

Para- sexiphenyl/C₆₀ bi- and multilayers grown by hot wall epitaxy

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Abstract

We have shown that highly ordered single and multilayer PSP/C₆₀ structures could be grown on mica by Hot Wall Epitaxy. Therewith C₆₀/PSP bilayers show a surface morphology, which strongly depends on the layer sequence in the structure.

Keywords: Epitaxy, Thin film structures, Fullerene, Oligo-phenylene, Atomic force microscopy

1. Introduction

Conjugated oligomer/fullerene bi- and multilayers are very interesting for photovoltaic devices due to the ultrafast photoinduced charge transfer, which occurs in this case at the interface [1]. The interface morphology, molecular packing and structural properties of the donor and acceptor layers are essential for the photovoltaic response of conjugated oligomer/C₆₀ bilayer devices.

This work focuses on the study of multilayers of para - sexiphenyl (PSP) and C₆₀ grown by Hot Wall Epitaxy (HWE). In contrast to the physical vapor deposition or molecular beam epitaxy [2-4], the HWE allows growing epitaxial layers close to thermodynamic equilibrium. As a consequence the organic molecules can find the most suitable arrangement before being incorporated into the crystal lattice, resulting, as will be shown, in highly ordered epitaxial bi-and multilayer structures.

2. Experimental details

PSP and C₆₀ were purified by threefold sublimation under a dynamical vacuum of 1x10⁻⁶ mbar. The used substrates were freshly cleaved (001)-oriented mica or chemically cleaned glass and ITO coated glass. The vacuum during growth was about 6x10⁻⁶ mbar. The films were grown at a fixed PSP- and C₆₀ -source temperature of

240°C and 400°C, respectively. The wall temperature was in the range of 240-260°C for PSP growth and 400-420°C for C₆₀. The substrate temperatures were varied in a 70-180°C range. The further growth details can be found in Ref. [5].

The film morphology was imaged using optical microscopy and atomic force microscopy (AFM). The AFM was conducted using NanoScope IIIa Microscope operated in contact mode in air.

3. Results and Discussion

Fig.1 shows typical AFM images of single layer samples of PSP grown on amorphous substrates as glass (Fig.1a) and ITO coated glass (Fig.1b). In both cases the films consist of islands whose sizes increase with growth temperature. This is similar to results obtained for PSP and α -sexithienyl (T6) films grown by physical vapor deposition on GaAs or mica [2,4]. At substrate temperatures higher than 180°C no film growth was observed. As depicted in Fig.1a, PSP on glass forms a more compact film compared to PSP on ITO.

Fig.2a shows a typical AFM image of single layer sample of PSP grown by HWE on crystalline mica. In this case, in contrast to glass substrates, PSP forms a large scale ordered structure, consisting of well-oriented crystallites looking like long "needles" separated by rather flat areas.

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As shown in Ref. [5] the needles are strongly anisotropic geometrically and optically and their axes align according to one preferential direction predetermined by the crystal lattice of mica. Such large scale ordering was not observed for comparable systems like T6 on mica [4] or PSP on GaAs [2,3] grown by other techniques.

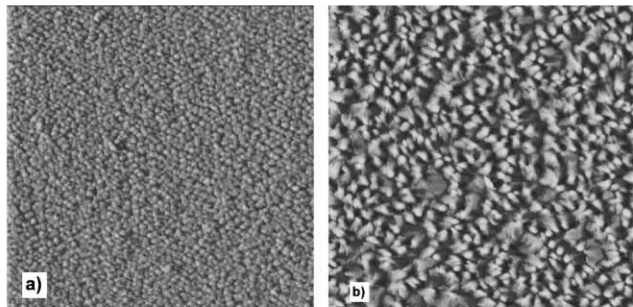


Fig. 1. 10 x 10 μm AFM images (so called “deflection or error” images of the feed back signal) of PSP films grown at 70°C. Deposition time-60 minutes. a) glass substrate; b) ITO substrate.

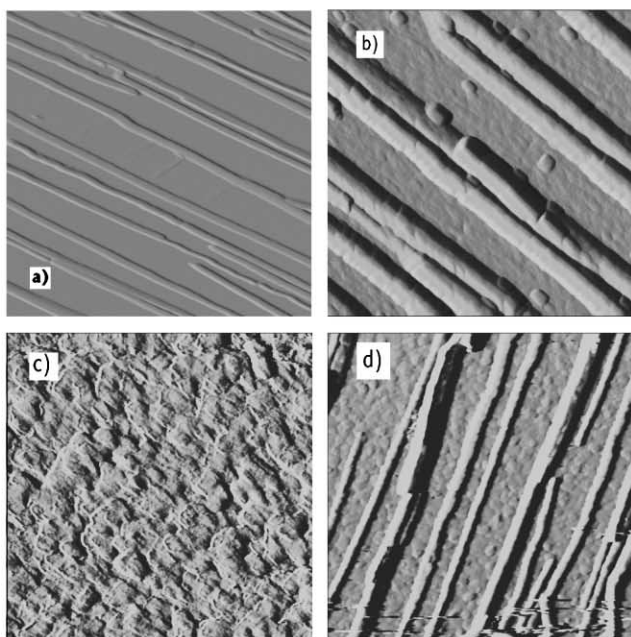


Fig. 2. 5 x 5 μm AFM images of PSP/C₆₀ structures grown on mica at 130°C: a) single layer of PSP; b) bilayer PSP/C₆₀; c) bilayer C₆₀/PSP; d) multilayer 4 x {C₆₀/PSP} grown on PSP buffer.

Also bi- and multilayers of C₆₀/PHP were grown on mica substrates. It was found that the nature of first layer determines to a great extent the morphology of the overgrown structure. Namely, if the first layer on the mica substrate is formed with PSP (see Fig.2b and 2d) the typical large scale ordered needles structure is preserved even after

further deposition of several layers of C₆₀. C₆₀ forms on PSP surface well-shaped epitaxial islands (compare Fig.2a and 2b), which orientation is mostly aligned with those of the PSP needles. On the other hand, deposition of PSP on mono crystalline C₆₀ film grown on mica (see Ref. [6]) results in much less oriented islands of PSP. In this case no large-scale ordered structure like “needles” was detected (compare Fig.2a and 2c). These observations suggest that a crystalline substrate favour growth along preferential directions.

4. Conclusion

Highly ordered single and multilayers structures of PSP/C₆₀ were grown on mica. A self-organization of PSP molecules occurs during HWE growth on mica resulting in „needle“ like structures with a strongly expressed preferential direction. In contrast to PSP growth on mica, single films grown on glass or ITO consists of disordered islands. C₆₀/PSP multilayers show a strong dependence of its morphology on the layer sequence in the structure. The potential of the HWE technique to grow highly ordered structures, demonstrated in this work, has interesting aspects for optoelectronic devices based on conjugated oligomers.

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