Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Synthetic Metals xxx (2004) xxx–xxx
SYNTHETIC METALS
www.elsevier.com/locate/synmet

# Pattern formation in *para*-quaterphenyl film growth on gold substrates

G. Hlawacek[a,*], C. Teichert[a], S. Müllegger[b], R. Resel[b], A. Winkler[b]

[a] *Institute of Physics, University of Leoben, Franz Josef Straße 18, A-8700 Leoben, Austria*
[b] *Institute of Solid State Physics, Petersgasse 16, Graz University of Technology, A-8010 Graz, Austria*

**Abstract**

Polycrystalline films of conjugated organic semiconductors offer attractive potential for optoelectronic applications. Controlling the film morphology is essential for preparing thin films tailored for optimized devices. Here, we use atomic-force microscopy (AFM) to investigate the morphology of *para*-quaterphenyl (4P) films deposited under UHV conditions onto Au(1 1 1) gold surfaces and polycrystalline gold films.

Films of 4P with and without additional carbon pre-coverage have been investigated on an Au(1 1 1) single crystal surface. Individual rod like 4P crystallites as well as chains of rod like and tetragonal crystallites were observed for thick films. For thin films, depending on the carbon pre-coverage either fan like arrangements of linear 4P chains, bent 4P crystallites with a distinct height distribution, or growth hillocks of upright standing molecules were found.

In order to study the effect of different surface orientations on shape and arrangement of the crystallites, 4P has been deposited onto a polycrystalline Au foil. On individual gold grains, preferential orientations of the 4P crystallite chains can be found. The orientation of the chains is linked to the crystallographic orientation of the underlying Au grain. In addition, growth hillocks with 1.8 nm high terraces of upright standing 4P molecules are observed.


*PACS:* 68.37.3.Ps ; 68.55.Jk

*Keywords:* Oligomers; Atomic force microscopy ; Morphology ; Organic semiconductors ; *para*-Quaterphenyl

## 1. Introduction

Conjugated semiconducting oligomers like *para*-quaterphenyl (4P) and *para*-sexiphenyl (6P) have a large potential as materials for organic thin film transistors (OTFT) [1]. As they are optically active [2], they can also be used for devices like organic light emitting diodes (OLED) [3], organic lasers and solar cells. The common challenge in manufacturing these devices is to create smooth interfaces between the different layers, because the device performance is highly influenced by the interface quality. The film morphology and molecular orientation can be controlled by a variety of growth parameters, like temperature [4], substrate, magentic field [5], surfactants and many more. Two of them, the crystallographic orientation of the substrate and the pre-coverage with surfactants were chosen. We performed a detailed ex situ atomic-force microscopy analysis of the growth morphology of 4P on gold surfaces to study the influence of substrate orientation and carbon pre-coverage. 4P consists of four phenyl rings which are connected by single bonds. At 300 K it forms a monoclinic crystal with $P2_1/a$ symmetry. The unit cell parameters are $0.811\,\text{nm} \times 0.561\,\text{nm} \times 1.791\,\text{nm}$ with a nonorthogonal angle of $\beta = 95.8^\circ$ [6,7].

Depending on the experimental conditions we observed distinct arrangements of rod like and tetragonal crystallites. A polycrystalline gold foil was used to show the effect of different substrate geometries. The influence of a small carbon pre-coverage was investigated on a series of experiments on the Au(1 1 1) single crystal surface. In addition, we could clearly identify growth hillocks built from upright standing molecules in close vicinity of crystallite arrays. Furthermore, we could show that a small carbon pre-coverage can change the film structure dramatically, so that even bent crystallites occur.

* Corresponding author. Tel.: +43 3842 402 4668; fax: +43 3842 402 4602.
*E-mail address:* gregor.hlawacek@unileoben.ac.at (G. Hlawacek).
*URL:* http://www.unileoben.ac.at/spmgroup (G. Hlawacek).

0379-6779/$ – see front matter © 2004 Published by Elsevier B.V.
doi:10.1016/j.synthmet.2004.09.002