BRIDGING NANO AND MACRO WORLDS WITH WATER MENISCII: ATTOMOL CHEMISTRY AND NANOFABRICATION BY LOCAL OXIDATION NANOLITHOGRAPHY

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Scanning probe-based lithography has opened a variety of fascinating methods for the modification of metallic, semiconducting, biological and organic surfaces [1]. However, only a few of them seem suitable for large scale fabrication of nanostructures. The sample requirements (ultra high vacuum) in some cases or the extreme dependence on tip conditioning in others have limited their application.

Local oxidation or nano-oxidation lithography is arguably the most promising SPM-based approach for the fabrication of nanoelectronic and nanomechanical devices [2]. Here we describe the major features of local oxidation nanolithography when this is performed with the AFM tip several nanometers above the sample surface. This requires the use of a dynamic AFM tip and its operation the low amplitude solution or non-contact mode [3].

In a typical non-contact AFM oxidation experiment, the tip is placed a few nanometers above the sample surface. In a rich water vapor ambient the application of a voltage between tip and sample drives the oxidation of the surface. The oxidation is mediated by the formation of a field-induced water bridge. Once a liquid bridge is formed, its length and neck diameter can be modified by changing the tip-sample separation [4]. The liquid bridge provides the ionic species and the spatial confinement to oxidize semiconductor, metallic and organic surfaces. The small number of active ionic species within the bridge, a few attomoles allows a very precise control of the lateral and vertical size of the oxide.

The minimum feature size is determined by the size of the liquid bridge and the electrical field distribution inside it. We have measured the linewidth of silicon oxide isolated lines and forming packed structures. The structures have been fabricated in the proximity of an object of known shape and size. The comparison between local oxide structures and sexithiophene islands reveals that AFM images reproduce faithfully the size and shape of local silicon oxides. The oxide lines on silicon have a trapezoidal shape with a flat section at the top. The angle with the horizontal ranges between 3 and 8º. We have produced linewidths of 7 nm and 20 nm at the top and base respectively. Shallow angles imply a feature size of 14 nm for an oxide protruding 1 nm from the surface [6].

Several applications of local oxidation in the fabrication of nanometer-scale devices will be presented, such as: (i) arrays of 5000 dots with a periodicity of 40 nm and an average width of 10 nm, (ii) masks for template growth of organic molecules. Specifically we present a process for nanoscale fabrication of ordered monolayer films of conjugated organic molecules The process is based on the integration of local oxidation nanolithography of the substrate and template growth of the molecular thin film.

Finally we will present a method to turn the sequential AFM local oxidation process into a method for parallel oxidation of macroscopic cm^2 surfaces. The method requires the simulatanous formation of millions of nanometer-size liquid bridges [6].

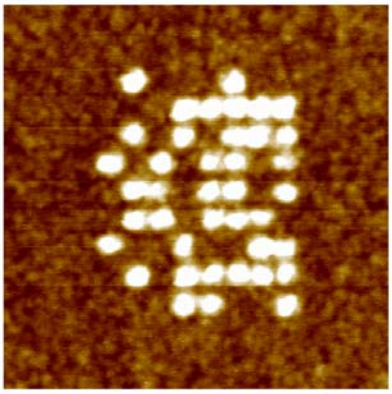
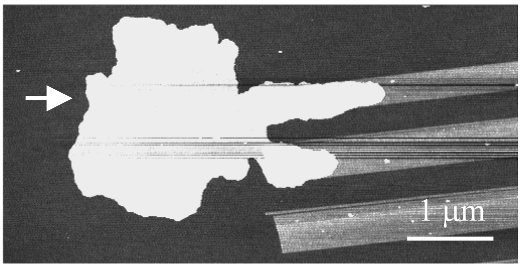


Image of π (3.14159265358979323846) in binary code written on a silicon surface. Each dot (SiO_x) is about 25 nm in diameter.



Anysotropic growth of conjugated molecules on local oxide stripes [7]

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