特 集 8
研 究 速 報

Trends in Nanoscale Science and Technology: Nanocantilever Fabrication, Force Gradients and Local Elasticity Measurement

ナノスケール科学技術における傾向：ナノカンチレバーの製作，発生力と局所的な弾性の測定

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1. Overview and situation of the project:

In the past two decades, the size of both electronic devices and micro-machined structures has been reduced drastically. The size standard of today's microtechnology is moving from micrometer to nanometer dimensions. Nanoscale shows qualitatively new phenomena such as changes of physical and chemical properties and laws depending on the dimension of the objects. Exploiting phenomena and interaction's mechanisms in nanoscale is one of the driving force for the future development of this interdisciplinary research field. Our goal is the development of new tools and sensing methods with which we can operate in the nanoscale with high accuracy and reliability.

Among the various techniques to interact with individuals, Atomic Force Microscopy[1] has gained a great interest in the last few years, according the ability to contact-less image and manipulate many kind of materials including biological and it can operate in vacuum, air or water medium. In dynamic-mode of AFM, the cantilever plays a key role for measurement of long-range force and force gradients. The forces acting on the resonating cantilever induce a shift in the resonant frequency. The increase of the operating resonant frequency allows to increase the frequency shift and then to improve the sensitivity to force gradient[2]. We investigated the two alternatives to increase resonant frequency allowing a significant enhancement of force sensitivity. Investigation of the potential of highest resonant modes of conventional micro-machined cantilevers is one possibility[3]. The other possibility is to fabricate a nanocantilever with a such small mass that it can vibrate at ultrahigh frequencies in the range of 100 MHz – 1 GHz. In this paper we report different aspects of investigations in nanoscale science and technology. Particular advanced techniques for nanofabrication, fine instrumentations for sensing in nanometer order and force interaction mechanisms are studied.

2. Nanofabrication

For the fabrication of the nanostructures such as cantilevers, different approaches and techniques can be used. Garcia and Binh [4–5] proposed a method based on surface self diffusion. It consisted of heating a STM tip in vacuum environment to produce mobility of atoms towards the apex of the tip and then to form the ball at the end of the tip. One of the criticisms of this technique is that the mobility of atoms occurs at various region of the tip that make the fabrication very difficult to control. On the other hand electrochemical etching techniques are well controlled and are currently used to fabricate sharp tips for scanning tunneling microscopy[6] and field ion microscopy (FIM)[7–8] We extended successfully chemical etching in order to fabricate nanostructures. It consist of use of a very thin electrolyte layer of around 1 μm thick in which a wire-sample to be etched is placed[9]. While controlling the position of the sample to be etched through the liquid film and etching time, different shapes can be obtained. Some samples are shown on next Figures.

3. Development of fine displacement measurement system: Fine Instrumentations

Optical methods for displacement measurement are very suitable for a wide applications. For Scanning force Microscopy, Optical Beam deflection[10] and interferometry[11] are the most employed techniques. Each of these methods has drawback and advantage. Optical Beam deflection is much sensitive to local

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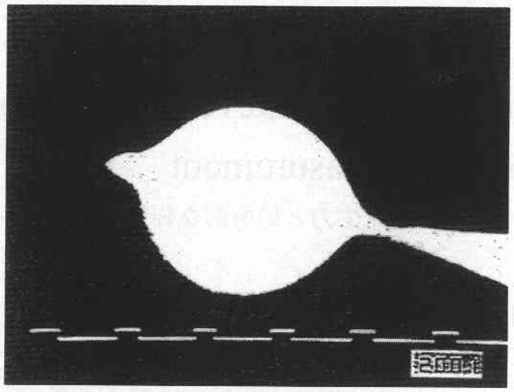

Fig. 1 nanoball

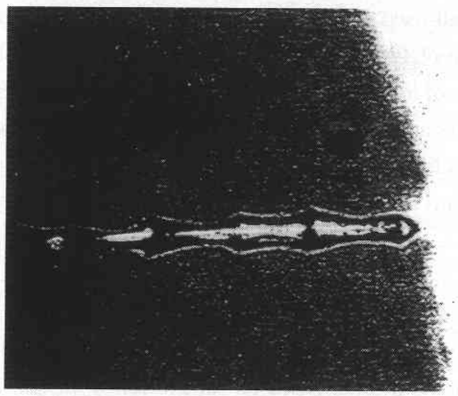

Fig. 2 nanostrutures

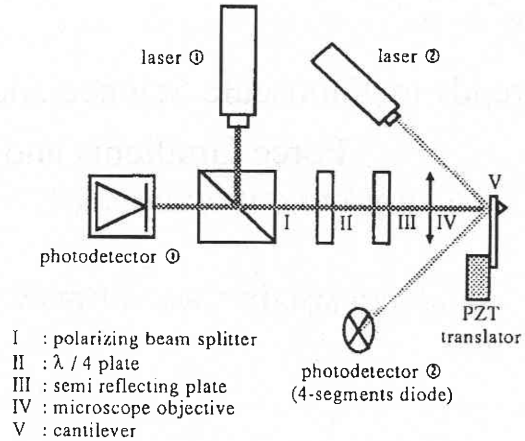

Fig. 3 Experimental setup: Fabry-Perot Interferometer ∂ and Optical Beam Deflection β

Fig. 4 Zinc Oxide whisker on a tungsten metalic tip

Fig. 5 Interferences fringes near the whisker

deflection of the target. On the other hand it is well known that interferometry is much sensitive to normal displacement. We implemented an original technique combining both methods in order to characterize resonant structures with multi-degrees of freedom[12]. The experimental setup for the simultaneous detection is shown on figure 3.

These technique is actually under investigation in order to develop high speed measurement bench. For submicron size Targets, we are investigating an other original technique. It is based on local interferometry due to diffracted light by the target. Interference between diffracted light and incident light induces conical shape fringes that can be seen around the nanostructure. For this experiment, we have been using ZnO whiskers of around 200 nm leg's diameter (Fig. 4 – Fig. 5).

4. Conclusion and Future directions

For the future work, high speed controller and RF electrical circuit will be fabricated. Measurement of frequency shift of the nano-cantilever with high accuracy and resolution is one of the most important experiment. This part is now in process and will be followed to test force measurement and manipulation with the nanocantilever. This experiment requires very precise and fast RF- instrumentation.

(Manuscript received, September 26, 1997)

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