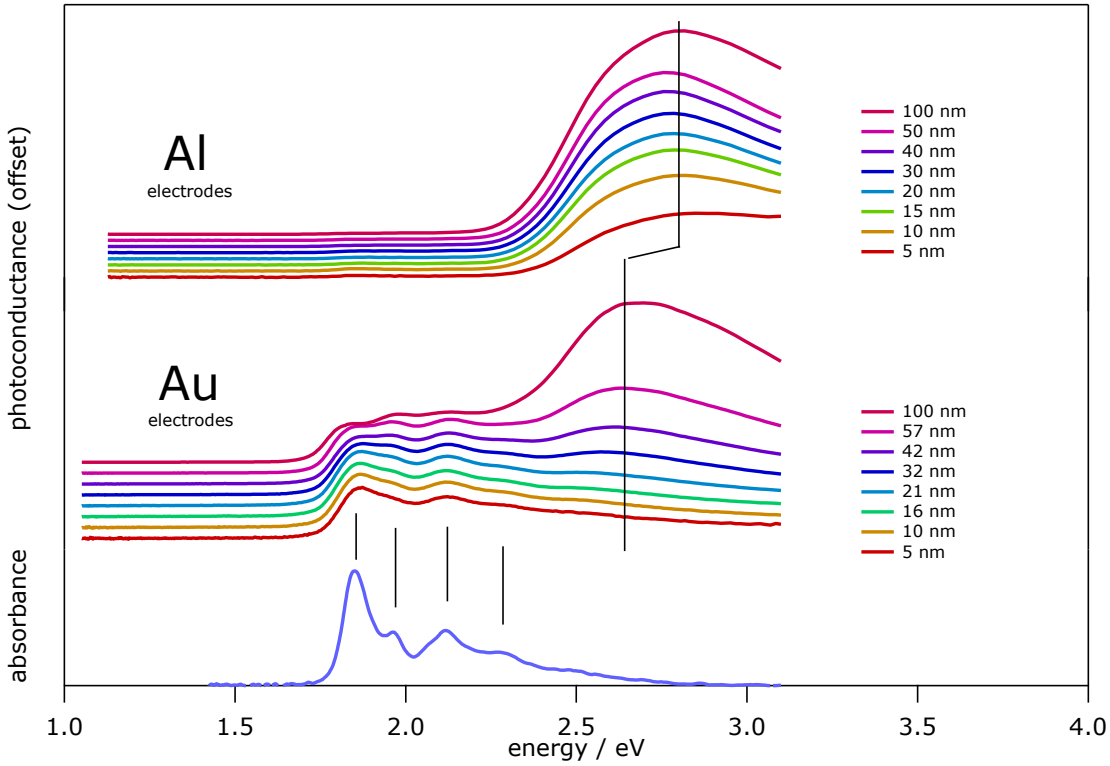

Figure 2. Photoconductance of pentacene films of the indicated thickness. The optical absorbance of an 8 nm pentacene film is shown for comparison. The reported photoconductances are normalized against the incident photon flux and film thickness.

Results and Discussion

The electrode metal influenced the dark conductivity of the film. The conductivity of the pentacene film with Au electrodes was 6×10^{-8} S m^{-1} for films less than 20 nm thick, falling at higher thicknesses. The conductivity with Al electrodes was below the measurement threshold of 10^{-9} S m^{-1} for all thicknesses measured. The photoconductivity is also dependent on the electrode metal, as shown in Figure 2. The broad peak at around 2.7 eV is attributed to intrinsic photo-generation by excitation of electrons across the transport energy gap[1]. The cluster of peaks at lower energy correlates closely with the optical absorbance of the thin film and are assigned to a de-trapping mechanism where long lived triplet excitons excite trapped charges into mobile states. The de-trapping currents dominate for the thin pentacene films with Au electrodes, corresponding to the thicknesses where the dark conductivity is highest. The de-trapping photocurrent is an order of magnitude lower when Al electrodes were used, and the intrinsic photocurrents saturate only slightly at the lowest observed thicknesses. A 0.1 eV shift of the intrinsic photoconductivity peak to higher energy is also noted.

[1] D. V. Lang, X. Chi, T. Siegrist, A. M. Sergent and A. P. Ramirez, *Phys. Rev. Lett.* **93**, 086802 (2004).