Characterization of Pentacene-Based Thin Film Transistors using the MM-16 Spectroscopic Ellipsometer

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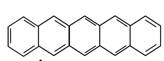
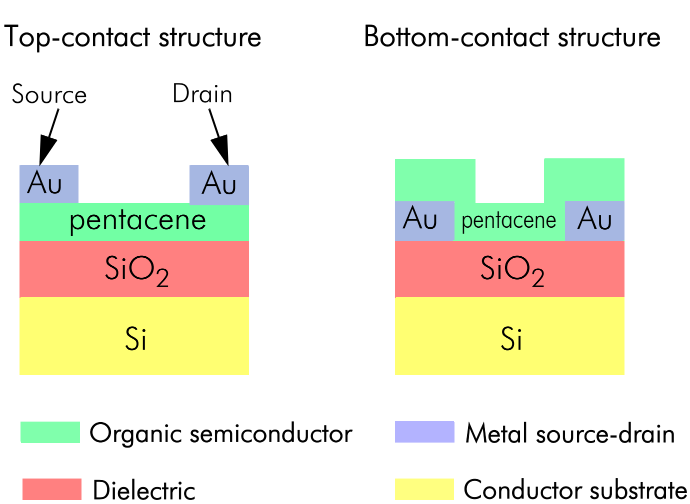
The performance of organic thin-film transistors (OTFTs) using small molecules has considerably improved during recent years. Organic materials have the key advantage of potentially simple and low-temperature thin film processing, using techniques as spin coating, inkjet printing or stamping. This fact suggests that OTFTs could be useful for applications requiring large-area coverage, low temperature processing and low cost.

Organic Thin Film Transistor Structure

Thin film transistors (TFTs) using organic semiconductors as the active material are of interest for a number of applications. Used as pixel-access devices in active-matrix displays, organic TFTs could complement liquid-crystal valves or organic light emitting diodes to allow inexpensive display fabrication on flexible, lightweight polymeric substrates.

Moreover, among the OTFTs with organic semiconductor as the active chanel, those fabricated with pentacene allowed the highest performance. Its high hole mobility approaches or even surpasses the mobility values found in amorphous Si. The most usual gate dielectric in these pentacene devices is thermally grown silicon dioxide on crystalline silicon. The effects of pentacene channel thickness influence the field-effect mobility of the material, and spectroscopic ellipsometry is an ideal, non-destructive tool for its characterization.

Pentacene ($C_{22}H_{14}$) is a polycyclic  aromatic hydrocarbon that contains five benzene rings.
There are two types of geometry of organic field effect transistor, below you can see two representations of these structures:

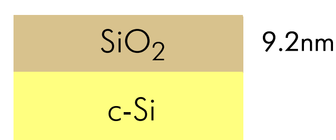


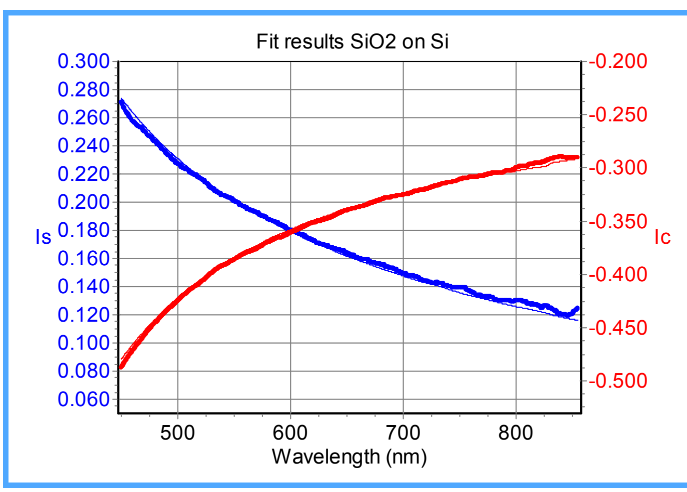
Results

The ellipsometric data were measured using the HORIBA Jobin Yvon MM-16 spectroscopic ellipsometer which is based on liquid crystals modulators.
The experimental data were acquired at an angle of 70°across the spectral range 450-850nm.
The analysis is made in two steps, firstly the characterization of silicon oxide followed by characterization of the pentacene layer.

characterization of Silicon Dioxide

A single layer model has been used. The optical properties of the SiO_2 are taken from the standard DeltaPsi2 optical library.





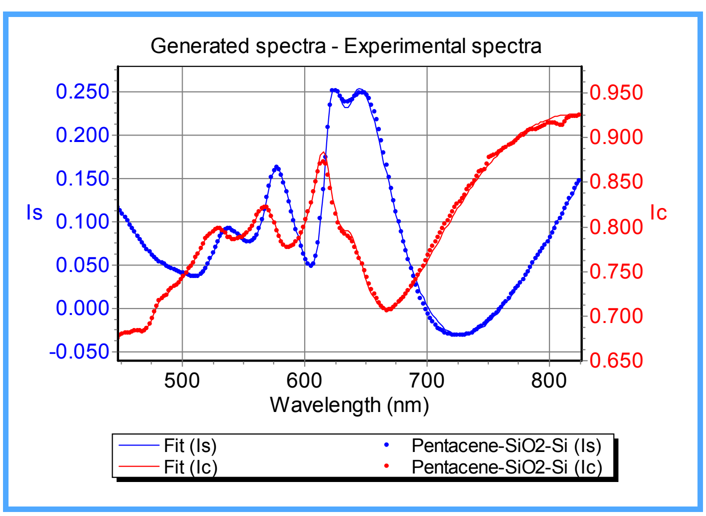
Pentacene characterization

The oxide thickness has been fixed in the sample structure of OTFT.
First the model was fitted using the spectral range 600-850nm. The optical constants of the pentacene were determined using a four oscillator dispersion formula. The optical properties were then extended near the lower energies using an advanced function of DeltaPsi2 software: the NK fit.

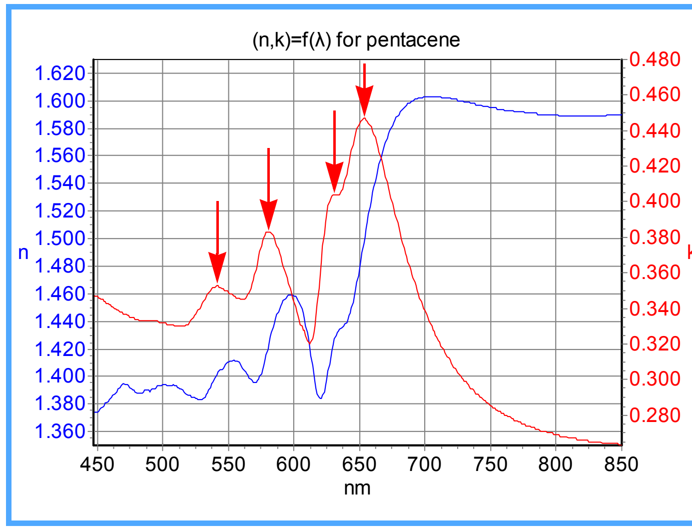
$$\varepsilon = \varepsilon_\infty + \sum_{j=1}^{4} \frac{f_j \omega_j^2}{\omega_j^2 - \omega^2 + i\Gamma_j \omega}$$

This NK fit function makes a direct inversion of ellipsometric data to n and k, and allows us to extend a dispersion formula and to characterise features of the refractive index curve that are not possible using a dispersion formula. This function is not based on the Kramers-Kroning relation and must be used with care. For this characterization we believe that this approach provides a valid description of the material's optical properties.

pentacene	170.7nm
SiO_2	9.2 nm
c-Si	



The model fits the sample perfectly. There is an excellent agreement between the experimental data and the model.
Furthermore, the ellipsometry results show a sharp and strong peak in the extinction coefficient k at 654nm, with additional absorption peaks at 630nm, 580nm and 540nm.



Conclusion

Spectroscopic Ellipsometry based on the liquid crystal devices is an excellent technique for the highly accurate characterization of organic semiconductor in OTFTs device in the visible range.

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