Organic Field-Effect Transistors based on Thin films of a Charge Transfer complex based on a BTBT derivative and TCNQF$_4$

Lamiaa Fijahi , Adrian Tamayo , Tommaso Salzillo, Yves Geerts, Marta Mas-Torrent

Institut de Ciència de Materials de Barcelona (ICMAB-CSIC) ,Campus de la UAB, 08193, Bellaterra, Spain

INTRODUCTION

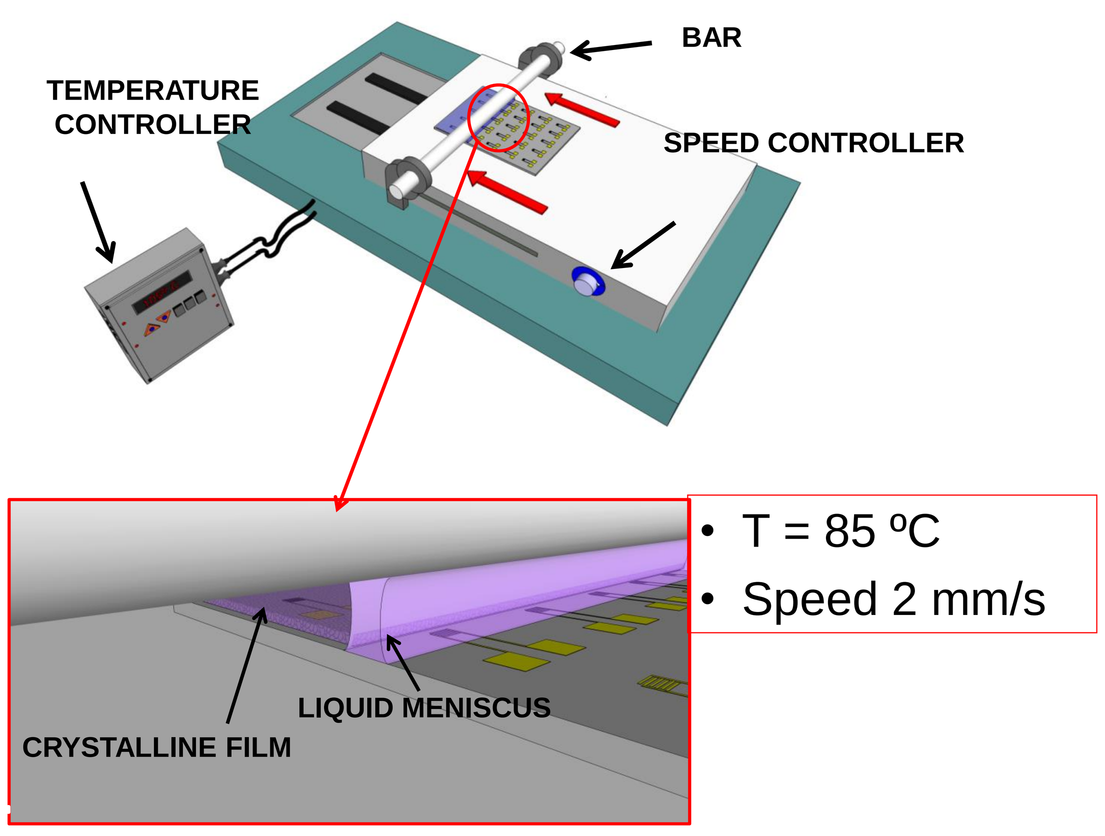
Charge transfer (CT) complexes have attracted great attention because of their potential as a new type of organic semiconductor material. Organic charge-transfer salts are formed from electron acceptors (e.g. tetracyano-quino-dimethane, TCNQ) and electron donors (e.g. tetrathia-fulvalene, TTF), and provide a new material with new physical properties. However, their application in organic electronics (OEs) has been mainly limited to ideal single crystals or to films prepared by the co-evaporated of their components. Herein, we prepared organic field-effect transistors (OFETs) of the CT salt based on C8-O-BTBT-O-C8 /F4TCNQ by a simple solution shearing technique (i.e., BAMS).

Strategies:

- Gate/Substrate: Si/SiO$_2$
- Active layer :(C$_8$-O-BTBT-O-C$_8$:TCNQF$_4$):PS$_{100k}$
- Ink Formulation: OSC 4: 1 PS in (CB:BZN)
- Source/Drain: Au/ PFBT-SAM
- Bar-assisted meniscus shearing (BAMS)

BAMS Coating Technique:

The BAMS has revealed to be a powerful approach for the fabrication of OFETs at low cost and high speed.

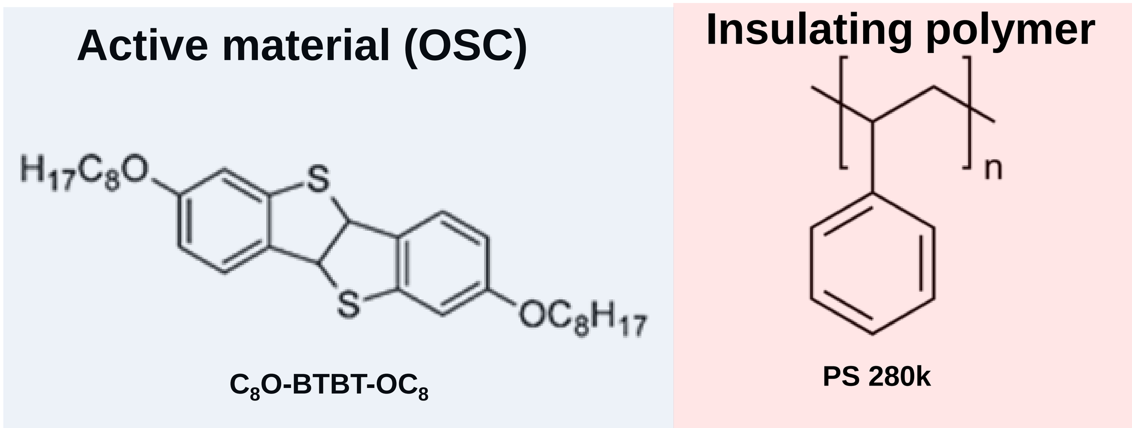


A solution of the semiconductor and an insulating polymer is placed between a bar and a heated substrate forming a menisucs. Such meniscus is then sheared by the movement of the bar and a dry thin film is deposited.

Experimental setup:

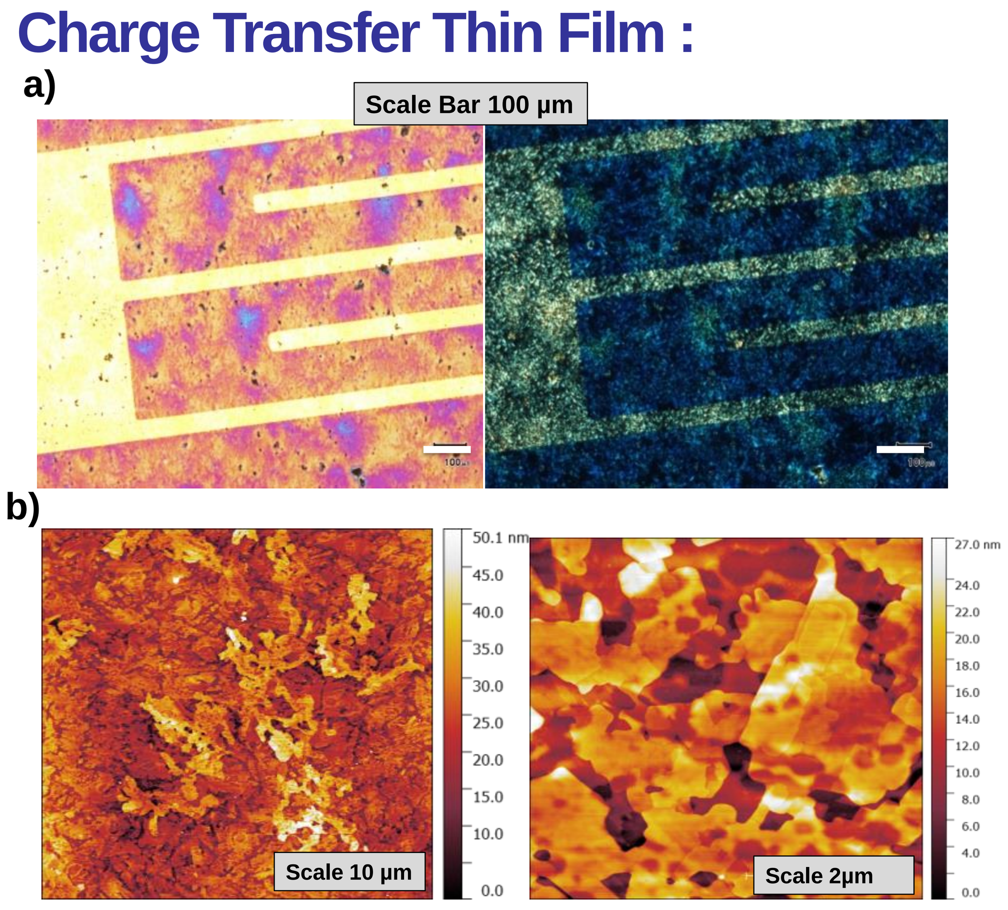
OFET devices were fabricated on Si/SiO2 with interdigitated Cr/Au electrodes, patterned by photolithography and deposited by thermal evaporation.

Thin films were deposited at ambient conditions by the BAMS technique using a home-designed bar coater. The ink was prepared by blending the active materials with polystyrene to promote film processability, reproducibility and stability. The resulting OFET devices, fabricated and measured in environmental conditions, exhibited an n-type behavior.



RESULTS AND DISCUSSION

Charge Transfer Thin Film :

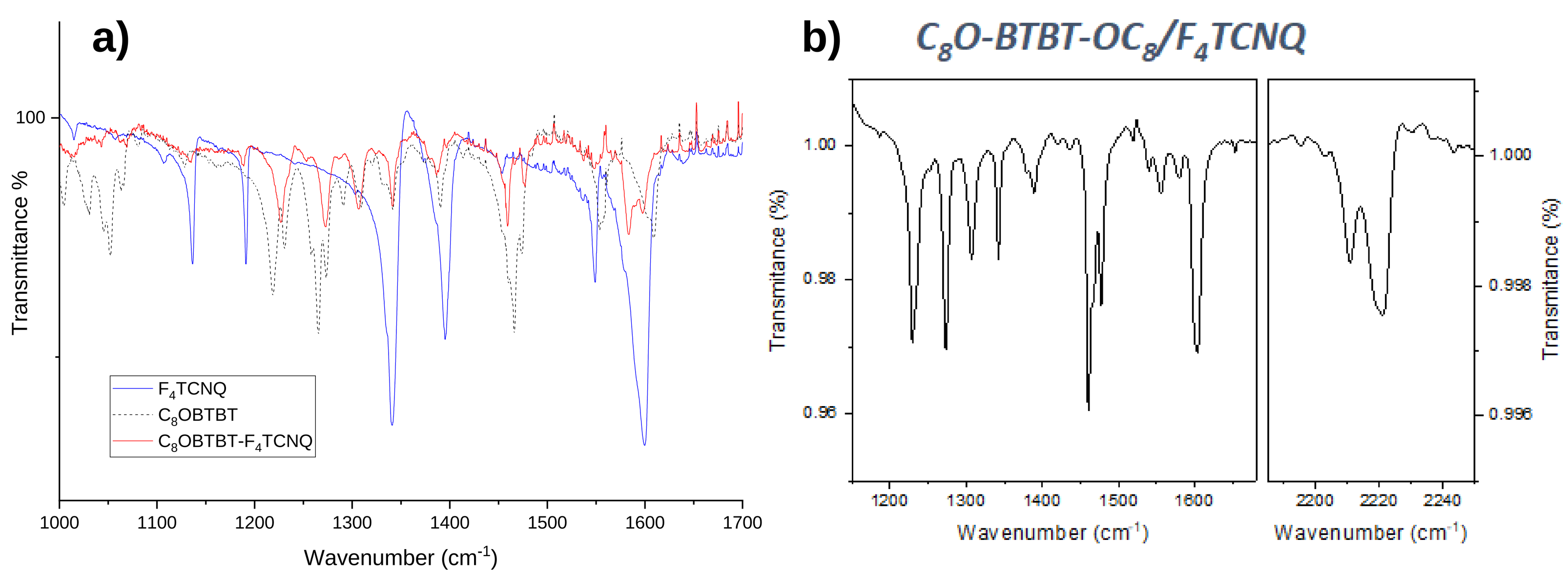


An excellent homogeneity and crystallinity of the semiconductor is successful obtained by combining C8-O-BTBT-O-C8/TCNQF4:PS blends with BAMS.

a) Optical polarized microscopy images and b) AFM images of the thin films. C8-O-BTBT/TCNQF4)/PS$_{280k}$ films deposited at 2 mm/s at substrate temperature of 85 º.

Small polycrystalline domains were observed by optical polarized microscopy and no preferential orientation relative to the shearing direction was observed. The topography AFM images provide information about the stratification of the films and microcrystals were observed.

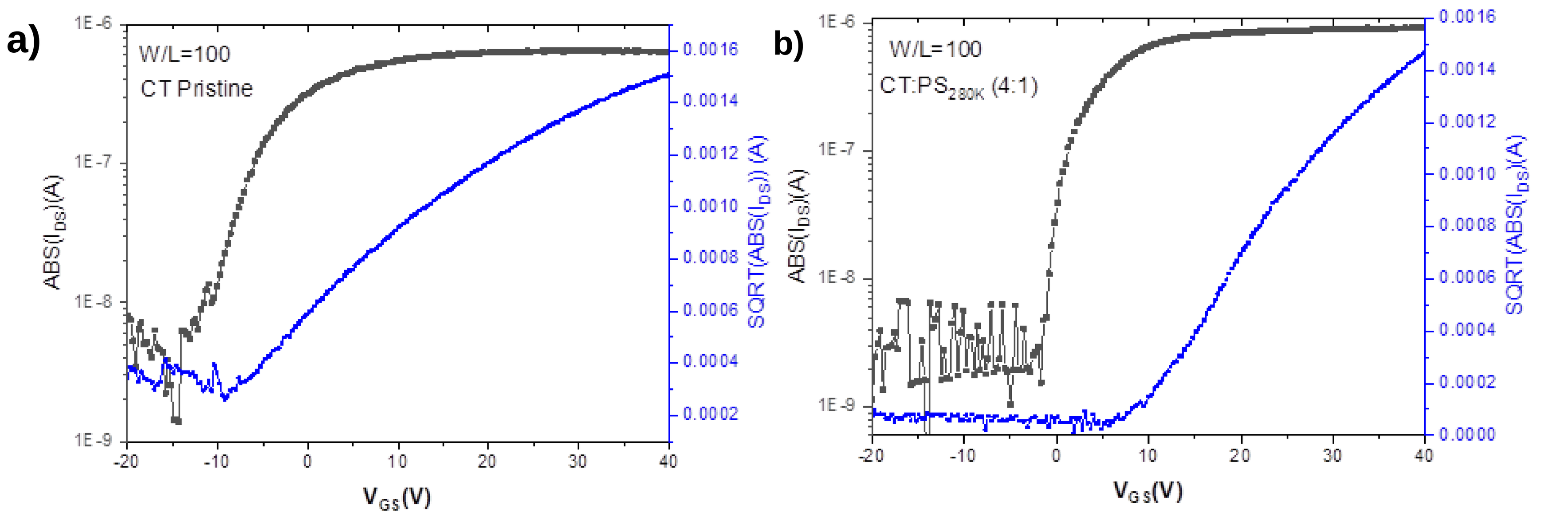
IRRAS Characterization :



a) Left: IR spectra of C8O-BTBT-OC8 (blue trace), F4TCNQ (dash black trace) and of the CT complex C8O-BTBT-OC8/F4TCNQ (red trace). b) IRRAS spectra of the CT complex C8O-BTBT-OC8/F4TCNQ of the thin film

From the shift of the CN stretching the CT interaction is confirmed .The C=C stretching shifts from 1454.8 to 1442.9 cm-1 and the CN from 2224.5 to 2218.7 cm-1.

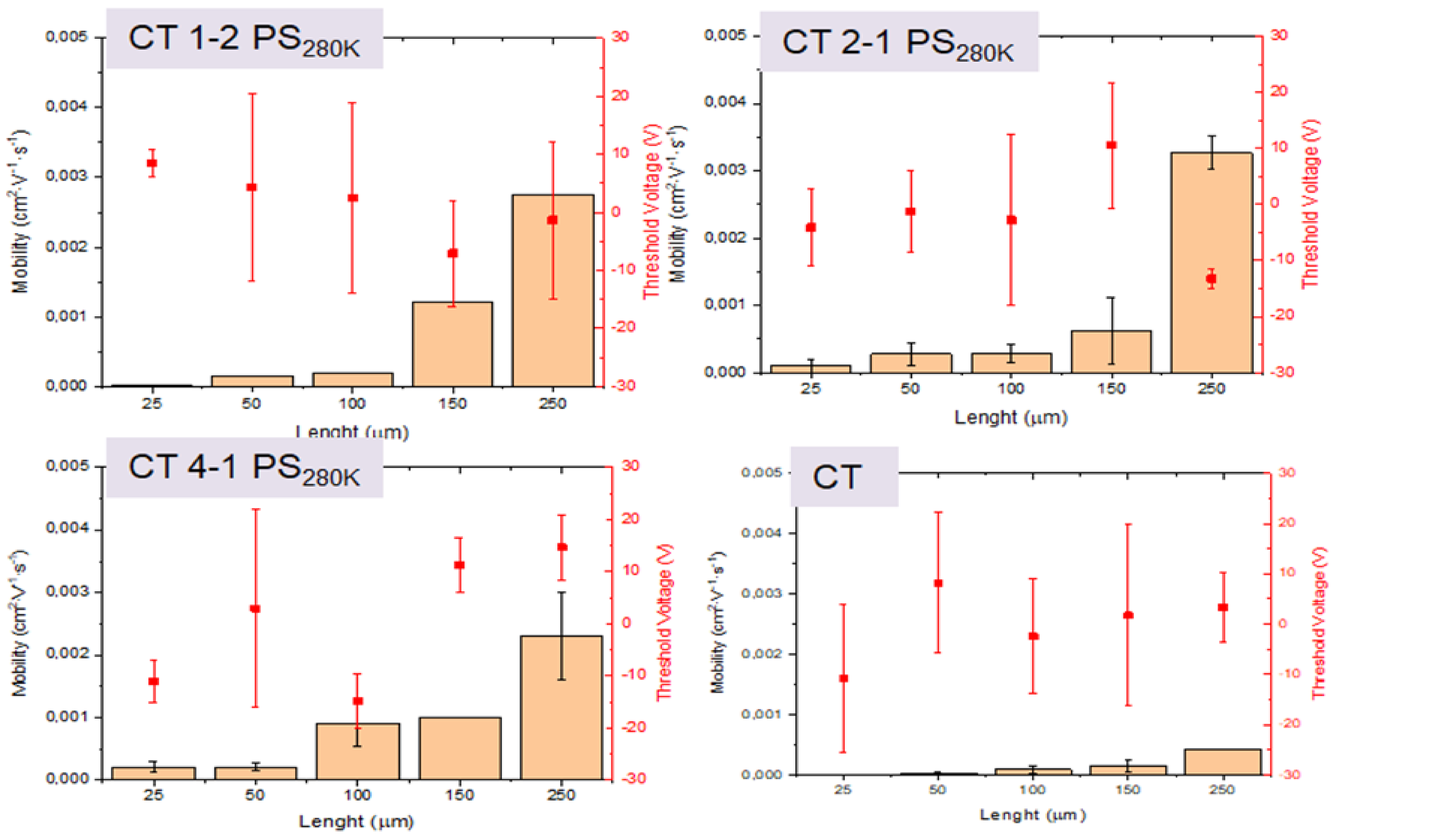
Transistor characterizations:



Electrical characterization: a) transfer measurements of the (C8-O-BTBT:TCNQF4) and b) transfer measurements of the (C8-O-BTBT:TCNQF4): PS (4:1) OFETs in Air. C8-O-BTBT/TCNQF4 and C8-O-BTBT/TCNQF4)/PS$_{280k}$ films deposited at 2 mm/s at substrate temperature of 85 ºC.

Our OFET devices present a field effect mobility (µ) of the order of 10^{-3} cm^2/Vs , a low threshold voltage (V$_{TH}$ close to 0 V) and a high on/off ratio. However the device performance shows a significant hysteresis that can be attributed to a high number of interfacial charge trap density.

Influence of the CT:PS ratio



Box-Plot statistics of the measured mobilities of the performing devices with different ratios (CT(1:2),(2:1),(4:1) and without PS) by channel length.

The highest mobility obtained is with L=250 µm and the blends exhibit a higher mobility with respect to the pristine CT.

CONCLUSIONS

- Thin films of the CT complex **C8-O-BTBT/TCNQF$_4$** blended with **PS** were fabricated implementing a low cost and solution shearing technique.
- Structural, spectroscopic and morphological characterization of the fabricated devices confirmed the formation of a homogeneous film with no preferential molecular orientation with respect to the substrate plane.
- The devices prepared display n-type transport in air with mobility values around 10^{-3} cm^2 V^{-1} s^{-1}.

ICMAB acknowledges the Severo Ochoa Program (MINECO, SEV- 2015-0496)

ACKNOWLEDGEMENTS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 811284