NONDESTRUCTIVE TESTING AND TECHNICAL DIAGNOSIS AIDS OF NANOPRODUCTS

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The subject of the report is dedicated to development of non-destructive testing (NDT) and technical diagnosis (TD) apparatus based on utilization of various nanoeffects.

In Russia, there is an "Industry of nanosystems and materials" formed as one of the development line of high priority. Also, there was founded the Interdepartmental Scientific and Technical Council for the problem of nanotechnologies and nanomaterials. Nanotechnologies' application leads to revolutionary changes in development and production of constructional and speciality materials, allowing to develop materials and constructions with unique characteristics and controlled features.

Modern nanotechnologies utilize dimensional effects when characteristics of nanoparticles, threads, tubes, and coating drastically change in comparison with macroparticles of the same substance even at dimensions less than 100 nm.

Nanoparticles and nanotechnologies are being studied and controlled by means of optical and electronic microscopes but most commonly by scanning probe microscopes. All common methods can be divided into three groups:

- Scanning tunneling microscopy. Where maximum voltage is as high as 10V is applied between an electrodeductive probe point and a sample. And a tunneling current (dependent on properties and spacing of atoms on the sample surface being studied) is detected in a nanogap;
- Atomic force microscopy. Where detecting changes point to point in attracting force of a probe towards a surface. A probe is positioned at the end of a cantilever and is able to bend under the effect of low forces developing between the studied surface and the probe point. Deformation of a cantilever is detected according to deflections of a laser beam or by piezoresiting effect resulting from bending of a cantilever.
- Near-field optical microscopy. Where a probe is an optical beam guide tapering at the end, pointed towards a sample. At a small distance between a surface being studied and optical beam guide probe point, amplitude and reflected optical wave change and serve as a signal for three dimensional imaging of a surface.

The most important element of tunneling and atomic force microscopes is a probe located at a cantilever. The sharper a probe is the higher will be the resolution of an image.

Unique silicon probe for atomic-force microscopes is presented in Fig.1. It has radius of curvature of the end 2...3 nm with tip cone angle 3^0. The probe is necessary for nanostructures examination.

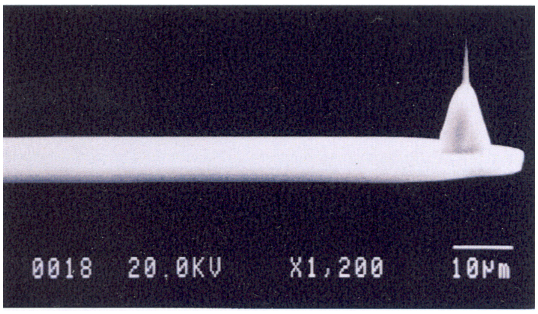

Fig.1. The "smart" probe.

Positioning systems are very important for probe methods. They are also rapidly developing using laser, capacitance, inductive methods and also elements on surface acoustic waves.

Exact positioning in probe microscopes and necessity of metrology of measurements stimulated methodology development to provide uniformity of measurements in the length range of 1nm...1μm, based on the principles of laser interferometry - phasometry. Fig.2 shows laser interferometr of nanodisplacements engineered at SRCSV (Moscow).

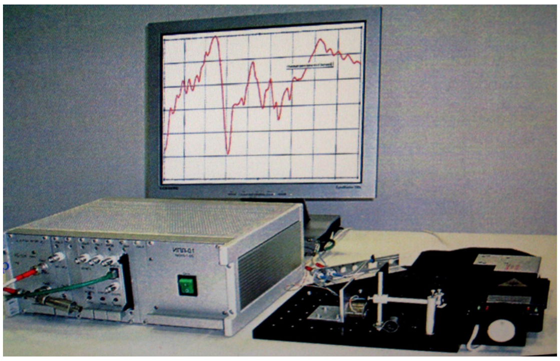

Fig.2. Laser meter of nanodisplacements.

This interferometr is designed for measurement of real-time linear displacements as well as for calibration of scanning and positioning systems in micro- and nanotechnologies, micromechanics, raster electronic microscopy and scanning probe microscopy. The range of displacement measurements lies within 1 nm and 10 mm with readability of 0.1 nm. Absolute error of measurements ranges from 0.5 to 3 nm.

At the same time, nanodisplacements can be also measured by other devices, for example by eddy current sensor or capacitance sensor of DT 6630 type ("Micro-Epsilon", Germany). They are designed for high-quality positioning and have remarkable resolution capability of 0.1 nm and excellent resettability of result of 0.4 nm.

Based on many probe microscopes whole nanolaboratories are created for the purpose of materials science and diagnosis, containing equipment for micromechanical tests and a variety of measuring techniques.

Development of **new generation NDT and TD** aids is inseparably associated with achievements of nanotechnologies themselves and nanosensors, nanodetectors, nanotransducers, nanoelements of electronic components and visual image systems created on their basis. Many nanotechnologies and nanotransducers utilize nanoeffects, dimensional effects, tunneling effect, superconductivity effects and giant magnetoresistance, quantum dots effects and drastic features change of composite nanostructures, negative exponent of refractive index and so forth. Thus, composite materials with electromagnetic properties which are extrinsical to any of composite elements are already created by nanotechnologies. They were named as metamaterials, among which metamaterials with negative exponent of refractive index are of the most interest. Image forming lenses made from such materials provide images of higher resolution, exceeding diffraction limit. Utilization of such elements in microwave, teracycle and optical diagnosis systems will, doubtlessly, increase their performance parameters.

New nanoscale ultrahigh-sensitized membranes dedicated for new generation vibroacoustic transducers will make it possible to create modern multichannel vibrodiagnostic systems for complex units and mechanisms.

Molecular filters and membranes, which were also created by nanotechnologies, enable to instantly increase strength of hazardous inclusions in the performance of analytical tasks of different industries, ecological monitoring, life-support and safety systems, creation of new types of antiterrorist devices such as gas-analyzers. Thus the new generation gas-analyzers "NanoSled" have sensitivity at the level of 10^{-14} г/см^3 at a very little analysis time.

Recently an active interest is taken towards the new types of materials – polymeric nanocomposites, which polymer matrix contain inclusions of nanoscale in the form of nanoparticles, nanoconductors, nanocoating of another substance. Such materials display unusual electrophysical, magnetic, catalytical and other chemical properties. Usage of such nanoelements makes it possible to produce compact matrices and portable analyzers of “electronic nose” type on their basis.

One nanotechnologic effect is knows as a giant magnetoresistance effect which occurs in 1 nanometer thickness ultrafine metal coating. Due to such a size, coatings acquired new magnetic and electric properties. The effect enabled to develop hypersensitive magnetic sensors of small geometrical dimensions. Magnetoresistant precision magnetic field transducers created on the basis of nanotechnologies made it possible to create matrix measuring transducers for magnetoviewers with hypersensitive and extended range of magnetic field measurement (see Fig. 3).

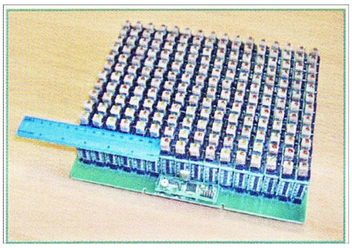

Fig. 3

Fig. 4

Infrared testing (IT) is a technology based on quantum wells - the new nanostructures, is developing and used in the new thermal viewers (see Fig. 4).

Nanotechnologies of semiconductor materials and heterostructures resulted in possibility to produce sensitive bolometers and terahertz emissions receivers which are fairly prospective in NDT and TD apparatus development.

Nanotechnology production can successfully be subjected to NDT and TD by means of already well-known and worth proven physical methods and technical means. There are many such examples: precise measurement of nanothickness using laser elliptometers and microwave methods; IT semiconductor heterostructures control by microscopes and nanoresolution X-ray microscopes; equal-density control of heat-protection elements made from superthin quartz fiber by means of deflected microwaves parameters detection; measurement of nanosolidity and roughness of surfaces; size control over nanopowder and other nanoparticles using laser diffraction analyzers.

Quality of coated surfaces in geometrical terms is usually determined by profilometers. Roughness is measured according to parameters Ra and Rz on the right-of-way base length below 6 mm. Roughness estimation error on modern portable devices with inductance and piezoelectric transducers reaches 10% in microroughness range from 10 nm to 40 μm (TR 200 device, China).

Microwave thickness indicator “Electrotest T” (Germany), Fig.5, is a typical example of SHF amplitude method employment. This device is operated on a frequency of 30 GHz in the range of thicknesses from 5 to 250 nm with measurement error ± 3% of measured value.

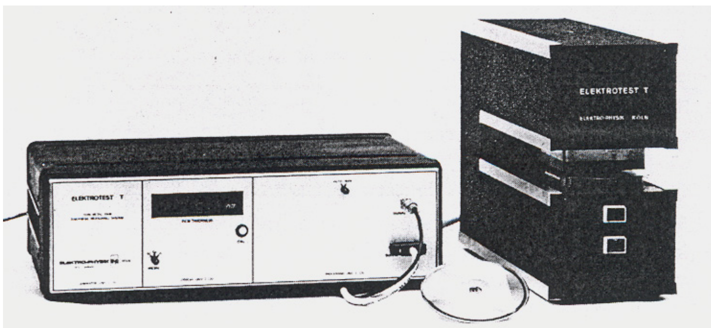

Fig.5. “Electrotest T”.

Locality of control lies within a circle of 10 mm diameter. Measurements are performed no-touch in the process of movement of coiled material between transmitting antenna and receiving antenna of microwave transducer. As a rule, among tested materials are aluminium, copper, silver, aurum, chrome and other materials that are applied on a dielectric basis in the form of thin films.

Thus, there is a close relationship between NDT/TD and modern nanotechnologies in their development.

Bibliography.

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