Journées Nationales en Nanosciences et en Nanotechnologies (J3N)

IMPROVE-LM Imaging probe for vacuum environment and liquid medium

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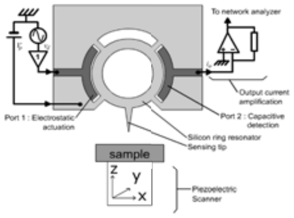
Abstract

The dynamic modes of the Atomic Force Microscope allow measurement of force variations under the picoNewton range. But to probe soft matter or biological nanosystems dynamics in liquid environment, we face the difficulty of the liquid motion which dampens the oscillating cantilever. To minimize the hydrodynamic forces, we choose an oscillation mode that reduces the velocity gradient between the active tip and the surface. The design of the NEMS sensor is based on a silicon nano-electromechanical resonator with integrated actuation/detection and nanotips. The aspect ratio of the tips must be very high, and will be obtained by grafting carbon nanotube (CNT) at the apex.

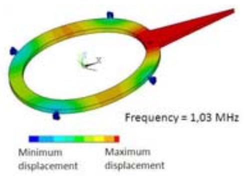
Conception and realization

Scheme of the force sensor



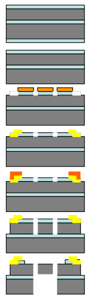
The resonator holds the active oscillating tip. The whole NEMS with its electrical connection is set at the free end of the cantilever.

ANSYS modal simulation



Displacement of a 250µm radius ring for an elliptic mode strain drived with a frequency of 1,03MHz.

Process Flow

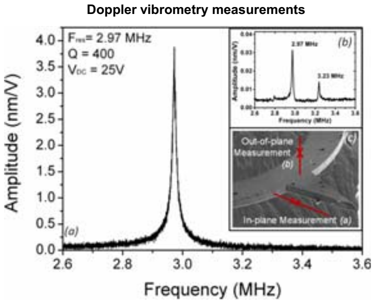


- SOI 20µm + wet oxide 600nm
- Oxide removing from the back side
- Front side lithography Reactive Ion Etching of the oxide
- Lift-off Pt/Ti/Pt/Au on contact
- Contact protection by resist
- Si etching using "bosch" process on the front side
- Si etching using "bosch" process on the back side and releasing

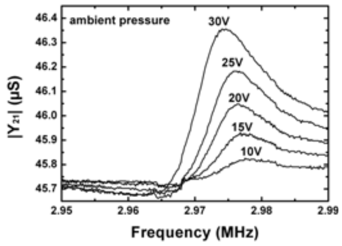
SEM picture of the silicon ring resonator

Characterizations

Doppler vibrometry measurements

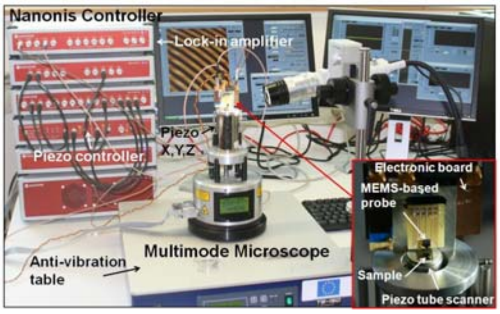


Electrical characterization

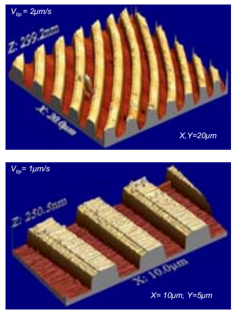


Admittance magnitude spectrum versus DC polarization

First AFM experiments



Topography of silicon trenches

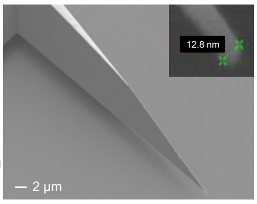


Current developments and perspectives

In-plane nanotips

Process flow

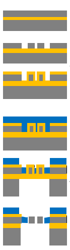
- SOI 5µm → silicon etching
- Low Temperature Oxide deposition
- Masking
- Oxide windows opening
- TMAH silicon wet etching
- Oxide removing



SEM picture of one in-plane tip

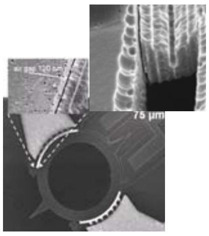
Small air gap < 100 nm

Process Flow



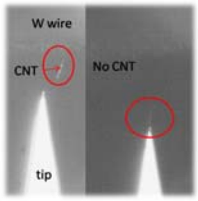
- SOI 5µm
- Dry etching
- Thermal dry oxidation
- Polysilicon deposition
- Polysilicon etching And back side etching
- Releasing

SEM pictures of the air gap



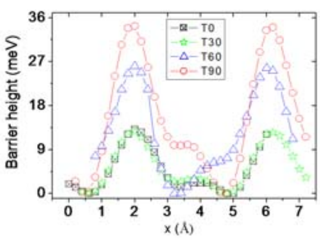
Carbon Nanotubes grafting

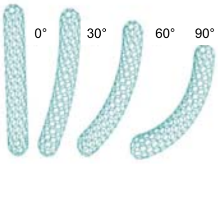
Optical image of one resonator approaching a tungsten wire



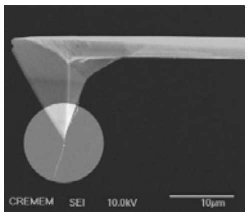
SEM picture of the tip close to the tungsten wire carrying nanotubes

Carbon Nanotude AFM tips



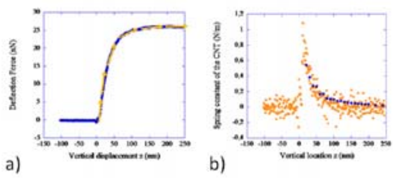


Simulated barrier height for different angle of contact between one carbon nanotube AFM tip and the surface. For a normal contact (T=0°), the barrier height is 0.5 k_BT @ 300K, for a contact angle of 90°, the barrier height is 1.4 k_BT.



SEM picture of one carbon nanotube grafted at the end of an AFM tip

Cantilever properties			Nanotube properties		
Resonant frequency	Quality factor	Stiffness	Length	Radius	Bending stiffness
62924 Hz	110	1.7 N/m	7 µm	35 nm	0.02 N/m



Comparison between the spring constant of the carbon nanotube described in the table determined by the deflection force curve (a) and the displacement of the resonant frequency of the thermal noise spectrum. The spring constants calculated from the deflection curve (a) thanks to the local slopes (yellow arrows) are plotted in blue on the curve (b) which is a good agreement with the values extracted from the thermal noise measurements (orange dots on (b)).

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