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IT-14-O-1830 In-situ Dynamic SPM Studies of Organic Semiconductor Thin Film Growth on Silicon Oxide

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The physics of organic field effect transistors (OFETs) is strongly correlated with the organization of the organic semiconductor. The optimization of device performance requires a deeper understanding on how the morphology evolves during the growth of the semiconductor. As reported in the literature, charge transport characteristics such as charge carrier mobility and threshold voltage is dependent on the thickness of the active layer of the OFET channel and on the growth condition. In the case of molecular semiconductors, which are deposited on silicon oxide by high- or ultra-high vacuum sublimation, the molecular organization arises from the nucleation and growth phenomena occurring at timescales which are often not easily accessed by standard ex-situ characterization. We use in-situ dynamic scanning probe microscopy (SPM) to study the early stages of growth of a conjugated oligomer semiconductor, viz. sexithienyl (T6), on a technologically-relevant substrate, native silicon oxide/silicon wafer. In an ultra-high vacuum chamber (~10-10 mbar) a Knudsen cell produces a thermal beam of T6 molecules with a rate of about 1 Å/min. In order to capture the dynamics of local growth of T6, a quasi real-time Atomic Force Microscopy (AFM) measurement during growth is employed. During the AFM measurement, the molecular beam is blocked by a cell shutter which allows us to visualize a static image of the growth process. When the static image is acquired, the tip is retracted to a sufficient distance in order to prevent shading of the molecular beam and the next deposition begins. Non-contact AFM images of the same sample area is acquired every 20% ML, till 5MLs, to be mounted into a movie depicting the growth of the ultra-thin film. In Figure 1. it can be appreciated the evolution of the first 0.5 ML of T6. A one to one correlation between same islands of different images is clearly visible due to the fact that we are scanning always the same zone. The coexistence of quasi-layer-by-layer and 3D growth modes, the latter promoted by heteronucleation on surface defects, is observed. By performing the experiment at different temperatures, RT, 50°C, 80°C, 100°C and 120°C, we aim to extract the relevant molecular energy barriers of T6 thin film growth: desorption energy, layer-dependent diffusional barriers and Erlich-Schwoebel barrier. Previous work, extended only up to 3 MLs, estimated the following values: 0.53 eV, 0.15-0.20 eV and 0.070 eV, respectively. The Erlich-Schwoebel barrier is cause of the transition from layer-by-layer to island growth, which appears to be universal occurrence in organic semiconductor growth with important implications in the charge transport in OFETs.

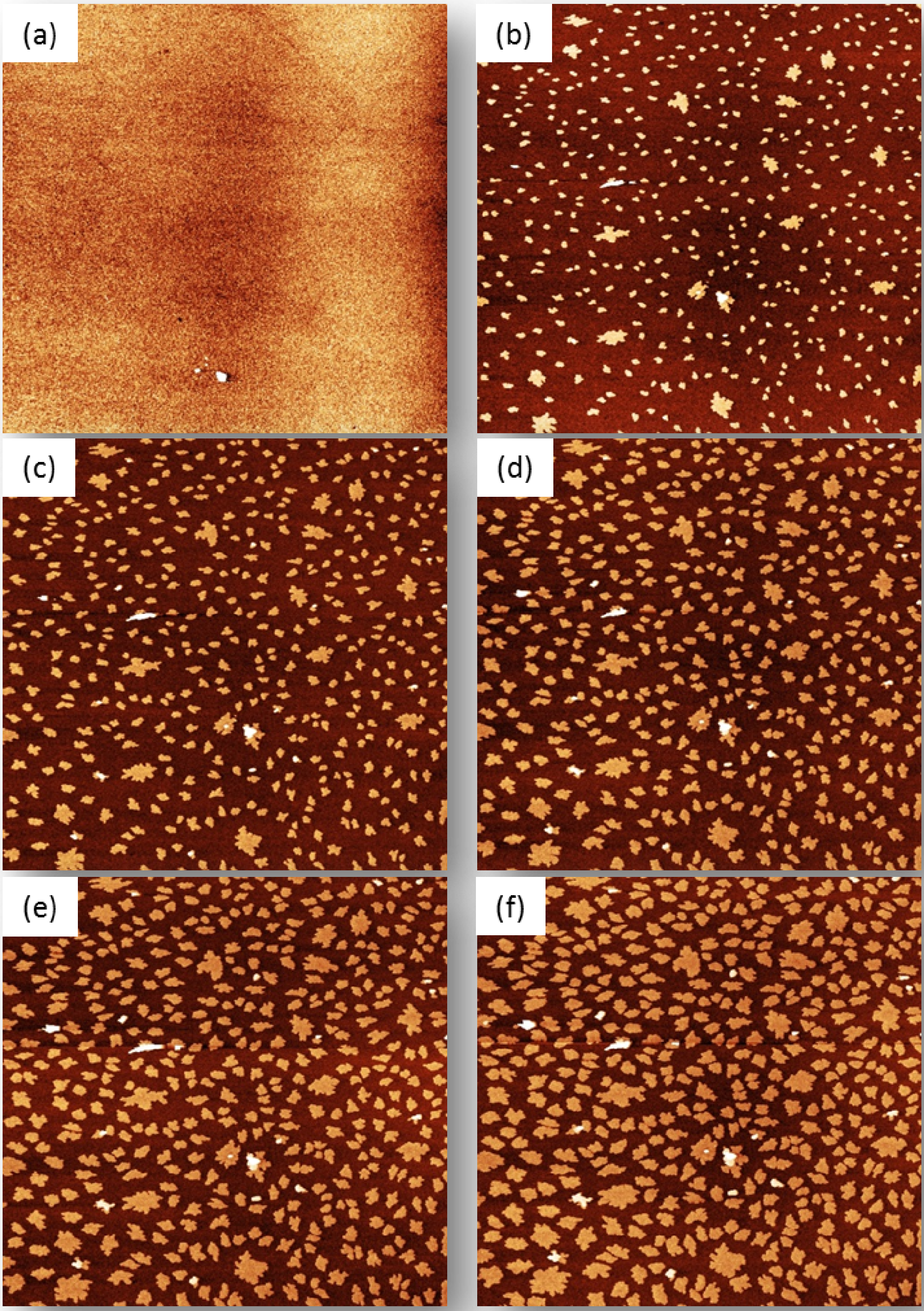

Fig. 1: AFM images of T6 on SiO2 with different coverages (scan size 6 x 6 µm2). a) bare substrate; b) 0.1 ML; c) 0.2 ML; d) 0.25 ML; e) 0.3 ML; f) 0.4 ML.