NEAR-FIELD SCANNING OPTICAL MICROSCOPY AND SCANNING TUNNELLING MICROSCOPY IN DEFECTOSCOPY

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ABSTRACT

This paper is dealing with a conjuction of STM and SNOM methods in defectoscopy. First part is focused on common description of STM method, the tunnel effect and two modes of TS 3130 which is instrument for STM made by Tescan are described. Next part gives details about SNOM method and its advantages and disadvantages in the local nondestructive measurement.

1 INTRODUCTION

Defectoscopy went through huge improvement during last century. Until recently the word “nanotechnology” was only music of the future or hot object of the Sci-Fi discussions. In the present, thanks to many methods, we can observe tested items on the atomic level and herewith defectoscopy obtains new proportion. For better examination of the sample is good to use more methods of defectoscopy. These methods can offer us different view on the tested surface of the object. Two of the most used methods from SPM (Scanning Probe Microscopy) group are STM (Scanning Tunnelling Microscopy) and SNOM (Scanning Near-field Optical Microscopy). With regard to their similarity in this article is described connections of these ones.

2 TUNNEL EFFECT

STM method uses an effect known as a tunnel effect for testing procedure. This phenomenon is one of the headstones of quantum theory.

2.1 ONE-DIMENSIONAL TUNNELING

Figure 1 shows an energy level diagram for the system consisting of the sample and tip that are separated by an vacuum.[1] Here, the tip is considered to be a metal with a constant density of states, while the sample also contains a distribution of surface states as shown. When the sample and tip are independent, their vacuum levels are considered to be equal, as in Fig.1a, and their respective Fermi energies (or levels), E_f, lie below the vacuum level by their respective work functions Φ_s and Φ_t. The quantum-mechanical wave functions of the electrons are periodic in the solid and decay exponentially into the vacuum region like

$$\Psi = A\exp(-2\sqrt{2m(-E)}\frac{Z}{h},$$

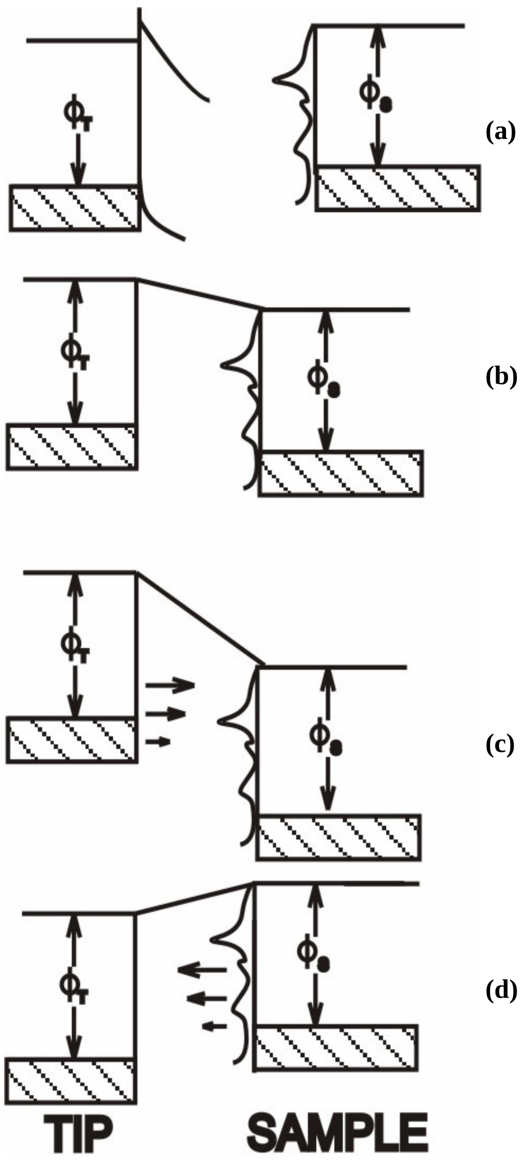

Fig. 1: *Energy level diagram of sample and tip*

where Z is the distance perpendicular to the surface plane and E is the energy measured with respect to the Fermi level. This energy-depend decay of the functions wave functions is also illustrated in fig. 1a, for different states of the tip. More strongly bound electrons have large negatives values for E and so decay quickly into the vacuum, while high energy states lying close to the vacuum level decay very slowly. The exponential decay of the wave functions onto the vacuum is often written in terms of a inverse decay length K as $\Psi = A$ exp (-KZ), where $K = 2\hbar H^{-1}\sqrt{2m(-E)}$. If the sample and tip are in thermodynamic equilibrium, their Fermi levels must be equal, as illustrated in fig. 1b. Electrons at tempting to pass from sample to tip (or vice versa) encounter a potential barrier, which is approximately trapezoidal in shape, but electrons can tunnel through, if the barrier is sufficiently narrow.

When a voltage V is applied to the sample, its energy levels will be rigidly shifted upward or downward in energy by the amount |eV|, depending on whether the polarity is negative or positive, respectively. At positive sample bias, the net tunneling current arises from electrons that tunnel from the occupied states of the tip into unoccupied states of the sample, as shown in fig. 1c. At negative sample bias the situation is reserved, and electrons tunnel from occupied states of the sample into unoccupied states of the tip, as in fig. 1d. Since states with the highest energy have the longest decay lengths into the vacuum, most of the tunneling current arises from electrons lying near Fermi level of the negative-biased electrode.

For any given lateral position of the tip above the sample , the tunneling current (*I*) is determined by the sample-tip separation (*Z*), the applied voltage (*V*), and the electronic structure of the sample and tip which is quantitatively described by their respective density of states. Information relies on changing the voltage V, but it can be obtained in a number of ways depending on which of the other variables are held constant and which are measured.

3 STM, TS 3130

STM belongs to the group of the methods with raster probe known as SPM (Scanning Probe Microscope). [2] These microscopes work in this way: the surface of the object is scanned by the help of thin mechanical probe, which is proceeding very close to the surface and the signal acquired from particular point forms subsequently whole picture of the object. The carrier of the information can be electric flow or voltage.

STM uses a tunnel effect, which is coming up when an electric charge breaches the air barrier. The electric charge breaches the barrier even if the distance sample-tip is very low (a few nm). Therefore we need to place the probe very close to the object. When electric current breaches the barrier the magnitude of this current can be read and compile one point of the image. Example of the STM microscopes is instrument made by TESCAN Company. Its name is TS 3130.

TS 3130 can operate in two modes, constant current mode and constant height mode.

3.1 CONSTANT HEIGHT MODE

The value of the tunnel current, which is thorough the air barrier is very depend on the distance between the probe and the sample. If a probe of the microscope is kept in constant height Z above the object, which is not ideally smooth, the electric current is changing in dependence on thin of the air barrier. If the size of the passing current is known, the relief of the sample can be reconstructed. Figure 2 shows a model of the probe-sample system during scanning the metal material.

3.2 CONSTANT CURRENT MODE

In this mode, the current is scanned, modified and fetched to the input of the nanomanipulator, whereby is kept constant distance between probe of the STM and tested sample. To construct the image is necessary to scan movement of the manipulator.

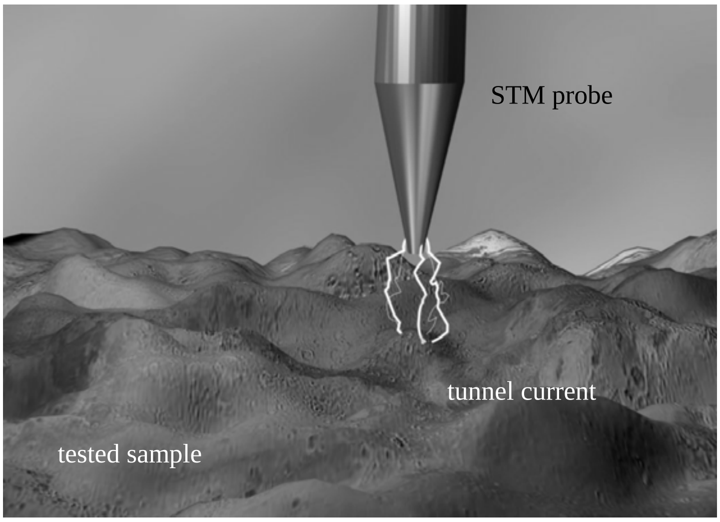

Fig 2: *Model of STM probe-sample system*

3.3 ADVANTAGES AND DISADVANTAGES OF STM:

Advantages:	**Disadvantages:**
STM method is very simple Resolution till 10 nm Service is cheap and simple Low claims on the construction of the probe Passing a diffraction limit Large application possibility Non-destructive method	Difficult setting of the apparatus Possibility to scan only conductive elements

4 SNOM

This method offers the use of a very small light source as the imaging mechanism. By using a quasipoint light source with a diameter much smaller than the wavelength of light, one can achieve resolutions better than the diffraction limit (~250 nm). To reach the resolution better then diffraction limit is necessary to lighten the sample from vicinity, often only a few nm. Thereby will be disturbed so-called “near-field”. Instruments of the SNOM method can operate in two principal modes, reflection and transmission mode.

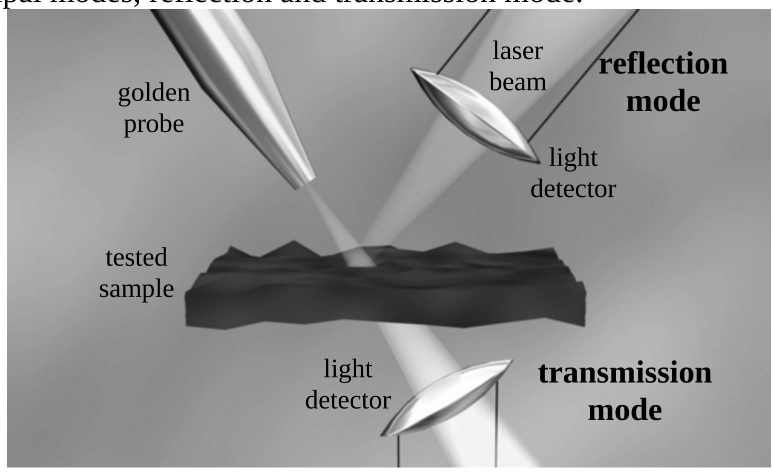

Fig. 3: *Reflection and transmission mode of the SNOM method*

Figure 3 shows the different between reflection and transmission mode. The transmission mode can be used only if the material is transparent. With regard to that, the use the reflection mode is necessary for opaque materials. STM method needs conductive material to its function. Only few materials are conductive and transparent at the same time, so if we want to use both methods together we need to use reflection mode.

If the sample is lightened through the very narrow aperture very close to the surface, the reflected light can’t expand and his intensity carries the information about the place under the probe. Expanding of the light behind the sample unaffects information about the tested sample. Resolution is in virtue of the size of the probe.

Typically laser light is fed to the aperture via an optical fiber. The aperture can be a tapered fiber coated with a metal (such as Al or Au). In our case a probe from single-mode fibre is going to be used. Our fibres made by SIM Company are coated with 100 nm layer of gold.

4.1 ADVANTAGES AND DISADVANTAGES OF SNOM:

Advantages:	**Disadvantages:**
Resolution is better than 50 nm	High claims on the construction of the probe
Passing a diffraction limit	High claims on the construction of the light detector
Large application possibility	Low intensity of detected light
Non-destructive method	
Possibility to test non-conductive materials	

5 CONCLUSION

By creating of the instrument, which can use SNOM and STM at the same time, it is possible through one scanning process to obtain two images of the tested material and use all advantages of both methods. Thanks to similarity of both methods it is possible to use only one probe for either side. If the scanning probe is coated by metal or another conductive material, there is a possibility to use it for STM and SNOM simultaneously. Movement of the sample below the probe performs a nanomanipulator. This instrument is manufactured by Physics Instrument Company. Both of the methods need to use nanomanipulator and it’s the one of the most important component for STM and SNOM. It can be used one instrument for both methods together. Thereby production of the system is getting cheaper and simpler.

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