Subproject B6: Force sensor arrays for Atomic Force Microscopy

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1 Introduction

In the project B6 of the SFB 379, cantilever arrays for Atomic Force Microscopy (AFM) are developed. In the first three years of the project till 2003, the general applicability and the function of single devices have been studied. A specialized measurement set-up has been developed which is able to work with the cantilever arrays and to evaluate the signals from two or more cantilevers simultaneously. The main part in 2004 was the application of the new devices for some new physical experiments.
On the way to these experiments, the procedures for tip etching and the materials used to contact the single cantilever membranes had to be improved [1,2]. The following report will shortly consider some basic improvements of the cantilever arrays and then describe their usage in a physical experiment.

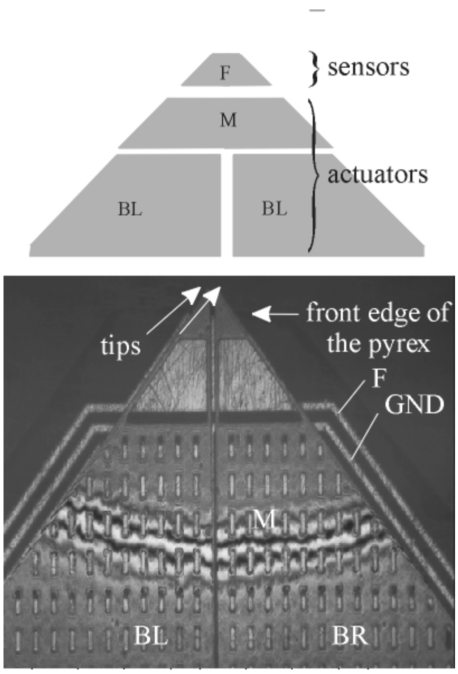

Fig. 1: Sketch of the electrode structure and interference microscope image of a real double cantilever device.

2 Cantilever development

2.1 Basic principle

The multiple cantilever devices consist of a silicon membrane and a glass substrate. They are anodically bonded onto each other. While the glass substrate provides an electrode structure (Fig. 1), the silicon is devided into single membranes by sleshes, each of them contacted to a separate electrode via the bonding connection. The movable cantilever parts have about 10 µm distance to the underlaying electrodes.
Each cantilever membrane consists of an actuator part, which allows a slow vertical movement of the tip over a range of up to 6 µm, and a sensor part, which is used for the force measurements to work in the dynamic mode AFM.
Based on geometrical considerations it is possible to form tips at the outermost end of each cantilever.

2.2 Tip geometry

The tips are formed by an anisotropic etching of the partly oxidized silicon membrane as shown in Fig. 2. Changes in the processing of the silicon membrane and the usage of serial lithography (wafer stepper) instead of parallel lithography have lead to tip diameters of about 5 nm.

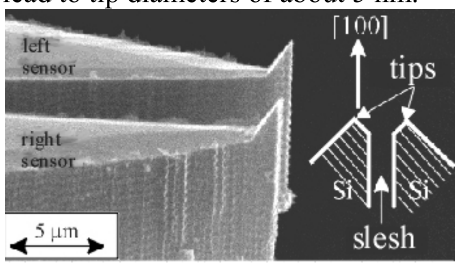

Fig. 2: Scanning Electron Microscopy image of the integrated tips. Sketch of the geometrical conditions for tip formation.

3 Mesoscopic temporary devices

3.1 Temporary devices

The aim of this physical experiment is it, to investigate surface states on semiconducting surfaces by measuring electrical characteristics in an nondestructive way. Our approach is therefore, to use a contacting device with two point contacts, which creates a transistor-like DUT (?) only for the moment the measurement is done. We designate it as a temporary device, because it can be created and cancelled on every surface point. [3]

3.2 Experimental procedure

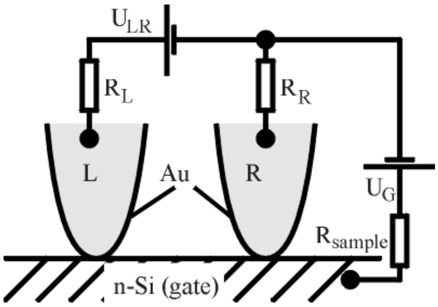

Fig. 3: Schematic drawing of the experimental set-up including electrical connections between substrate and contact tips.

A cantilever device with two gold coated silicon tips has been used to form two point contacts on a silicon surface (Fig. 3). The lateral distance between the tips is 10 µm. They are independently movable in vertical direction and the contact force is defined. While the contacts are closed, a complete set of electrical characteristics of the system is measured.

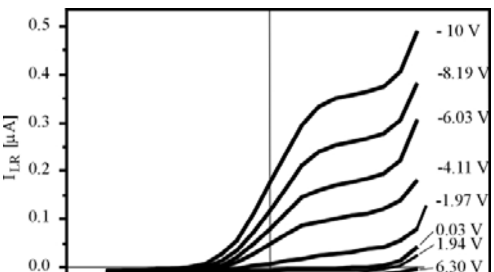

Fig. 4: Experimental data obtained on a hydrogen passivated Si(100)-surface with two gold coated n-Si-tips.

As sample surface, n-doped Si(111) was used. The n-Si/Au-interface should form a Schottky contact with a barrier height of 230 mV. The sample is mounted in the specialized AFM setup and contacted with InGa alloy. The contacts show an Ohmic resistance of less than 300 Ω.
The approach is done in a dynamic mode for each cantilever separately, while the measurements are done in a contact mode regime. In the results shown in Fig. 4, an Ohmic current and a field dependent current are found, demonstrating that the system behaves like a FET.

3.3 Results

The detected curves have been compared with circuit simulations (Fig. 5) in which the temporary device has been emulated as MESFET. In order to obtain simulation results that are close to the detected curves, the contact resistance of the sample had to be increased to over 5 MΩ.

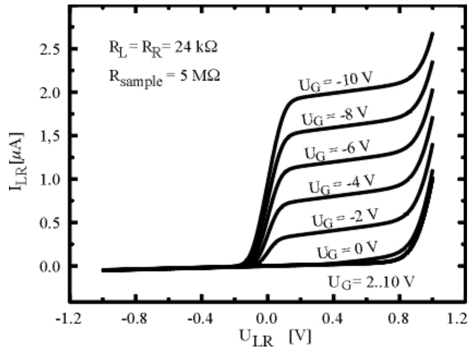

Fig.5: Best fitting simulated curves and parameters used for simulation.

From these simulations together with the measurement results it has been concluded that the coupling between the substrate surface and the bulk material is very weak in the created temporary device. The detected conduction processes take place at the surface or at the interface between Si and SiO_2. The bias dependence of the detected current proves that the current is influenced by the electrical field applied through the bias voltage.

4 Related works

An important task in new physical experiments is the preparation of suitable samples. For the silicon samples used in the descibed experiments, a glove box with clean room conditions has been built up. The samples are prepared in cooperation with the Hahn Meitner Institute in Berlin. Other samples prepared in our group contain special nanostructures for imaging, as porous alumina on silicon [4] or monolayers of organic molecules on crystalline surfaces [5, 6].

5 References

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