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Self-assembled growth of highly oriented para- sexiphenyl thin films

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Abstract

We have used atomic force microscopy to investigate the structure of highly ordered para-sexiphenyl thin films grown by Hot Wall Epitaxy on mica. We have shown that the substrate temperature and the growth time are important parameters for control of the film morphology in terms of the degree of anisotropy and long range order.

Keywords: Epitaxy, Single crystalline thin films, Oligomers, Atomic force microscopy

1. Introduction

The ability to achieve and control the molecular order in thin films consisting of anisotropic oligomers is very important both for understanding the relation between their structure, morphology, optical properties and charge transport and for future improvement of devices. In particular, *para-sexiphenyl* (PSP) is a very interesting model material for studying basic physical properties of conjugated organic semiconductors. Additional practical interest in well ordered PSP films originates in its big potential for the application in light-emitting diodes (LED's) [1].

Thin films of PSP have been grown on oxidized and non-oxidizes GaAs, KCl, glass and ITO-coated glass using conventional physical vapour deposition [2-4] and organic molecular beam epitaxy (OMBE) [5]. It was shown that the nature of the substrate, substrate temperature and the deposition rate are determining parameters for molecular packing. It was also shown that the films grown by vapour deposition on oxidized GaAs consist of randomly oriented islands [4] while the large epitaxial islands of PSP, which were oriented into two perpendicular twin directions, could be obtained by OMBE on GaAs(001) [5].

Recently, we reported that highly ordered crystalline films of PSP could be grown by Hot Wall Epitaxy (HWE) on well-defined crystalline mica substrates [6]. It was shown that a self-organization of PSP molecules occurs during HWE resulting in large scale ordered „needle„ like structures with a length to width ratio up to 500. However, the growth process of such high anisotropic structures was not clear jet.

In this paper the early growth stage of the PSP films on mica was investigated, in order to find the process controlling parameters.

2. Experimental details

High purity PSP was purified by threefold sublimation under dynamical vacuum. The used substrates were freshly cleaved (001)-oriented mica. The vacuum during growth was about $6x10^{-6}$ mbar and the PSP source temperature was fixed at 240°C. The substrate temperature was varied from 70 to 170°C, growth time was in a range from 14 sec to 60 min. Further growth details can be found in Ref. [6].
The film morphology was imaged by atomic force microscopy (AFM) using AutoProbe CP PCI Microscope.

3. Results and Discussion

The PSP film morphology with increasing growth time is shown in the AFM images of Fig. 1. In this series of experiments the substrate temperature was 90°C. The surface morphology changes drastically if growth time is varied from 14 to 25 sec. After that only continuous changes in PSP islands dimensions are detected, as

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quantitatively depicted in Fig. 2. This behaviour can be interpreted as evidence that PSP grows on mica in the Stranski-Krastanov (layer by layer + three-dimensional islands) growth mode well known in inorganic heteroepitaxy.

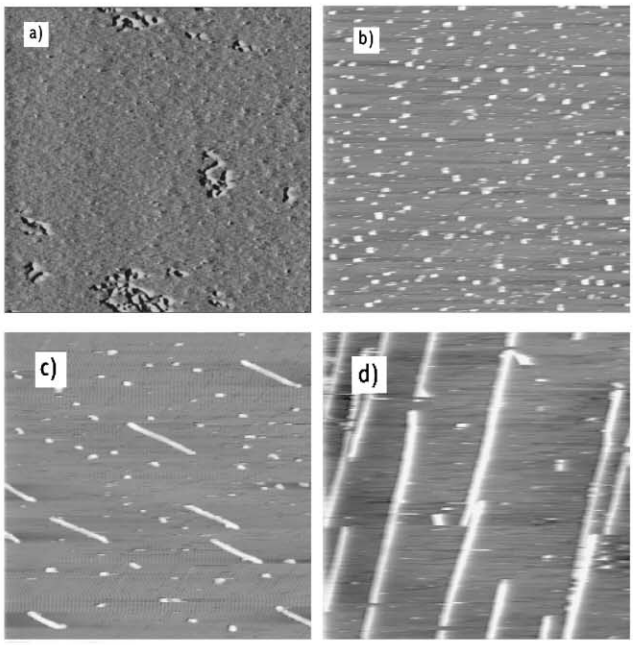

Fig. 1. 5μm × 5μm AFM images of the PSP films grown at a growth time of a) 14 sec; b) 25 sec; c) 46 sec; d) 94 sec. The substrate temperature was 90°C.

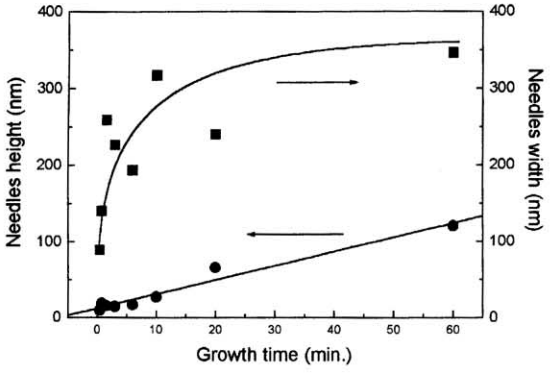

Fig. 2. Quantitative analysis of three-dimensional PSP islands (needles) on mica. Plotted is the average needles height and average needles width versus growth time for a substrate temperature 90°C.

At the early growth stage the surface morphology was strongly depended on the substrate temperature. As shown in Fig. 3 (in this series of experiments the growth time was 46 sec) the layer grown at low temperature (79°C) consists dominantly of randomly oriented islands, while at higher substrate temperatures (up to 170°C) the typical needle like structure with very elongated islands develops.

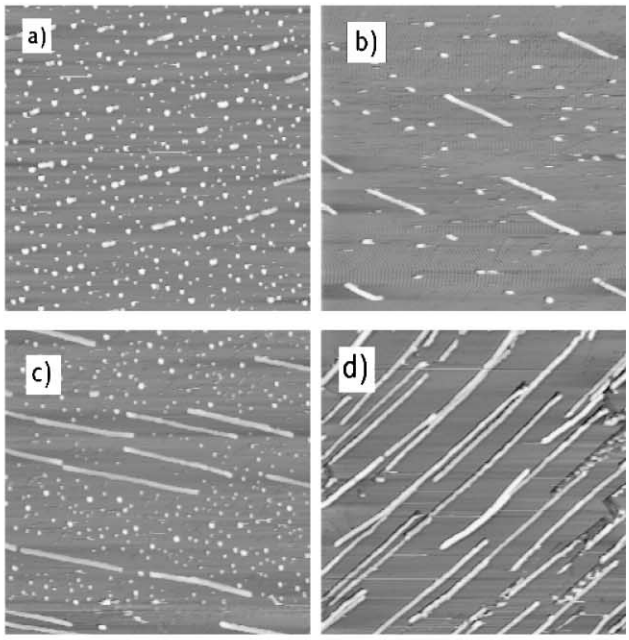

Fig. 3. 5μm × 5μm AFM images characterizing the surface morphology at different substrate temperatures: a) 79°C; b) 90°C; c) 110°C; d) 150°C.

4. Conclusion

It could be shown that the growth of PSP films can be controlled mainly by the substrate temperature. That means that growth methods, like the HWE, working close to thermodynamic equilibrium, can be successfully used to fabricate highly ordered organic structures.

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