

ANALYSIS OF MODULATION MODE ATOMIC FORCE MICROSCOPY ON THE BASIS KANTELBERG MECHANICAL TYPE

This paper is considered and analyzes the modulation mode by scanning the surface of an atomic force microscope based cantilever mechanical type. The developed method for calculating the forces Van der Vals to configure the interaction of bodies.

Keywords – cantilever, atomic force microscope, probe, microscope

Introduction

One of the most modern devices, which are widely used in various Microsystems, is the atomic force microscope (NFM) [1]. Atomic force microscope - a device that allows using kanelberg to receive images and to investigate various properties of solid surfaces with atomic-level resolution. Currently, the AFM has become an indispensable tool for research in many fields of science and technology. First of all, it is physics and surface chemistry, biology and medicine, engineering and microelectronics. Atomic force microscope probes the surface of a sample with a sharp probe, which is located on the free end of the console Canceled.

Force arising between the tip and the sample surface, cause deformation of the console, which is in the process of scanning is detected in the optical system. The signal from the optical system is used to build an image of the surface. Depending on the scanning distance there are three basic modes of operation of the NFM contact mode, contactless mode, napivkoloniyu mode (vertical distance scan may vary widely). For all modes there are two methods of signal registration: the direct measurement of the deviation console Canceled (mode topography and the mode of lateral forces) and modulation measurements (registration amplitude, frequency or phase console kanelberg and duprene mode).

Interest calculating the trajectories of the motion of sandovich sensors NFM. This interest is caused mainly by two reasons. First, calculations provide a more correct interpretation of experimental data obtained using NFM. Secondly, calculations allow a deeper understanding of the interaction between the probe and surface in modern Microsystems recording and reading information. The calculations are normal and lateral movement trajectories console kanelberg NFM in the approximation of the effective mass of the oscillator. The calculated forces (attraction and repulsion) for probes of different forms.

Calculation of forces interaction

For calculation of the interatomic potential uses a standard approximation:

$$U(r) = U_0(X^2 - 2X), \quad (1)$$

where the first term in brackets considers repulsion, and the second is the attraction of atoms; r - the distance between atoms; U_0 - the depth of the potential well; X - some function, dependent on distance.

If we assume that the atoms of the probe are characteristic of Van-der-Vals forces a power dependence of the form $X = \left(\frac{r_0}{r}\right)^6$, where r_0 - equilibrium distance in the absence of chemical interaction, you will get the potential of Lennard-Jones:

$$U(r) = U_0 \left[\left(\frac{r_0}{r} \right)^{12} - 2 \left(\left(\frac{r_0}{r} \right)^6 \right) \right] \quad (2)$$

The atoms of the probe and the sample is evenly distributed across its volume. Taking into account (2) probes for various forms of the task force calculation is reduced to the calculation of the following integral:

$$\left. \begin{aligned} F &= -\frac{A}{2\pi} \int_0^\infty \left[(h+\xi)^{-4} - \frac{r_0^6}{5} (h+\xi)^{-10} \right] \Omega(\xi) d\xi; \\ A &= 2\pi^2 n_1 n_2 U_0 r_0^6 = \pi^2 n_1 n_2 C_6, \end{aligned} \right\} \quad (3)$$

where A - the constant of Kamakura; n_1, n_2 - the bulk density of the atoms of the probe and the sample; $C_6 = 2U_0 r_0^6$ - constant of Van-der-Vals; Ω - the cross-sectional area of the needle that depends on vertical coordinates.

The value of the interaction of macroscopical bodies received in additive approximation can be misrepresented 20-30% in General correct asymptotic behavior of the function at large distances [3]. To address this shortcoming is proposed rule "renormalisation of" constant interaction. The application of this rule gives this formula:

$$A = \frac{4\hbar\bar{\omega}}{4\pi} = 6\pi C \quad (4)$$

where C - constant of Liftshyts; $\bar{\omega}$ - characteristic frequency spectrum absorption.

For typical combinations of materials of the probe and the sample is in a narrow range from 0.01 to 0.1 eV.

After computing the integral (3) and replacing constants And constant, we obtain the following expression for the force of interaction:

$$F = -a \left(\frac{1}{h^n} - \frac{b}{h^{n+6}} \right) \quad (5)$$

where a, b, n - the approximation parameters depend on the tip shape and material properties of the sample and the probe.

The results form the needle to the pyramids and cones where the following notation is used: θ - angle at the vertex of a cone angle between opposite sides of a square pyramid.

For the needle in the form of a cone of the formula will be as follows:

$$\begin{aligned} a &= \pi C t g^2 \left(\frac{\theta}{2} \right) \\ b &= \frac{r_0^6}{56} \\ F_0 &= -\frac{6}{49} a \left(\frac{7^5}{b} \right)^{\frac{1}{6}} \\ h_0 &= 7^{\frac{1}{6}} b^{\frac{1}{6}} \end{aligned} \quad (6)$$

For the needle in the form of a pyramid formula will be as follows:

$$a = Ctg^2\left(\frac{\theta}{2}\right) \quad (7)$$

b , F_0 , h_0 - will the formula same as in the needle in the form of a cone.

Modulation mode

Oscillations of a beam kantelberg describes the differential equation in parts of the derivatives of 4-th order, analytical solution of which cannot be obtained. However, you can find a solution corresponding to the main tone (harmonic oscillations. It corresponds to the approximation of the effective mass of the oscillator. The effective mass is entered using the ratio $m = \frac{k_n}{(2\pi f_0)^2}$, where k_n and f_0 - rigidity and resonance frequency of the beam in a lack of interaction.

Let's write down the main beams kantelberg calculation of natural frequencies and stiffness kantelberg received at the close method of the Rayleigh-Ritz:

For rectangular beams resonant frequency will be determined by the formula:

$$f_0 = 0,162 \frac{d}{L^2} \sqrt{\frac{E}{\rho}} \quad (8)$$

and the rigidity of the beam Canceler:

$$k_n = \frac{EB}{4} \left(\frac{d}{L}\right)^3 \quad (9)$$

For triangular beams resonant frequency will be determined by the formula:

$$f_0 = 0,648 \frac{dtg^2\left(\frac{\nu}{2}\right)}{H^2} \sqrt{\frac{E}{\rho}} \quad (10)$$

the rigidity of the beam Canceler:

$$k_n = 4EB \left(\frac{dtg\left(\frac{\nu}{2}\right)}{H}\right)^3 \quad (11)$$

For cylindrical beams resonant frequency will be determined by the formula:

$$f_0 = 0,14 \frac{d}{L^2} \sqrt{\frac{E}{\rho}} \quad (12)$$

the rigidity of the beam:

$$k_n = \frac{3\pi d^4 E}{64L^3} \quad (13)$$

where L - the length of rectangular and cylindrical consoles; d - the thickness and diameter consoles; B - width consoles, H end ν - the distance and angle between the beams; E end ρ - modulus and material density.

Thus, the oscillations of a beam kantelberg considered fluctuations hypothetical point oscillator with effective mass m . Movement of such an oscillator described by classical equations of motion, which in our case takes the form:

$$\frac{d^2z}{dt^2} + 2\gamma \frac{dz}{dt} + \frac{1}{m} \left(k_n - \frac{dF}{dh} \right) z + \frac{F}{m} = \frac{F_u}{m} e^{-i\omega_{gen}t}, \quad (14)$$

where F - is determined by formula (3); γ - the attenuation coefficient oscillator in a vertical direction; F_u - the amplitude of the external force (its value depends on the modulation of voltage and properties of piezoelectric ceramics); ω_{gen} - the frequency at which violated fluctuations canceler.

The solution of equation (14) has the form

$$z = A e^{i(\omega_{gen}t + \varphi)} - \frac{F}{k_n} \quad (15)$$

where A and φ - the amplitude and phase of oscillations depend on the scanning distance.

The second term in the right-hand part of (15) describes the initial offset console canceler.

Conclusion

Analyzed modulation mode when scanning the surface by atomic-force microscope based cantilever mechanical type. Developed the method of calculation of strength van-der-Waals for configuration interaction phone by using this method, the dependence of the force-distance. Defined the basic formula for the calculation of natural frequencies and stiffness cantilever for rectangular, triangular and cylindrical beams.

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