MULTI DATA MODE METHOD IN THE SCANNING PROBE MICROSCOPY

S.P. MOLCHANOV, I.A. CHERNOVA-KHARAEVA
Technology research and development Institute CRC, Moscow, Russia

S.H. ABDULLAYEVA, S.D. ALEKPEROV
Institute of Physics of National Academy of Sciences of Azerbaijan,
Az-1143, H. Javid av., 33

Scanning probe microscope "ForceMaster-402MD" (Russia) combines structurally and functionally two devices with different principle of operation – scanning tunneling microscope and atomic-force microscope. All these facts allows surface of any substances with any degree of conductivity, and also surfaces of any dielectrics to be investigated in detail. This device provided with the unique so-called multiparameter method (this method covered by patent) which ensures possibility to obtain distribution map of some parameters of objects with the surface topographer (conductivity, polarization, thickness of adsorbent layer and etc.).

Scanning probe microscopy (SPM) is a well known powerful tool for surface topography investigations [1-2]. However, in most cases the image of topography does not answers all questions of the researchers. For complete information we frequently need the data on various physic-chemical, electrical, magnetic and other properties of the explored surface which would allow to distinguish or even identify the objects of various nature on a surface.

To solve this problem it has developed and permanently improves the new mode of probe microscopy – Multi Data Mode (MDM) (the patented method [3]). This mode has unique facilities to provide single-scan exploration of the surface to get the whole data set available in SPM. This ability is obvious and essential advantage over other SPM methods where as a rule we gain limited number of parameters using one device.

In probe microscopy, piezo elements of various kinds are used for precise surface scanning and a number of modulation techniques have been developed to eliminate viscous friction when moving a probe over the surface. In fact, a probe is not to be constantly in contact with the surface in any SPM. A reliable method would be the one that allows to bring a probe down to the surface, to make all the necessary measurements, to withdraw the probe into the region free of interaction, and then to move the probe to another point (Multi Data Mode method). In "ForceMaster-402MD" we used a beam deflection registrations scheme. Tips on the end of a DI rectangular silicon cantilever and a home-made rectangular tungsten cantilever served as probes (fig. 1).

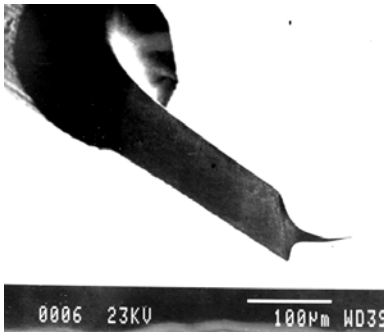


Fig.1.

To explain the principle of the operation of device, let us consider the behavior of a needle-probe on an elastic console near the surface under study [4]. Figure 2 (a) shows a typical dependence of the force *F(z)* acting on the tip upon the distance from the surface. Let us begin with the simplest case of pure solid surface. Assume the cantilever stiffness *k* is less than the maximum of function *dF/dz*. If the cantilever holder is positioned in point z_1, the force of attraction would bend the cantilever and the tip would be in point *A* which is the intersection of the curve *F(z)* and the straight line from point z_1, with the slope $tg\alpha = -k$, according to the conditions of force equilibrium

$$F(z) = k \times dx(z_1) \text{ with } dx(z_1) = z_2 - z_1$$

Now construct the plot of *dx(z)* versus the holder position (fig. 2 (b)) for decreasing *z*. In point *B*, where $dF/dz = k$ upon force equilibrium law, the condition of stable equilibrium is violated because $dF/dz > k$ to the left of the point, which situation forces the tip move to point *C*. The plot *dx(z)* would exhibit a jump. As *z* decreases, the function *dx(z)* is virtually a straight line with a slope of unity because of strong dependence of *F(z)* asymptotically approaching the *Y* axis. In point *D*, the sign change of *dx(z)* occurs, and this point can be termed the point of surface contact the point of surface touching. A set of these points describe the surface from the viewpoint of touching S_{tch}. By measuring the parameters of the *dx(z)* function, say, in an ***N×N*** square of point on the surface under study, we can reconstruct the relief S_{tch}, and create a map of heights of the constant gradient S_{tap}. If any other measurement *X* is made on the $N \times N$ points, this would give an additional map of the surface S_x by the parameter *X*. The property measured can be either the conductivity in the point *C* or the surface hardness as the slope of the function *dx(z)* in the region of repulsion *(z<0)*.

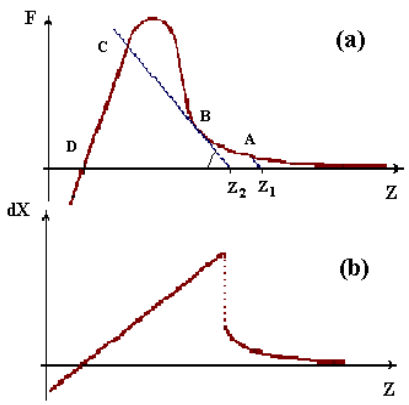


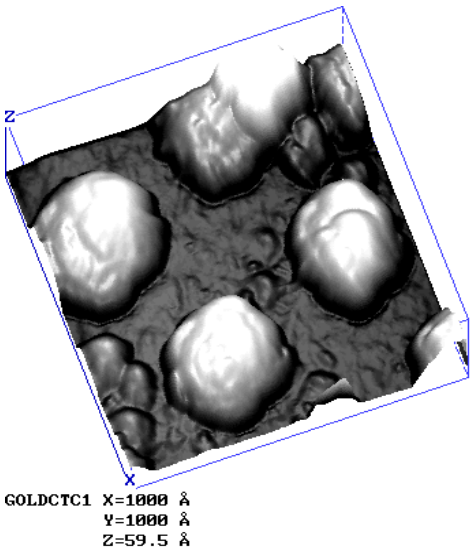
Fig.2.

MDM has peculiar abilities to explore surfaces with complex topography and large differences of heights. Moreover, it allows to exclude uncontrollable interaction of probe with sample, and artifacts caused by scanning process. In study of soft delicate objects the MD-mode can combine gentle action of tapping mode and non-contact mode with minuteness and high resolution of contact mode. The MDM image of the surface gives simultaneous and independent information about various surface layers including adsorbed layers and substrate. MDM solves problems associated with contamination and impurities. It opens the broad opportunities to study electrical, magnetic and polarization properties of surface and layers (including opportunities similar to Electric Force microscopy, Magnetic Force microscopy, Lift mode, Polarization mode, Scanning Tunneling microscopy and Scanning Tunneling Spectroscopy) together with adhesive forces and mechanical properties measurements (including opportunities similar to Phase Imaging mode, Force Modulation mode, Lateral Force mode).

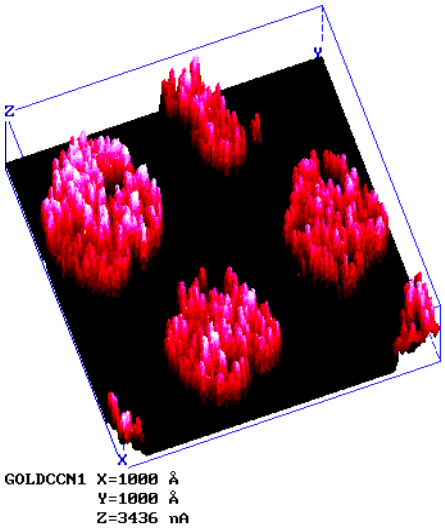
Below we present obvious example to demonstrate the potentialities of the method MDM. Research being held at the SPM-spectroscope "ForceMaster-402MD" (Russia) and electro conductive probe has also been used. A fragment of the matrix of golden islands on the surface of GaAs is presented in fig. 3 (a). The gold was based into the semiconductor to obtain an ohmic contact. The corresponding map of conductivity is shown in fig. 3 (b), which was measured on the sample at +0,3 V. The MD-mode image of the map of conductivity demonstrates that only golden islands have electrical conduction, and electric current isn't leak across of substrate of the GaAs.

The physical ground of the MDM provides the capability to register and build map of any kind of information the scanning probe microscopy does. Moreover, MDM enables to register the data inaccessible for other modes.

In MD-mode extraction of the surface topography and its properties, quantity of surface layers, their thickness, configuration and properties are not separated in time [5]. All measurements are carried out in the current point of surface simultaneously. It makes measured quantities comparable allowing to correct one using or relative the others, to divide the information on the surface object properties and the substrate surface, to build the distribution maps associated with and relative to the surface topography.



a)



b)

Fig. 3.

It's why the MDM image reflects the true picture of surface layers and their characteristics. The wide opportunities of MDM allows to obtain the results exclusive on the informational content, resolution and trustworthiness with high efficiency and reproducibility.

[1] *G. Binnig, H. Rohrer*. Helv. Phys. Acta. 1982, v. 55, pp. 726-735.

[2] *R.Z. Bakhtizin*. Sorosovskiy obrazovatelskiy j., 2000, t. 6, № 11, s. 1. (in Russian).

[3] *S.P. Molchanov and etc*. Patent № 2145055, Russia Federation.

[4] *S.P. Molchanov, V.V. Dremov*. All-Russian conference "Probe microscopy 99", Nizhny Novgorod, march 1999

[5] *S.P.Molchanov, I.A.Chernova-Kharaeva, S.H. Abdullayeva, S.D. Alekperov*. I International Scientific Seminar "Light in Nanosize Solids", Baku, 2004, September 22-28 (Proceeding of the Conference, pp. 47-48).

S.P. Molçanov, S.H. Abdullayeva, İ.A. Çernova-Haraeva, I.C. Ələkbərov

RASTR ZOND MİKROSKOPİYASININ ÇOX PARAMETRLİ METODİKASI

Rastr zond mikroskopu "ForceMaster-402MD (Rusiya) konstruktiv və funksional olaraq işləmə prinsipi müxtəlif olan iki cihazı özündə birləşdirir – rastr tunnel mikroskopu və atom-güclü mikroskopu. Bütün bunlar istənilən cismin və dielektrikin səthində misilsiz dəqiq tədqiqatların aparılmasına imkan verir. Bu cihaz unikal çox parametrli metodika ilə təchiz olunmuşdur (metod patentləşdirilib), hansı ki, səthin topoqrafiyası ilə birlikdə obyektin bölünmə növünün təyin edilmə xəritəsini almağa imkan verir (elektrikkeçirmə və s.).

С.П. Молчанов, С.Г. Абдуллаева, И.А. Чернова-Хараева, С.Д. Алекперов

МЕТОД МНОГОПАРАМЕТРОВОГО РЕЖИМА В СКАНИРУЮЩЕЙ ЗОНДОВОЙ МИКРОСКОПИИ

Сканирующий зондовый микроскоп “ForceMaster-402MD” (Россия) конструктивно и функционально объединяет в себе два прибора с различным принципом работы – сканирующий туннельный микроскоп и атомно-силовой микроскоп. Все это позволяет с необходимой детальностью исследовать поверхности любых веществ с любой степенью проводимости, а также поверхности любых диэлектриков. Этот прибор оснащен уникальной, так называемой многопараметровой методикой (метод запатентован), которая дает возможность одновременно с топографией исследуемой поверхности получать карты распределения электрических, магнитных и поляризационных характеристик поверхности.

Received: 12.01.05