Manipulation of organic “needles” using an STM operated under SEM control

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Abstract

Nano-sized P4P (para-quaterphenylene) organic crystallites grown on a gold substrate were removed and redeposited using the tip of an STM. The controlled lift-off of the needle-shaped crystallites was imaged by a simultaneously operated SEM. The forces exerted by the metal STM tip on the nano-crystal during this nano-manipulation process could be determined by monitoring the deflection of the STM tip. After the lift-off process the former contact area was imaged using the STM. These STM micrographs clearly demonstrate that the region between the needles is covered by a P4P layer with a thickness of at least 3 nm.

1. Introduction

Organic molecular beam deposition (OMBD) can lead to the formation of rather complex structures ranging from an almost epitaxial growth of the organic molecules to the occurrence of dewetting resulting in the formation of differently shaped islands [1]. Currently, single-crystalline needle-like shaped crystallites formed when oligophenylenes (e.g. para-quaterphenylene (P4P) and para-hexaphenylene (P6P)) are deposited on solid substrates using OMBD are attracting a substantial amount of interest with regards to application in optoelectronics [2–6]. Whereas originally the growth of these organic “needles” was discovered on mica substrates, more recent work has demonstrated that also on metal and metal oxide substrates appropriate growth conditions result in the formation of needle-like structures [6–8]. In a previous study we have demonstrated that on polycrystalline Au substrates the P4P needle growth is favoured on terraces with a width less than 2 nm or on crystalline surfaces consisting of (110) terraces.

The needles are oriented predominantly normal to the Au(1 1 0) direction above a critical terrace width and perpendicular to the steps below a critical terrace width [9]. In this previous study the question remained open whether the area between the needle-like structures is covered by a P4P monolayer containing flat lying molecules typical for the deposition of aromatic molecules on metals or whether a thicker organic film is present. In this study we have used the tip of an STM operated under SEM control to selectively remove single nm-sized organic P4P needles and to subsequently investigate the former contact area in STM mode.

2. Experimental

The growth of P4P multilayers on a recrystallized Au foil (thickness 100 μm) at room temperature was carried out under UHV conditions using organic molecular beam deposition [9]. Prior to P4P deposition the gold foil was cleaned by sputtering with Argon ions (1 kV, 5 x 10⁻³ Pa) and subsequent annealing (at 1000 K, resistive heating) cycles in UHV until no contamination of the surface could be seen in X-ray photoelectron spectroscopy (XPS). Most important, the sputtering/annealing procedure (repeated