Growth kinetics, structure, and morphology of para-quaterphenyl thin films on gold(111)

S. Müllegger,[a] I. Salzmann, and R. Resel
Institute of Solid State Physics, Graz University of Technology, Petersgasse 16, A-8010 Graz, Austria

G. Hlawacek and C. Teichert
Institute of Physics, University of Leoben, Franz Josef Strasse 18, A-8700 Leoben, Austria

A. Winkler
Institute of Solid State Physics, Graz University of Technology, Petersgasse 16, A-8010 Graz, Austria

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The adsorption, desorption, and growth kinetics as well as the thin film morphology and crystal structure of *p*-quaterphenyl (4P) grown under ultrahigh vacuum conditions on single crystalline Au(111) have been investigated. Thermal desorption spectroscopy (TDS) reveals two distinct first-order peaks attributed to monolayer desorption followed by a zero-order multilayer desorption. The saturation coverage of the full 4P monolayer has been quantitatively measured with a quartz microbalance to be 8×10^{13} molecules/cm^2. Using low energy electron diffraction the structures of the 0.5 and 1 ML (monolayer) adsorbates have been studied, showing highly regular arrangements of the 4P molecules, which are affected by the (111) surface structure. At the transition from 0.5 to 1 ML a structural compression of the overlayer has been observed. The behavior of thicker 4P films has been investigated by combined TDS-XPS (XPS—x-ray photoelectron spectroscopy). A temperature-induced recrystallization process at about 270 K has been observed for a 7 nm thick 4P film grown at 93 K, corresponding to a transition from a disordered layerlike growth to a crystalline island growth. *Ex situ* optical microscopy and atomic-force microscopy investigations have revealed needle-shaped 4P islands. Applying x-ray diffraction the crystalline order and epitaxial relationship of the 4P films with 30 nm and 200 nm mean thicknesses have been determined. [DOI: 10.1063/1.1767154]

I. INTRODUCTION

Conjugated organic materials have become promising candidates for various applications in molecular electronics and optoelectronics.[1–3] Amongst other materials oligophenylenes have been successfully used as active materials in organic light-emitting diodes[4,5] or in organic thin film transistors.[6] The fabrication of well-oriented highly crystalline thin films as well as the control of the organic/substrate interface are important not only for optimizing the device performance but also for exploring the underlying physics.[7,8] Several studies have been carried out on oligophenylene thin films grown on various substrates concerning the crystal structure,[9,10] thin film morphology,[11] and optical and electronic properties.[12–14]

The focus of the present study was to investigate the adsorption/desorption kinetics, the structure, as well as the thin film morphology of our model system *p*-quaterphenyl (4P), grown on single crystalline Au(111) under well-defined conditions. The emphasis was placed on the application of surface-sensitive techniques to investigate the organic/substrate interface. A variety of analytical methods were applied such as thermal desorption spectroscopy (TDS), x-ray photoelectron spectroscopy (XPS), Auger electron spectroscopy (AES), x-ray diffraction (XRD), optical microscopy (OM), and atomic-force microscopy (AFM). In particular, the structure of the 4P overlayer in the submonolayer and monolayer regimes was investigated using low energy electron diffraction (LEED).

II. EXPERIMENTAL METHODS

The sample preparation as well as the TDS, XPS, AES, and LEED measurements were performed *in situ* under ultrahigh vacuum conditions with a base pressure of $\sim10^{-10}$ mbar. The substrate was a high-purity Au single crystal (MaTecK GmbH) cut along the (111) plane with an angular deviation of less than 0.4°. It was cleaned by standard Ar^+-ion sputtering (5×10^{-5} mbar, 1 kV) for 30 min and subsequent annealing at 870 K for 10 min. AES and XPS were used to check the purity of the Au surface. In this context it should be noted that some 4P dissociation was observed on the Au(111) surface upon heating of a 4P film, resulting in a remaining carbon coverage of about 0.03 monolayer (ML). Higher carbon coverages could intentionally be obtained by x-ray irradiation of a 4P film. The influence of a carbon precoverage on the kinetics and growth of 4P films on Au(111) will be treated in detail in a separate publication.[15] For the present investigations the Au sample was thoroughly cleaned prior to each 4P film preparation step in order to ensure a minimum influence of surface carbon on

[a]Author to whom correspondence should be addressed; Electronic address: stefan.muellegger@tugraz.at

