Structural and electrical properties of poly(3-octylthiophene) (P3OT) films: A scanning probe microscopy study.

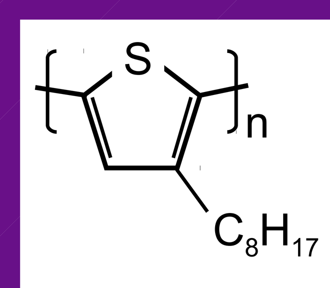
J. Abad[1], E. Palacios-Lidón[1], B. Pérez-García[1], A. Urbina[2], J. Colchero[1]

[1] Dep. Física, Centro de Investigación en Óptica y Nanofísica (CIOyN), Universidad de Murcia, Campus Espinardo,30100 Murcia,Spain.
[2] Dep. de Electrónica, Universidad Politécnica de Cartagena, 30202 Cartagena, Spain

Introduction

Poly-(3-octylthiophene) is one of the most promising materials for applications in organic opto-electronic devices such as field-effect transistors, light-emitting diodes or plastic solar cells due to its high hole mobility. Understanding the correlation between the morphological and electrical properties is of vital importance, since the structural arrangements of the molecules determines and limits the overall devices. In the present work we use scanning force microscopy techniques to study P3OT thin films, combining topographic, electrostatic, capacitance and electronic transport measurements .

Poly(3-octylthiophene) P3OT



Greater than 98.5% head to tail regioregular

Molecular weight Average $M_w \sim 142000$

Average $M_n \sim 54000$

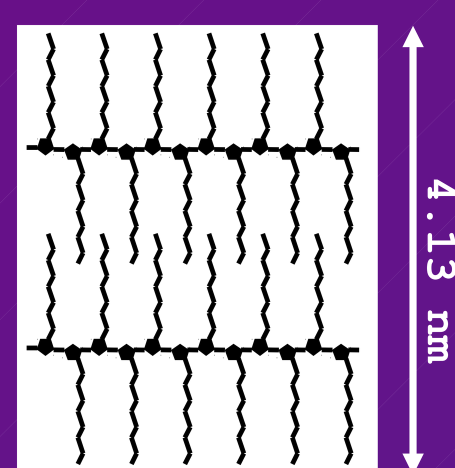
Polydispersity index ~ 2.6

Conductivity $1x10^{-6}$ S/cm

Our samples conductivity $1x10^{-5}$ S/cm

Solution of P3OT in Toluene

~5; 10; 20; 40 mg/ml



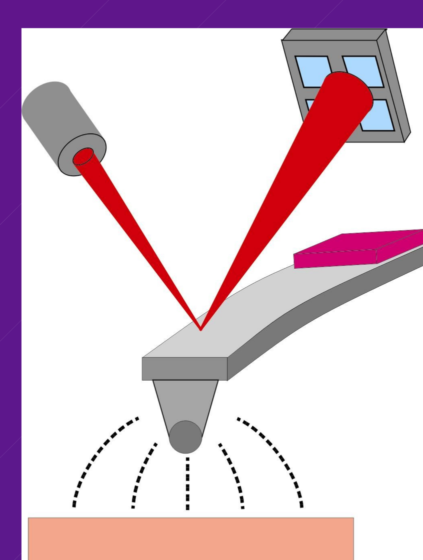
Kelvin, Electrostatic and Capacitance

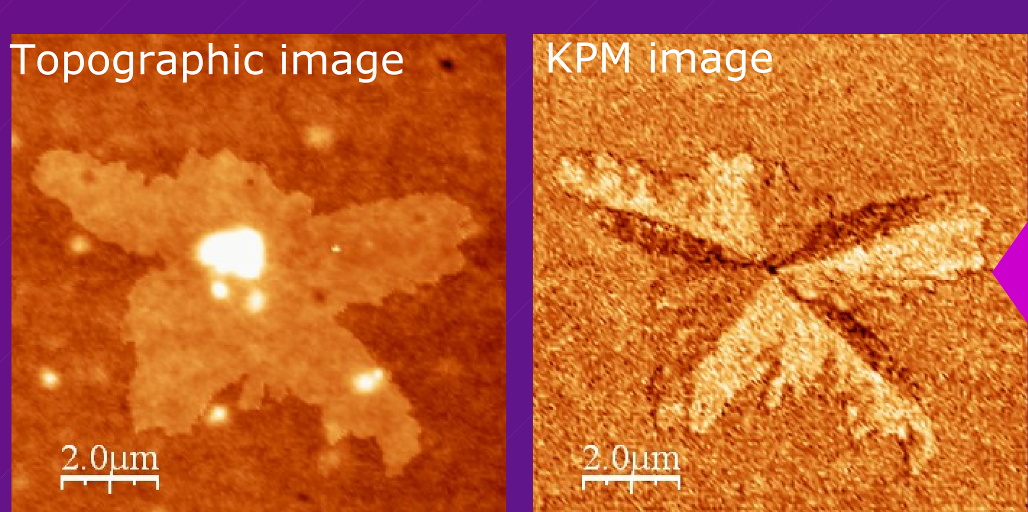
Electrostatic interaction $W_{electrostatic} = \frac{1}{2} C(d)(V_{bias} - V_{CP})^2$

$$W^{(1)}_{electrostatic} = F_n = \frac{1}{2} C'(d)(V_{bias} - V_{CP})^2 \quad W^{(2)}_{electrostatic} = \frac{1}{2} C''(d)(V_{bias} - V_{CP})^2$$

$$\Delta\omega = -\frac{\omega_{res}}{c_{lever}} \frac{1}{2} C''(d)(V_{bias} - V_{CP})^2 \qquad V_{bias} = V_{dc} + V_{ac} sen(\varpi t)$$

static | with ω: $\Delta\omega_{res}(\omega) \propto V_{ac} C''(d)(V_{dc} - V_{cp})$ | with 2ω: $\Delta\omega_{res}(2\omega) \propto V_{ac}^2 C''(d)$

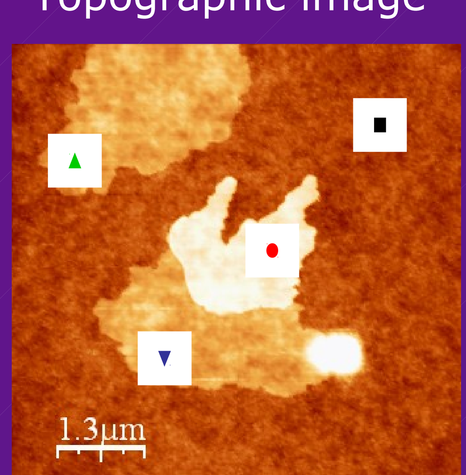


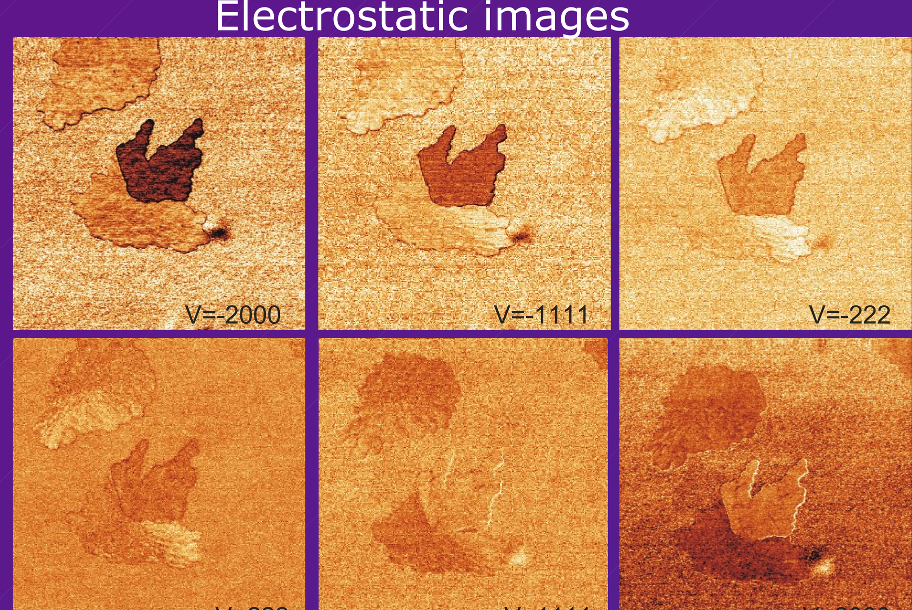


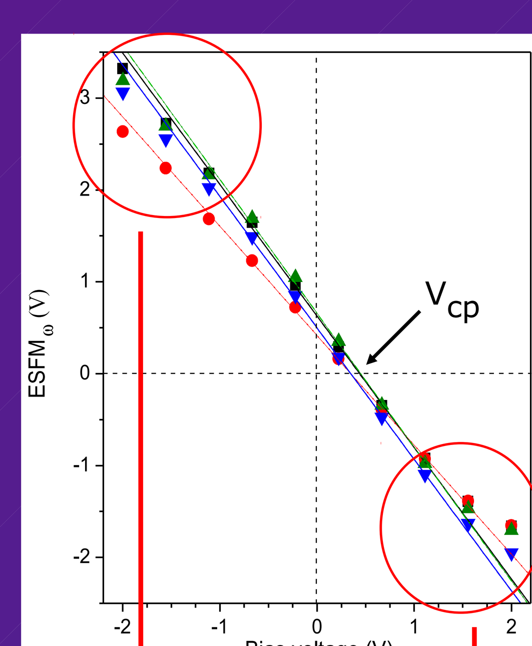
20 mg/ml on gold thin film

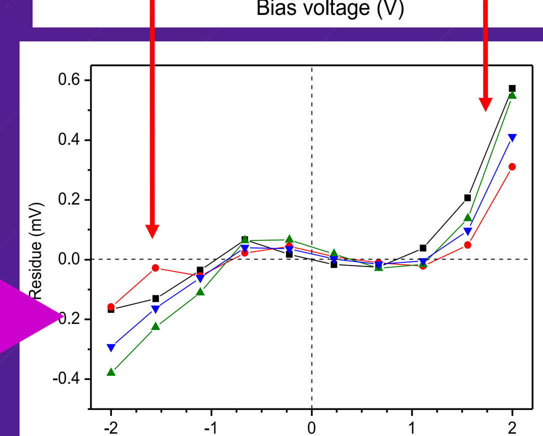
Different surface contact potential domains are shown

Zone	ΔCP (ω) [mV]	ΔCP (KPM) [mV]
■	0	0
●	93	32
▲	-10	-21
▼	43	25

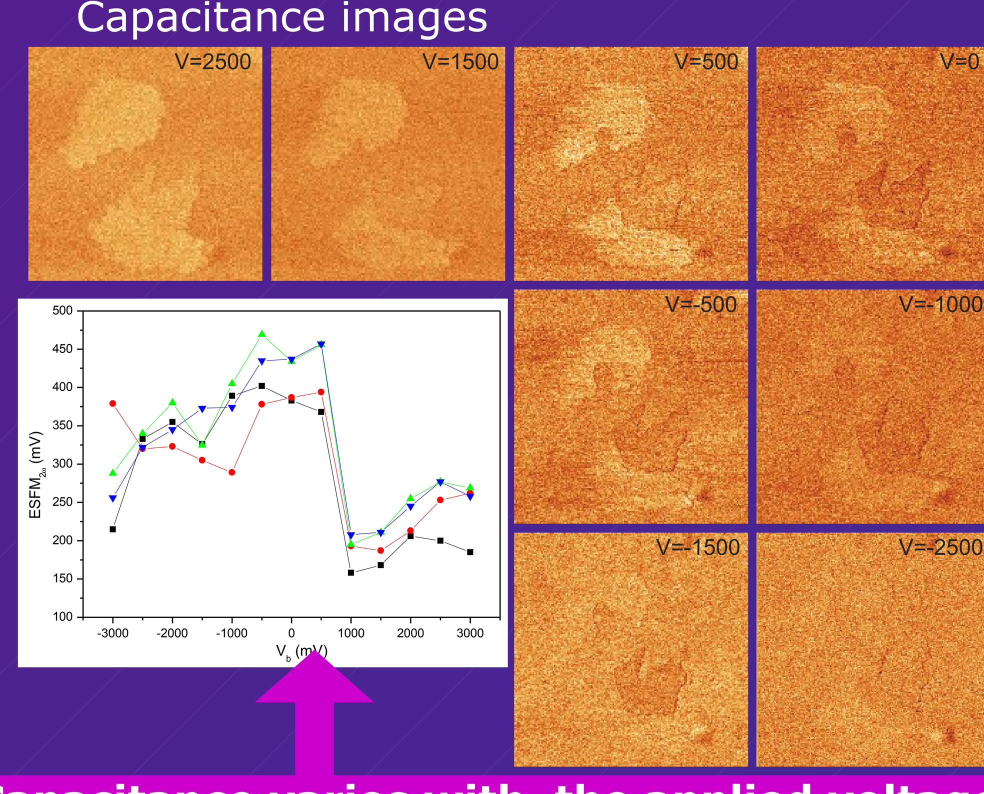








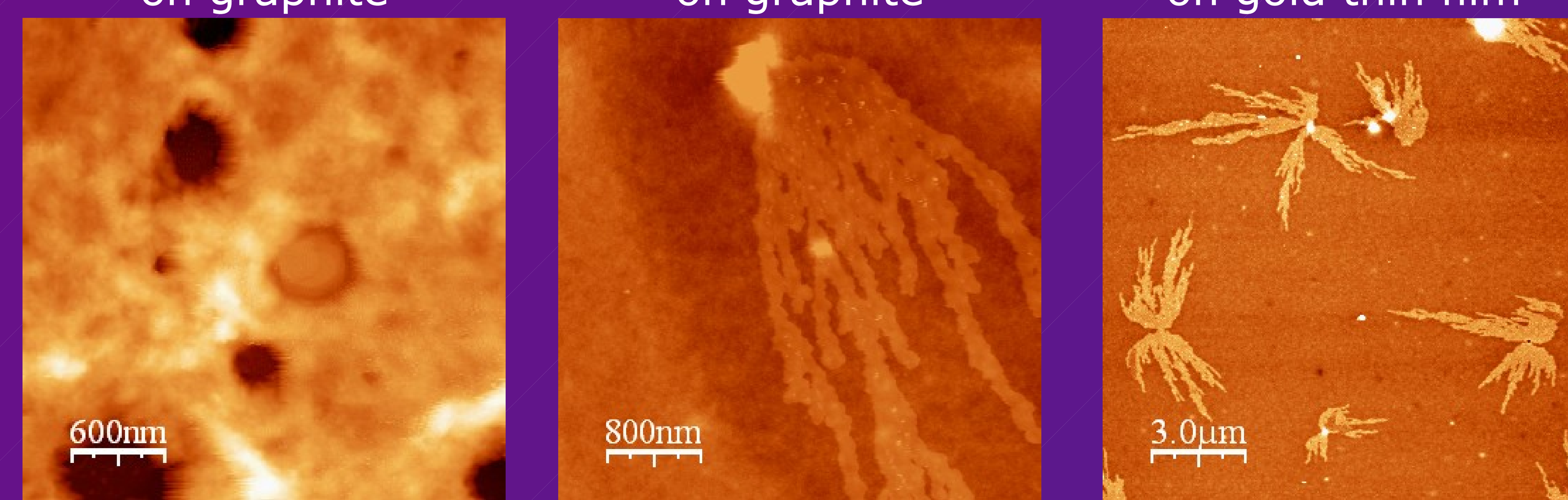
Deviation of the electrostatic model from the linearity with the applied voltage



Capacitance varies with the applied voltage

Morphology

Drop casting versus Spin coating

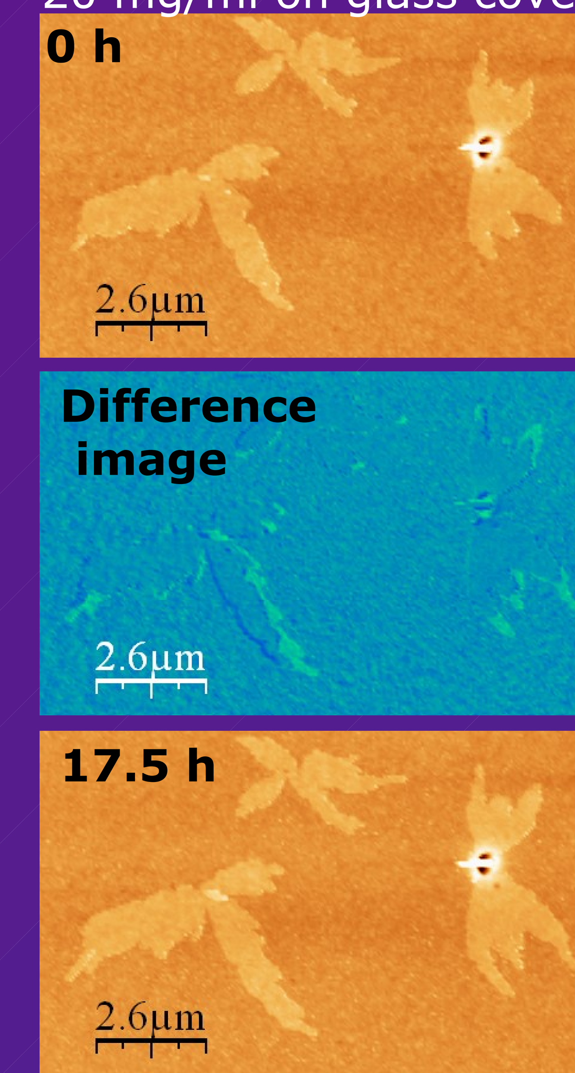


Rough morphologies with layered structures and many voids

Self-organized layered structures "jellyfishes" 1-4 layers of height 4-5 nm each one onto a disordered polymer layer

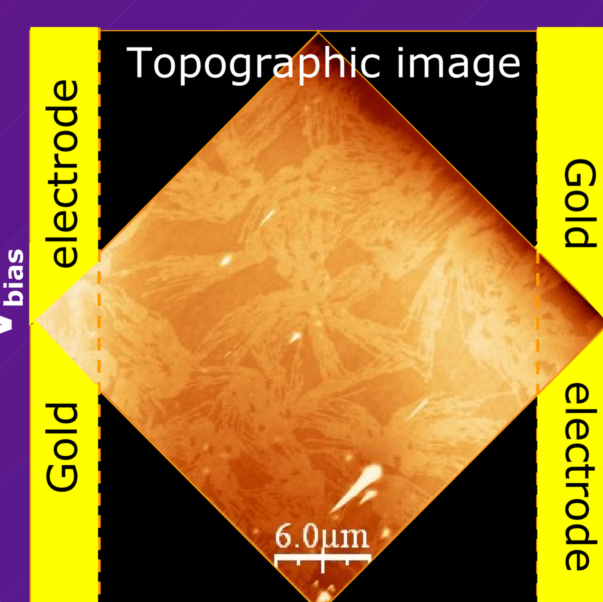
Growth dynamic

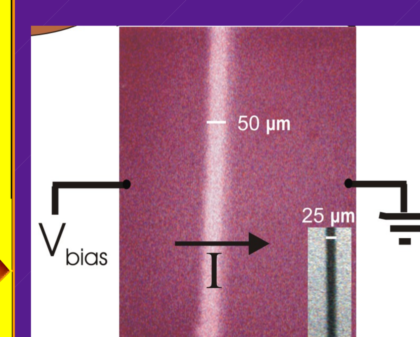
20 mg/ml on glass cover



V ~ 1–5 µm²/day

KPM and transport measurements



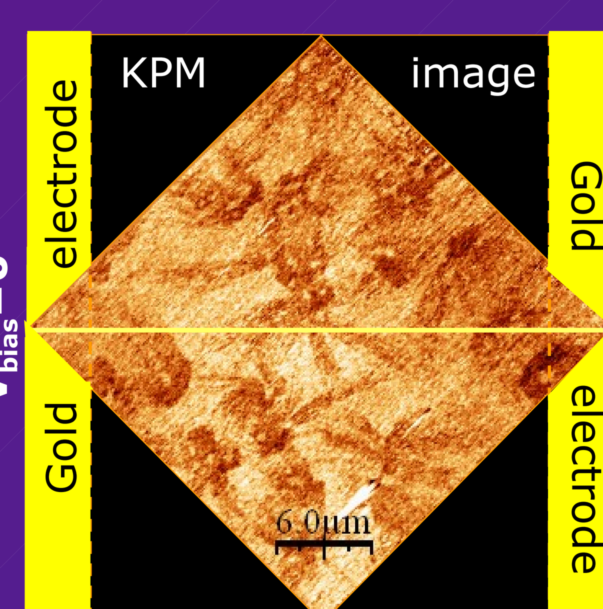


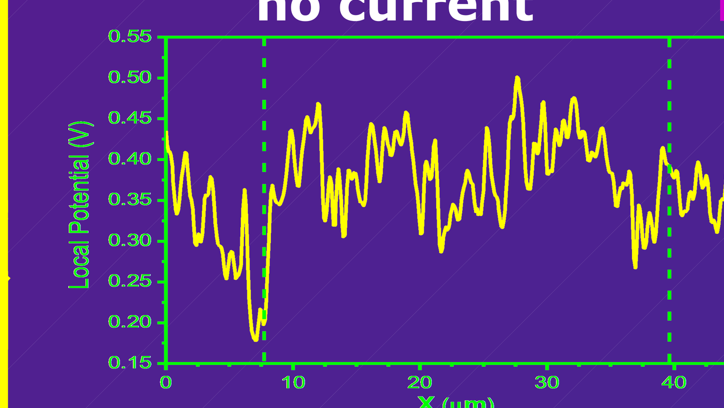
20 mg/ml

What we are measuring?

$V_{bias} = 0$; I=0 Local Potential $= V_{CP}$

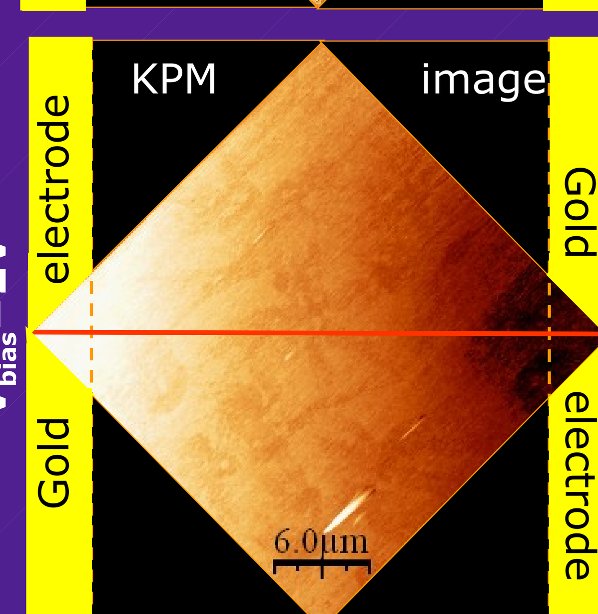
$V_{bias} \neq 0$; I≠0 Local Potential $= V_{CP} + I_{loc}R_{loc}$

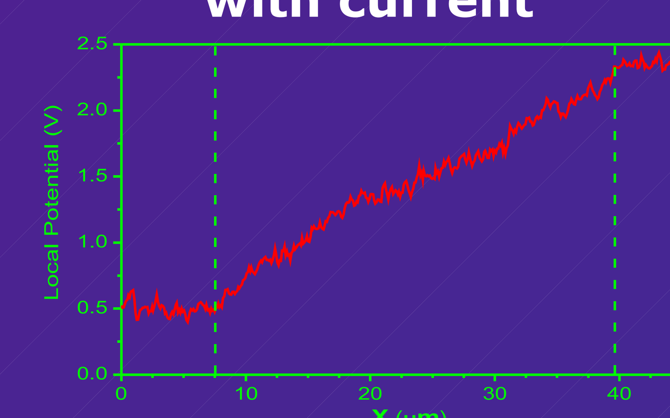


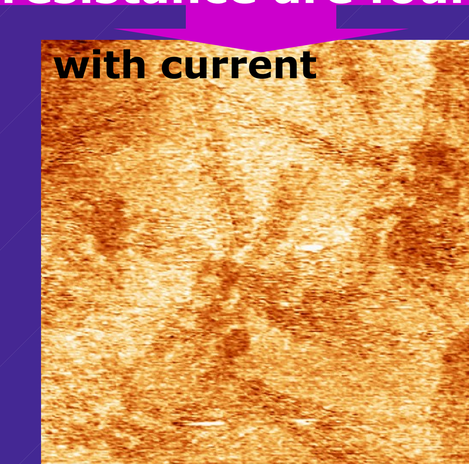


After subtracting the contribution of the global mean potential

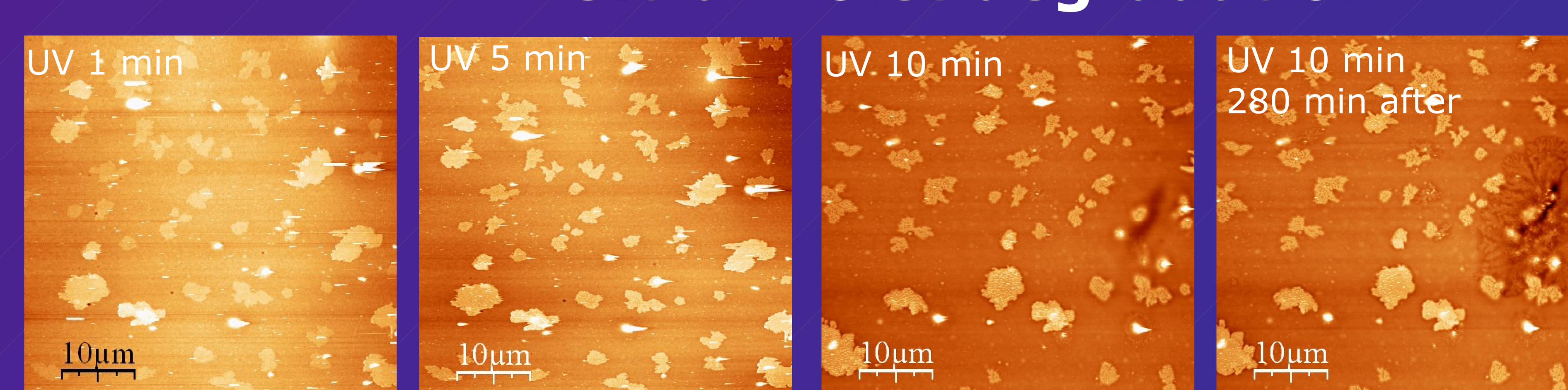
No differences due to resistance are found

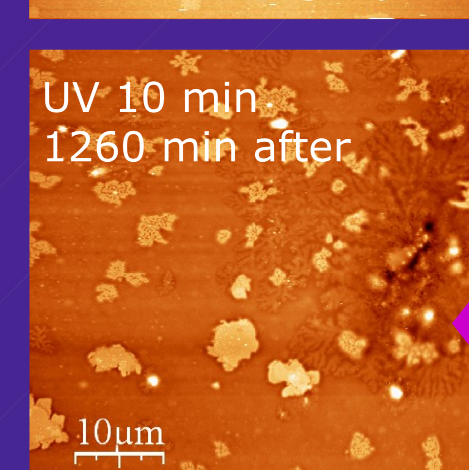






Ultra-violet degradation

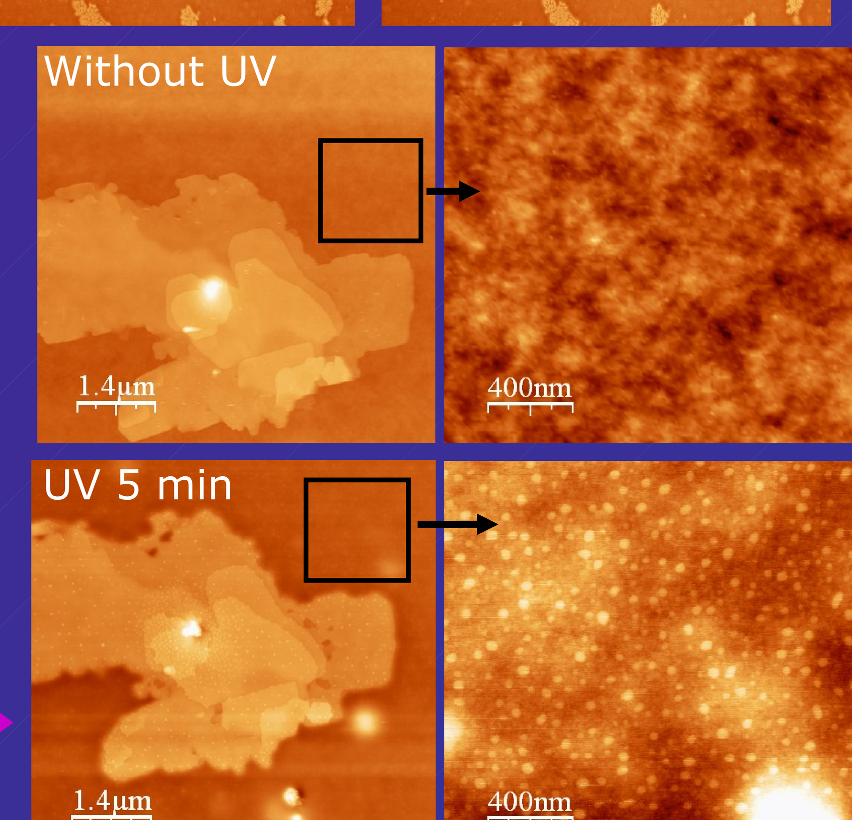




40 mg/ml on glass cover

Hole formation and growth of dendritic structures after the irradiation

V ~ 630 µm²/day



Faster degradation of the polymer background than the layered structures

Conclusions

In this work we have carried out the morphological and electrical characterization of P3OT thin films.

Finding self-organized structures, which show different surface contact potential domains. There is a deviation of the electrostatic model from the linearity and a variation of the capacitance with the applied voltage. The last one probably due to band bending effects.

No appreciable resistance differences between the different polymer regions has been found.

UV irradiation induces holes and the growth of dendritic structures. The degradation is faster in the polymer background than in the layered structures.