Moscow State Institute of Electronic Technology
(Technical University)

Zelenograd, Russia

Centre «Nanotechnologies in electronics»

Reporter: **Stas.V. Khartov**

Probe technology applications and molecule-based devices

THE BRIEF PLAN

- Historic background of the centre «Nanotechnologies in electronics», MIET
- Activities of the centre in the probe nanotechnology:

✓Probes and methods of their producing

✓ Objects visualization

✓ Objects manipulation

✓ Force Lithography

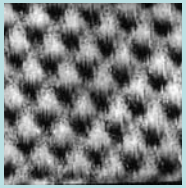
✓ Local anodic oxidation (LAO)

✓ Molecular conductors in polymeric matrix

& Conductive NT/polymer nanocomposites

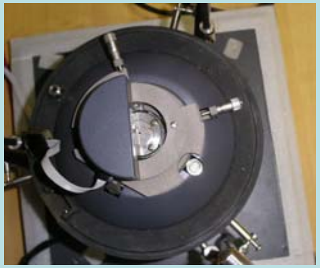
The Centre «Nanotechnologies in electronics», MIET

The first in Russia technological scanning tunneling microscope (1987)



Atomic resolution of HOPG surface

For the present moment the center has :



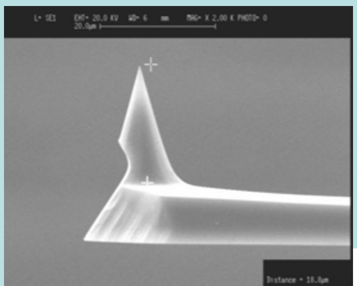
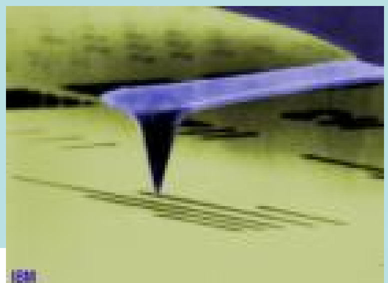
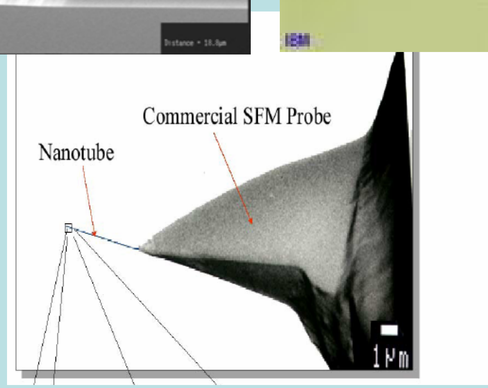
- Scanning probe microscope (SPM) for carrying out of precision lithograph (Solver Pro, NT-MDT)
- 3 universal SPM (NT-MDT)
- 5 scientific training SPM (Nanoeducator, NT-MDT)
- 2 scanning tunneling home-made microscopes (TTM)
- Equipment of molecular conductors formation

Installation of the first in the center ultra high vacuum SPM in structure of nanotechnology facility NANOFAB 100 (NT-MDT) with FIB and MLE blocks is planned.

NANOFAB 100 includes the three ultra high vacuum (10-11 Torr) chambers – analytical, loading and chamber of replaceable probe sensor assemblies

Probes and methods of their producing

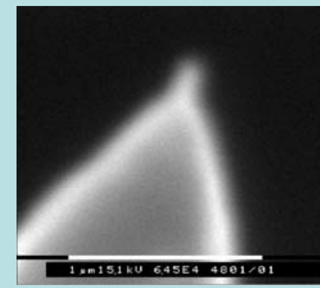
Atomic force microscope (AFM) probes

The basic material is Si;
The typical curvature radius is on the order of 10 nm; For aspect ratio increase the NT-based probes are applied

Scanning tunneling microscope (STM) probes

SEM image of Pt/Ir - probe (MIET, 2005)



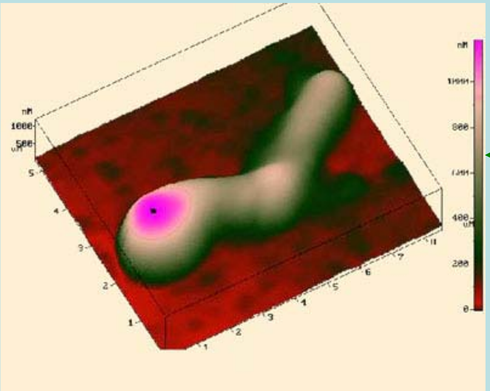
SEM image of W- probe (MIET, 2005)

Pt/Ir-probes are free from surface oxides and posts in manufacturing. The main method for preparing is mechanical cutting of Pt/Ir wire

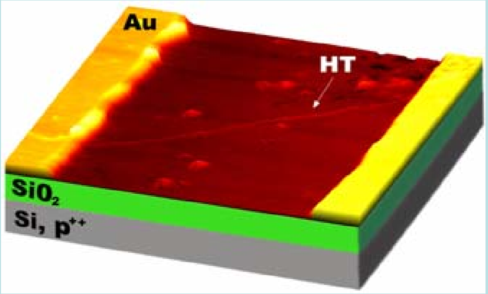
W-probes are prepared by electrochemical method. The typical curvature radius in our case is on the order of 15 nm and the aspect ratio is on a level of 30°

Primary application - objects visualization

Images of objects on insulating substrates

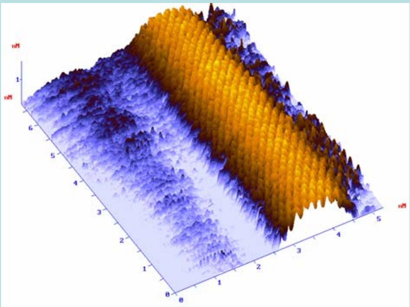


AFM image of Bacterium Corynobacterium diphtheriae on glass substrate (MIET, 2002)

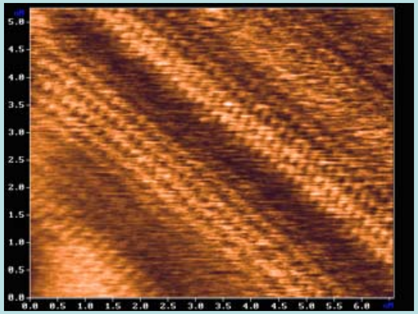


AFM image of NT between conducting paths (MIET, 2004)

Atomic resolution of carbon nanotubes in ambient conditions



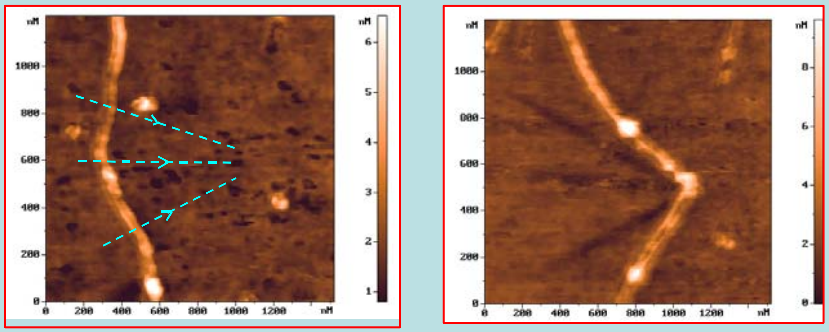
STM image of carbon nanotube (NT) (MIET, 2003)

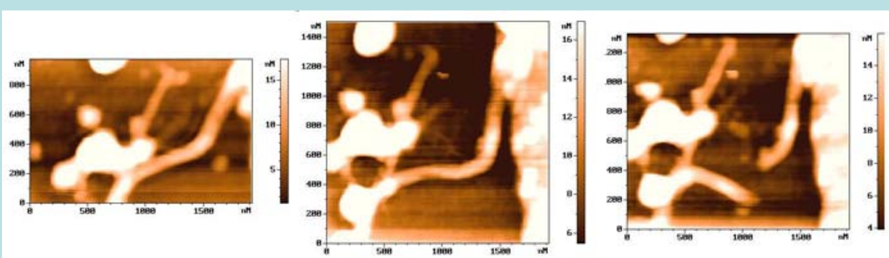


STM image of CNT bundle (MIET, 2003)

Micro and nanoobjects manipulation

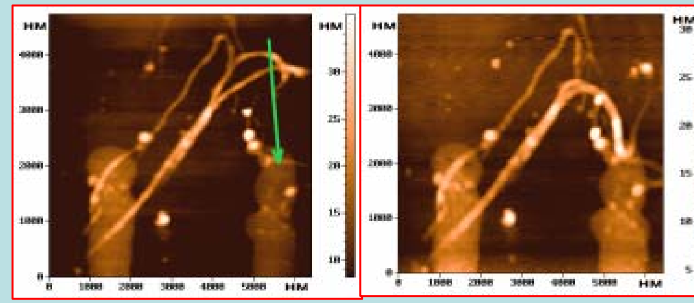
NT bending and rupture

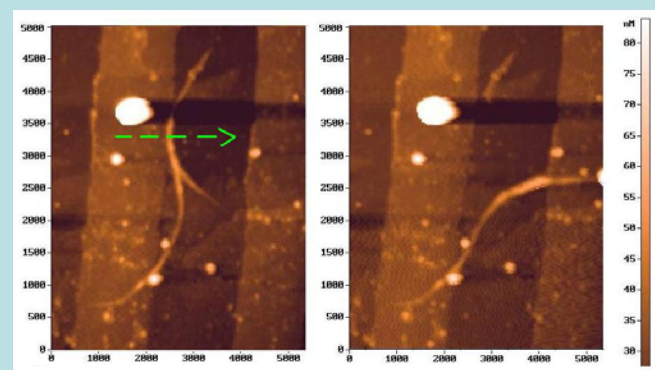




AFM images
(MIET, 2003-2005)

NT movement for formation of electric contact with path

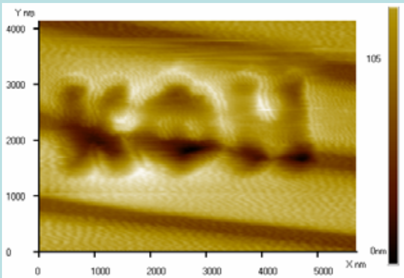




AFM images
(MIET, 2003- 2006)

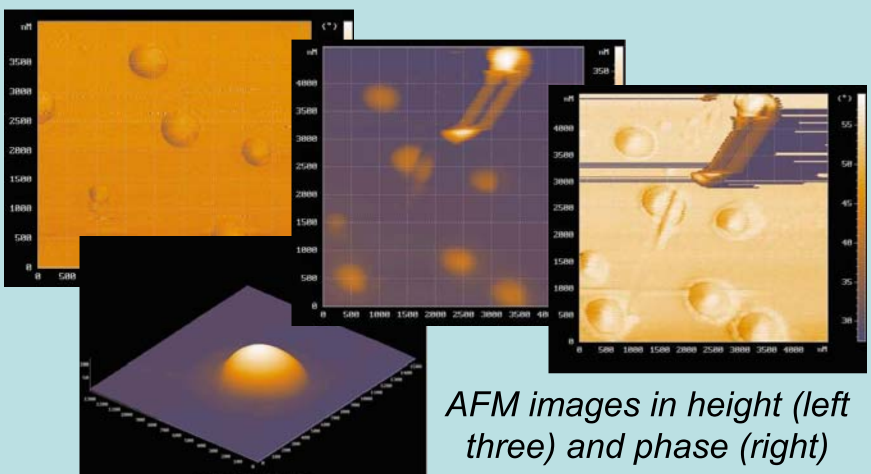
Force Lithography

Lithography on polymer (performed on SPM «NanoEducator»)



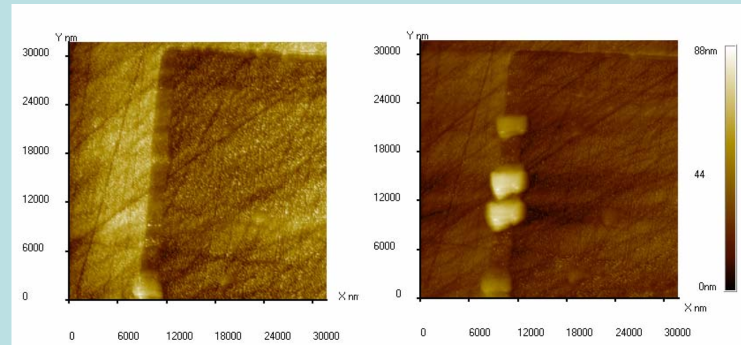
AFM image of polymer surface (MIET, 2005)

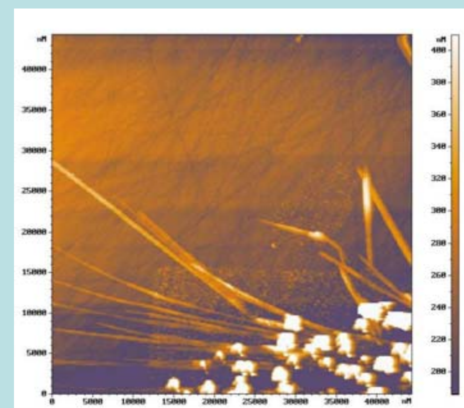
Breaking up of one of the knobs shows the viscous state of knobs' inside



AFM images in height (left three) and phase (right) modes (MIET, 2005)

Creation of the centers of NT growth on a film of catalyst (performed on SPM «NanoEducator»)

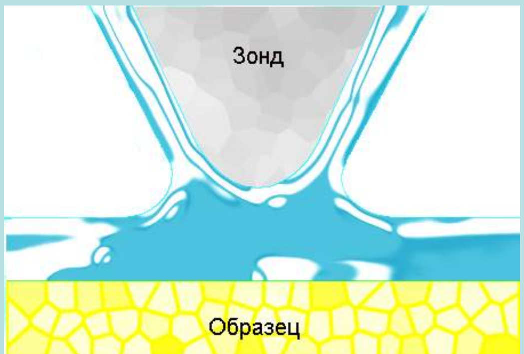


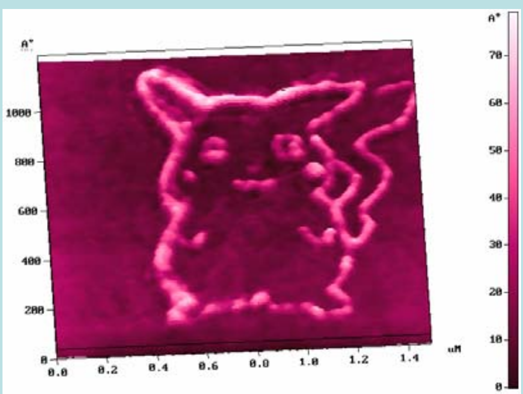


AFM image of modified catalyst film and NT grown on this film (MIET, 2006)

Local anodic oxidation (LAO)

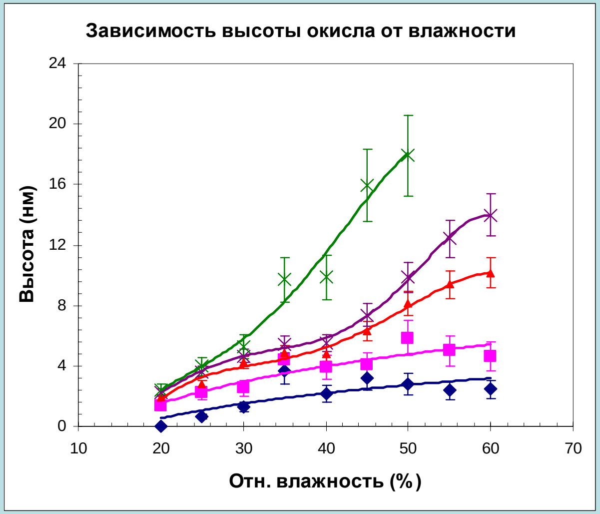
Model of system "probe – quasiliquid –substrate"





AFM image of LAO formed pattern (MIET, 2003)

Dependence of oxide height from humidity for Al on Si

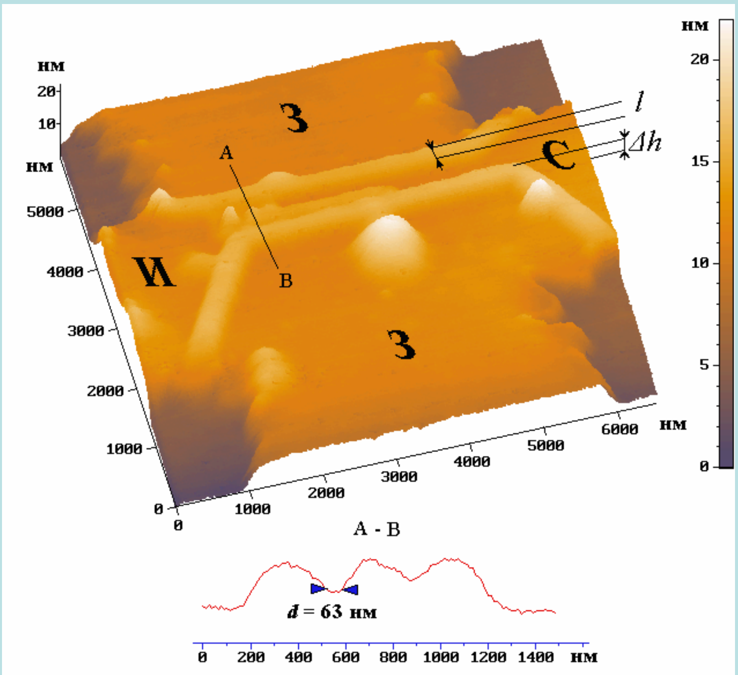


Bottom- up: voltage magnitude – 4 V, 4.5 V, 5 V, 5.5 V и 6 V. (MIET, 2004)

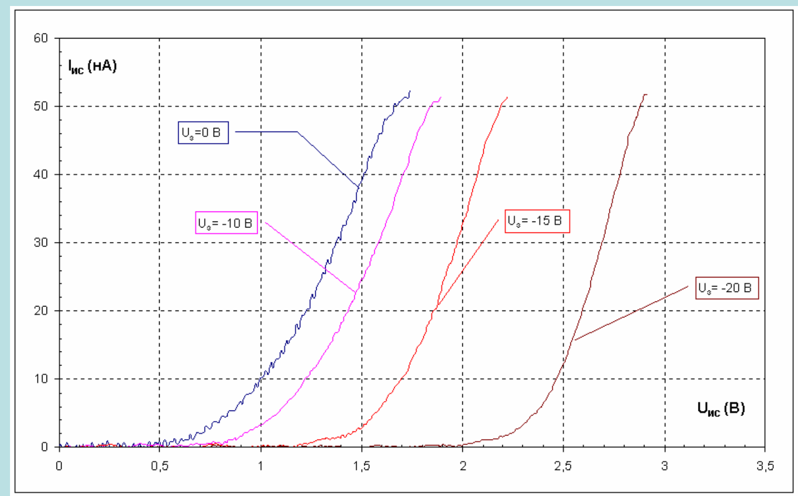
The natural air adsorbate plays the important role in LAO, since it is a source of ions of oxygen

Quasione-dimensional conductor on the basis of tantalic film in an external cross-section field

Topography of quasione-dimensional channel formed by LAO oxidation of tantalic cross : *l* –width, *Δh* –height of oxide over tantalic surface, *d* – visual width of AFM image of channel



AFM image of structure obtained by LAO (MIET, 2004)

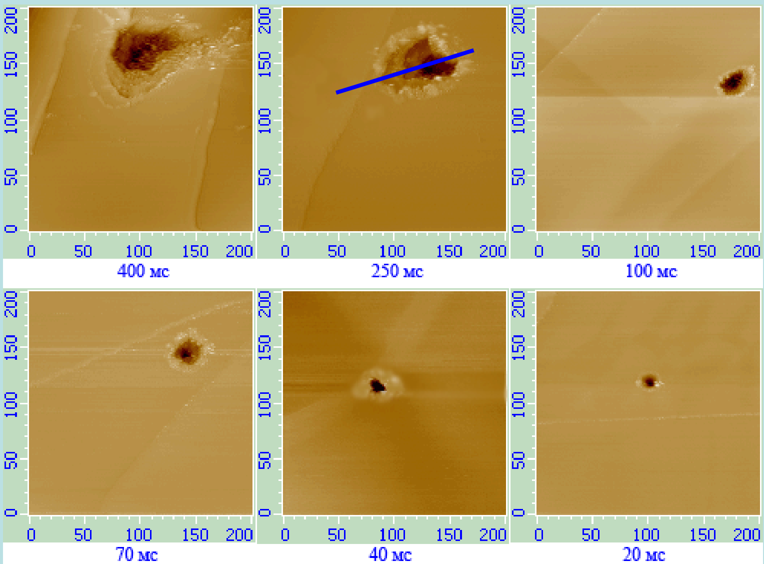


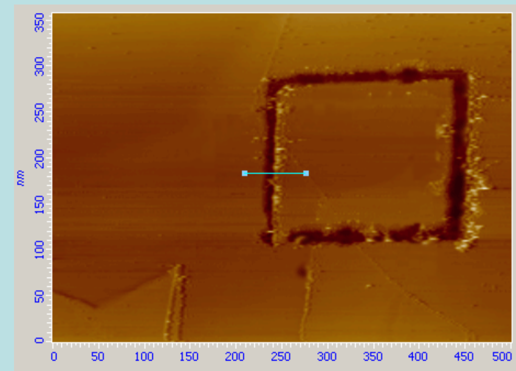
Static current-voltage characteristic of quasione-dimensional channel with visual width d < 60 nm (MIET, 2004)

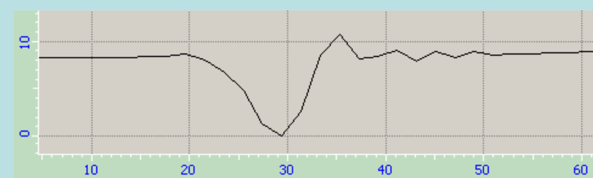
Local anodic oxidation of HOPG in tunneling mode

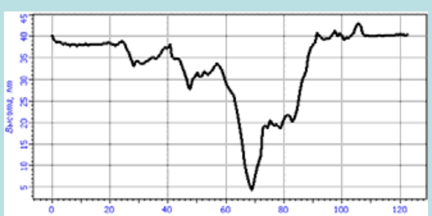
HOPG surface topography after LAO with voltage 3.6 V and duration of impulse 20, 40, 70. 100, 250, 400 ms correspondingly

Graphite sheets represent the highly ordered 2D structures with ballistic electron transport and have volatile oxide





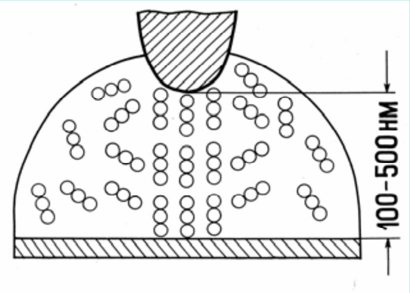




STM images of modified HOPG surfaces (up) and cross section of the cracks (bottom) (MIET, 2005)

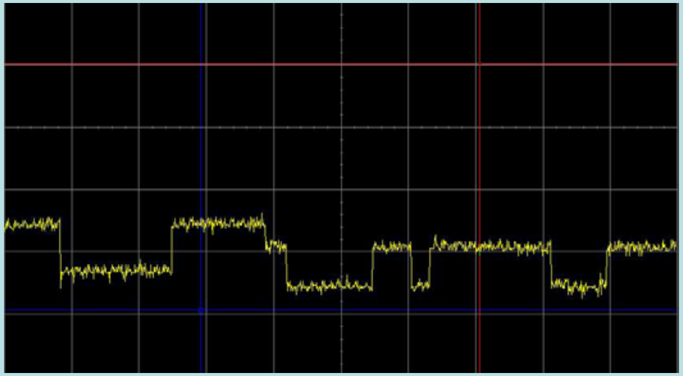
Molecular conductor between probe and substrate in polymeric matrix

Equivalent conductivity on 20 orders exceeds the conductivity of initial polymeric matrix and matches the silver



The scheme and view of the structure with molecular channel

Heating of the hardened matrix leads to its volumetric expansion which causes the series of spontaneous step switchings of resistance of the structure. The steps are aliquot from **13 KOhm** – the quantum of ballistic resistance.

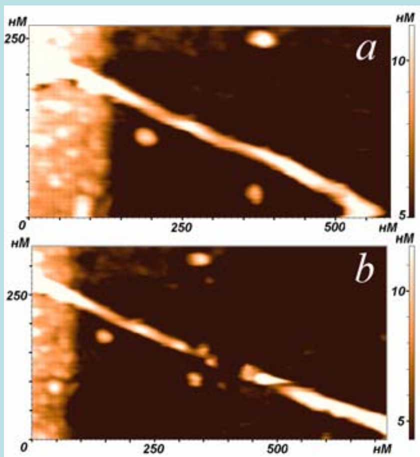


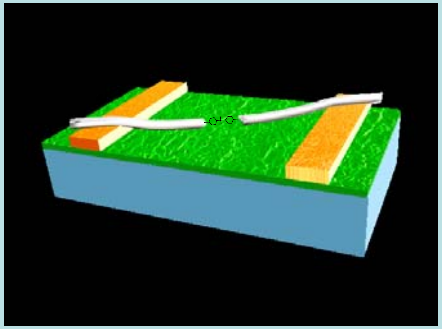
Oscillogram of signal from the structure, 10 mV and 1 ms per division (MIET, 2005)

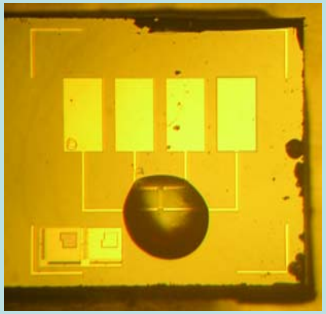
Planar molecular conductor in polymeric matrix

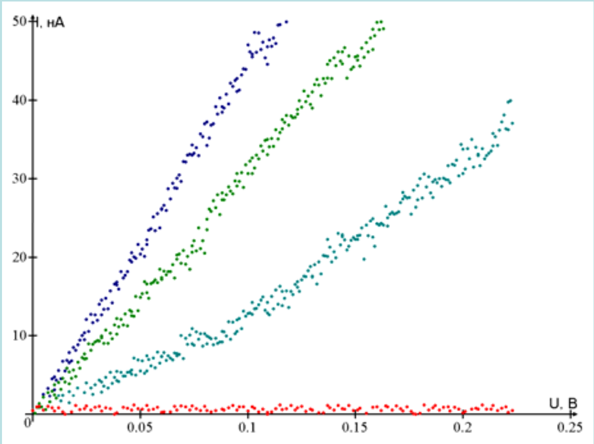
The multiwalled carbon nanotubes play the role of electrodes and provide the required configuration of electric fields for molecular channel formation in the gap

Experimental device exhibits the properties of a FET and a nonvolatile memory cell









AFM image of NT before (up) and after (bottom) cutting by LAO (MIET, 2005)

The model and top view of the structure with NT and molecular channel

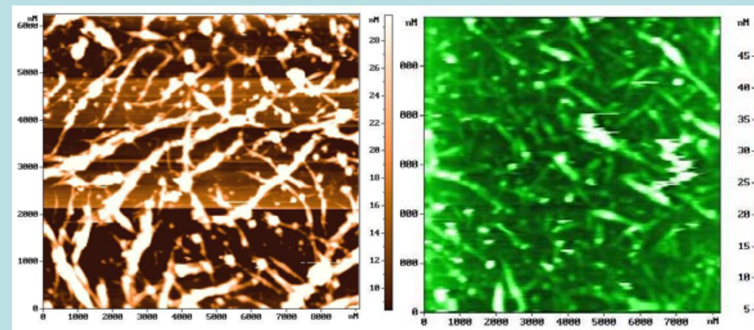
The modulation and switching of conductivity of molecular channel (MIET, 2005)

Conductive NT/epoxy nanocomposites

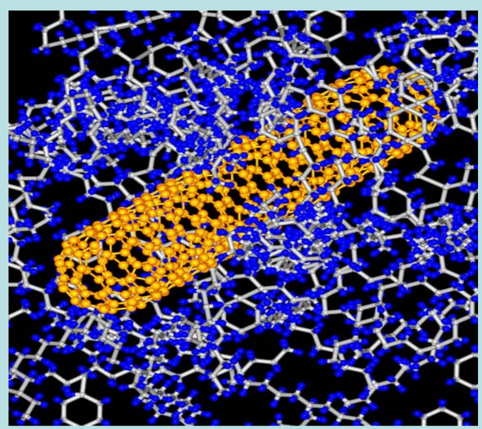
Nanotubes dispersed in polymer matrix acts as a system of electrodes for molecular channels

View of hardened NT/epoxy composite tablet with anisotropic conductivity (MIET, 2005)

Thin film composites are made on the base of NT nets



AFM images of NT nets with less (left) and more (right) densities (MIET, 2005)



Model of nanotube in polymeric matrix

Questions?