Influence of Ultraviolet and Ozone degradation on the nanomorphology and electrical properties of P3OT thin films studied by Scanning Probe Microscopy and related techniques

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Introduction

In the field of organic solar cells the power conversion efficiency and the durability are issues that have to be addressed before this technology is competitive with traditional silicon solar cells[1].
One of the research lines of our group is devoted to a better understanding of how the nanoscale properties determine the macroscopic behavior of such devices[2-5]. In order to understand the degradation mechanisms of plastic solar cells, we investigate in the present work the modification of thin P3OT films by ultraviolet (UV) irradiation and O_3 exposure. Films of 100 nm thickness have been prepared by spin-coating on conducting as well as insulating substrates. The samples were characterized by non-contact Scanning Force Microscopy (SFM), as well as by optical transmission measurements and macroscopic electronic transport measurements. Our experimental setup allows us to perform SFM nanoscale studies of the same region, even if the sample is taken out of the SFM system for different processes, and hence we can attribute the observed changes to the real effect of radiation and O_3 as compared to possible statistical variations of surface properties.

The samples

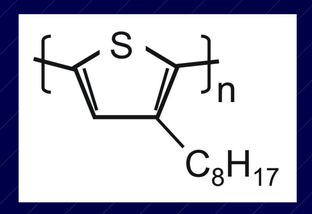
10 mg/ml solution of P3OT in Toluene

Spin cast at 4000 rpm

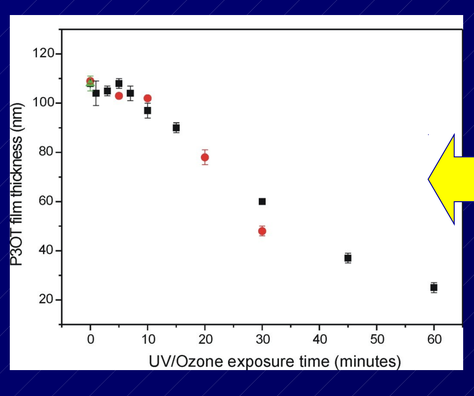
Substrate glass cover

UV lamp 50 W
50%; 254 nm
5%; 185 nm
Irradiance ≈ 2.5 kW/m²

Poly(3-octylthiophene)



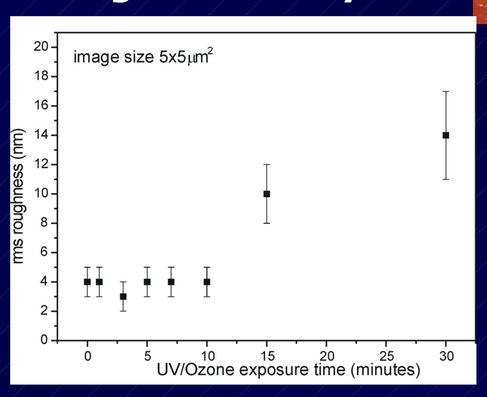
Thickness vs UV exposure



In the first 10 minutes of UV irradiation the film thickness does not change.

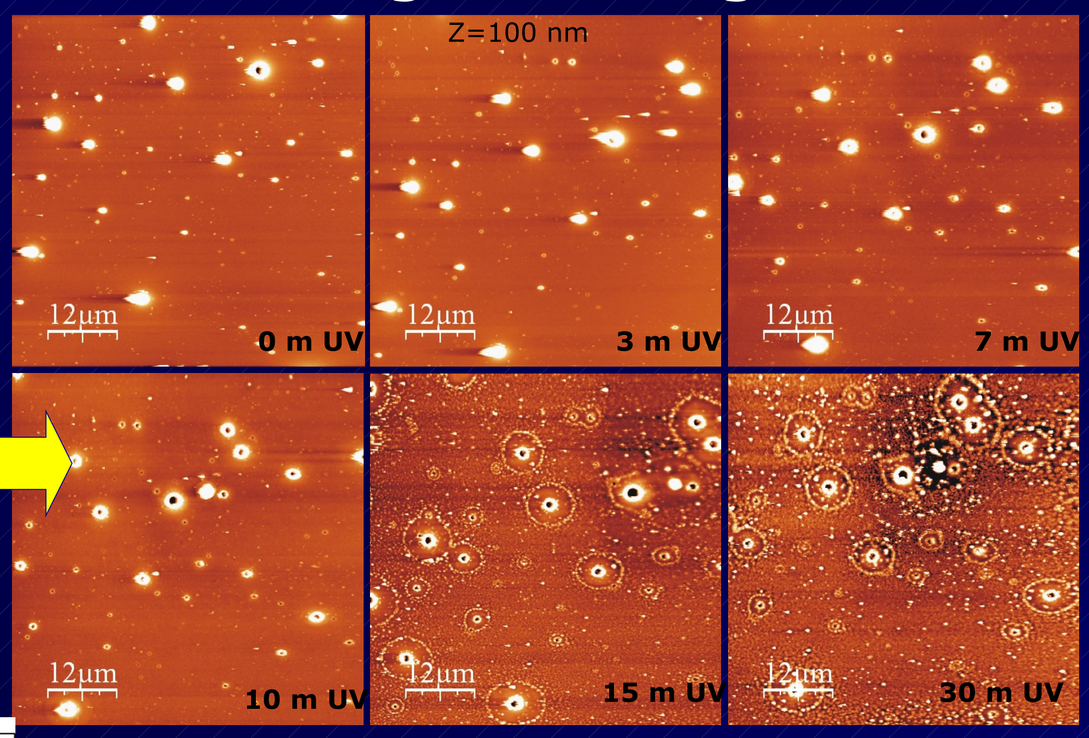
Main changes between 10-15 minutes located around the balls characteristic, rings of small spherical articles develops.

Roughness analysis

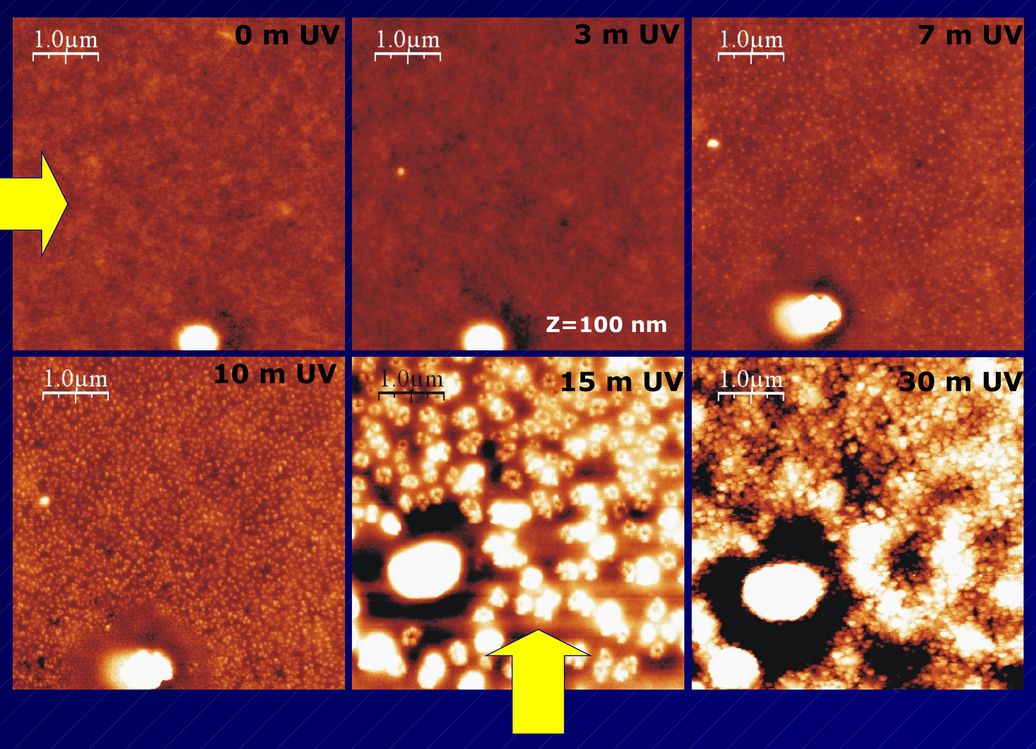


Roughness is constant for the first 10 minutes of UV exposure and increases after 15 minutes.

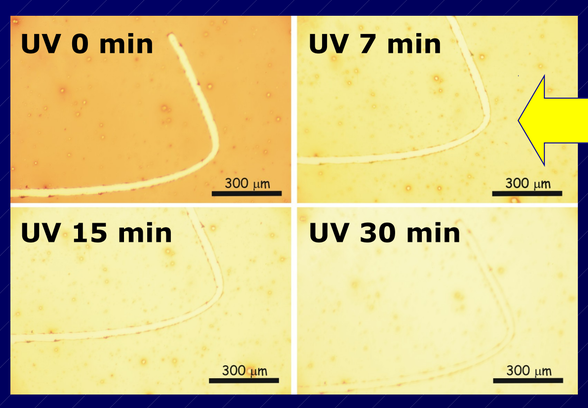
Large size images



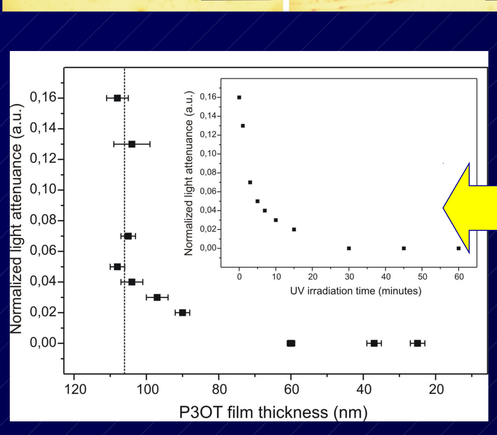
Small size images



Optical measurements

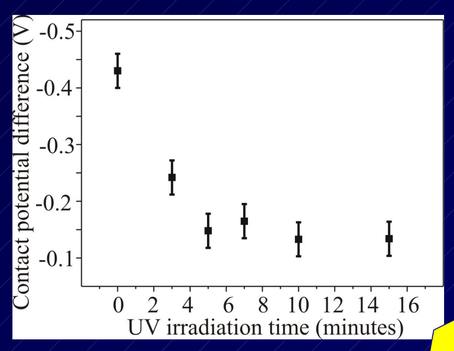


Loss of contrast between the polymer film and the glass substrate with the time exposure.



Very pronounced decrease of the light attenuace in the first minutes of exposure. However, the film thickness does not change.

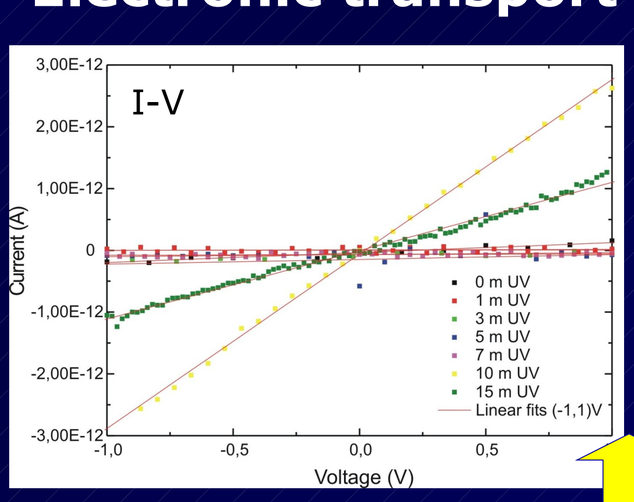
Contact potential



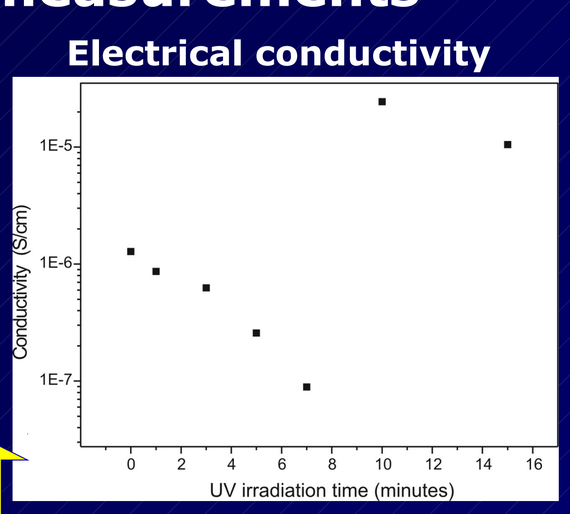
After 5-7 minutes small grain like structures appear. These grains become denser after 10 minutes of irradiation. Finally, the grains have merged into clusters.

Decrease of the contact potential difference in first 5 minutes of UV irradiation.

Electronic transport measurements



Electrical conductivity



Conductivity decreases exponentially with increasing time exposure. However, after 10 minutes of exposure the conductivity increases markedly.

Further UV exposure reduces strongly the thickness of the sample and we can not perform macroscopic transport measurements.

Conclusions

We have studied the effect of UV and Ozone exposure in the nanomorphology and electrical properties of P3OT thin films:

We find that for short time exposures (7-10 minutes) the roughness and the thickness of the films do not change, on the contrary the colour of the sample is lost (the light attenuance decreases) and the contact potential changes.

After 10 minutes of UV irradiation the roughness increases, the film thickness decreases, while the light attenuance and the contact potential are almost constant.

So two different degradation regimes are found: in the first 10 minutes "chemical degradation" and after morphological degradation.

Transport measurements show that an important degradation in conductivity occurs for the first minutes of UV irradiation. This is not correlated with a reduction in the thickness of the sample, which is kept constant until the first 7 min. After the change in morphology (roughness increase and thickness reduction), the conductivity is improved in a single step and start to reduce again upon additional irradiation.

References:
1. F. Krebs, Solar Energy Materials and Solar Cells 92 (2008) 715.
2. C. J. Brabec et al. Adv. Funct. Mater. 11 (2001) 15.
3. E. Palacios-Lidón et al. Adv. Funct. Mat. 16 (2006) 1975.
4. B. Pérez-García et al. Nanotechnology 19 (2008) 065709 .
5. J. Abad et al. European Polymer Journal 44 (2008) 2506.