AFM LITHOGRAPHY AND ITS APPLICATION TO METAL BASED QUANTUM DEVICES

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Scanning probe Microscopes offers powerful methods for patterning surfaces with a resolution limit beyond lithography processes based on resist exposure. Since STM and AFM operate in near field regime, lithography far less affected by diffraction and proximity effect which arise with optical or e-beam lithography.

Local anodisation with an AFM is a versatile method to make nanoscale quantum devices [1,2]. Here we present results based on the controlled oxidation of metallic ultra-thin films.

We start from a niobium film (2 to 5 nm-thick) epitaxialy grown on sapphire upon which the AFM tip is scanned in contact mode. Under voltage pulse with 40 % relative humidity local electrochemistry takes place. As the electric field is confined under the tip, oxides lines are grown with a present 20 nanometers width resolution on Nb and can reach 12 nm resolution on NbN [1].

Adjusting the film thickness and the tip bias the oxidation depth can be either partial or total, thus allowing us to fabricate three kinds of basic structures: nano-bridges, tunnel junctions [3], and completely insulating patterns.

In order to improve our current 12-20 nm linewith resolution [fig 1], we also addressed the issue of an enhanced field focalisation by making nanotube ended tips in situ made by chemical vapor deposition [fig 3].

Making connected devices require two steps. Firstly a prefabrication of micro strips with an atomically controlled surface, and the AFM nano-oxidation itself. The Strip oxidation is either total or partial, which lead to three-dimensional nano-constrictions. Such a process provides an original fabrication method for electrical transport studies at mesoscopic scales. Two types of circuits have been made: superconducting junctions (SQUID devices) operating at low temperatures and Coulomb blockade devices working in the normal state of the metal [5].

Transport measurements taken from 30mK to 300K will be presented. The modulation of the SQUIDs critical current is a signature of the physical phenomena occurring in the nano-bridges. In particular, we deduce [6] that nano-bridges dimensions lie in the range of the superconducting coherence lengh (about 10nm). In Coulomb blockade based structures, we present a single electron transistor which drain source current exhibit Coulomb-blockade oscillation in the nanoamps range at 4K. Furthermore our technology easily provides model system to study dynamical Coulomb blockade.

References:

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Figures:

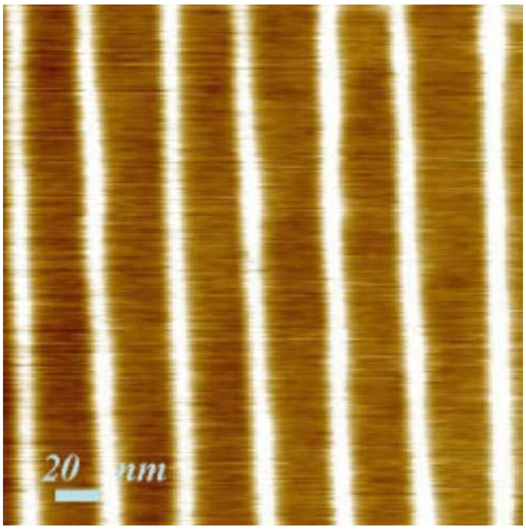

Figure 1: 12 nm width oxide lines made by AFM lithography on a 4 nm thick NbN film

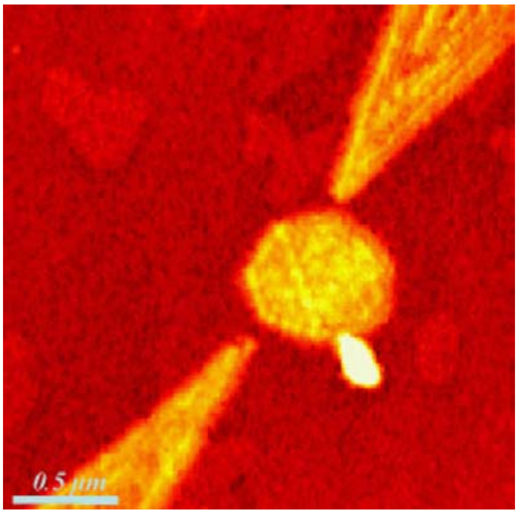

Figure 2: first demonstration of a AFM made SQUID coupled to a single iron nano-crystal

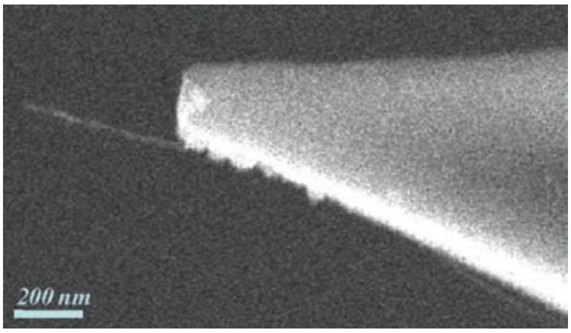

Figure 3: CVD Grown SWNT nanotube on a commercial AFM-tip.

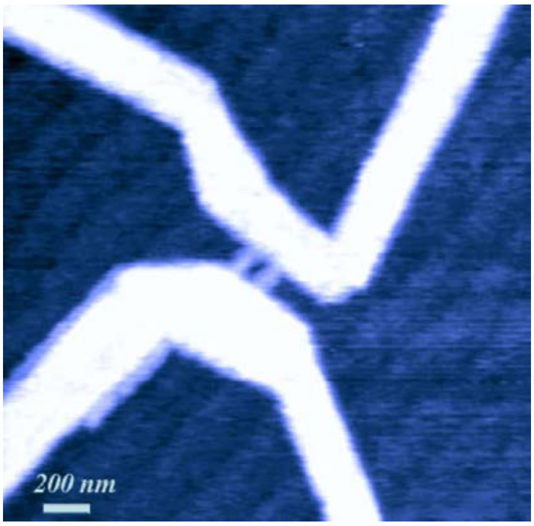

Figure 4: Single electron transistor with nanoscale in-trench barriers, made with AFM lithography.