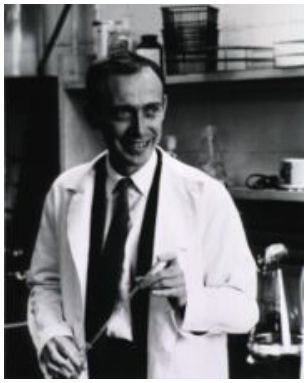
DNA Nanostructures. Gene Vectors and Nanowires

Nina A. Kasyanenko

Faculty of Physics

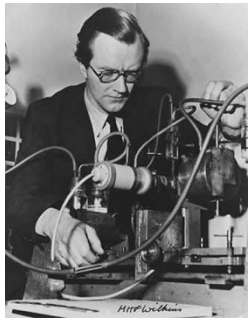
St.-Petersburg State University

Department of Molecular Biophysics

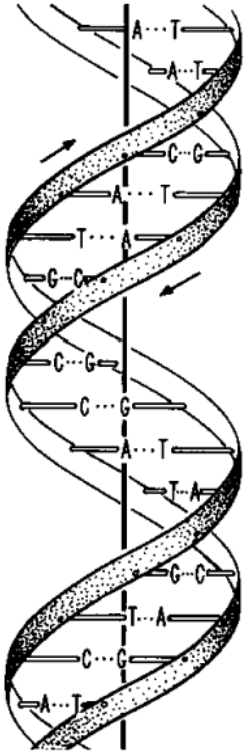


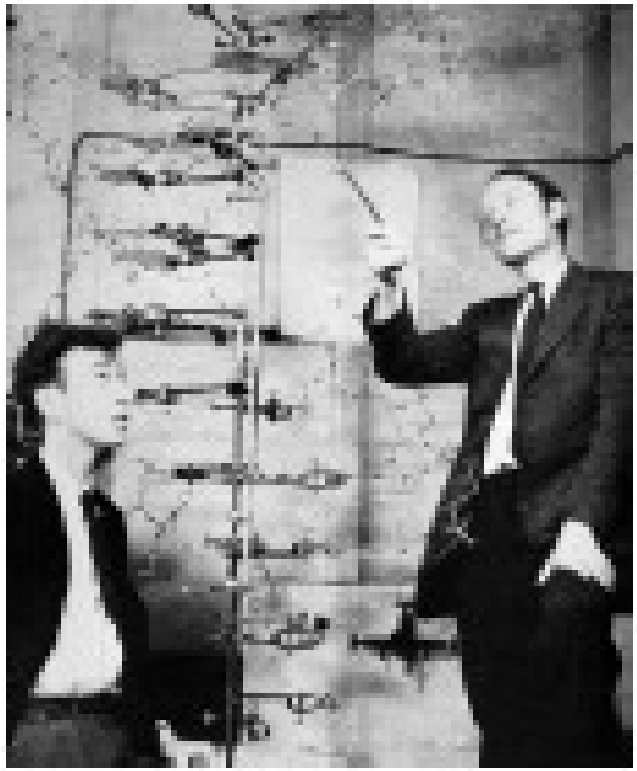
James Watson
1928-

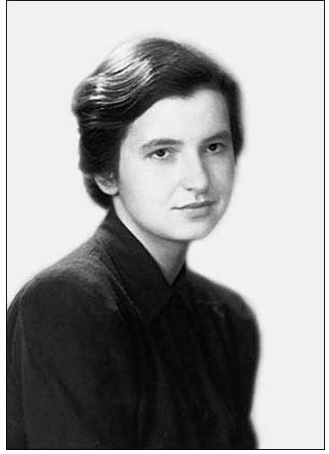
Francis Crick
1916-2004



Maurice Wilkins
1916-2004







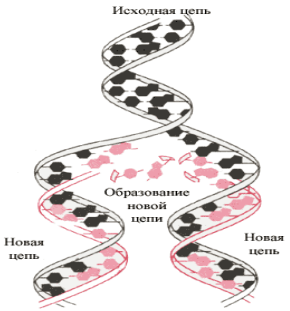
Rosalind Franklin
1920-1958

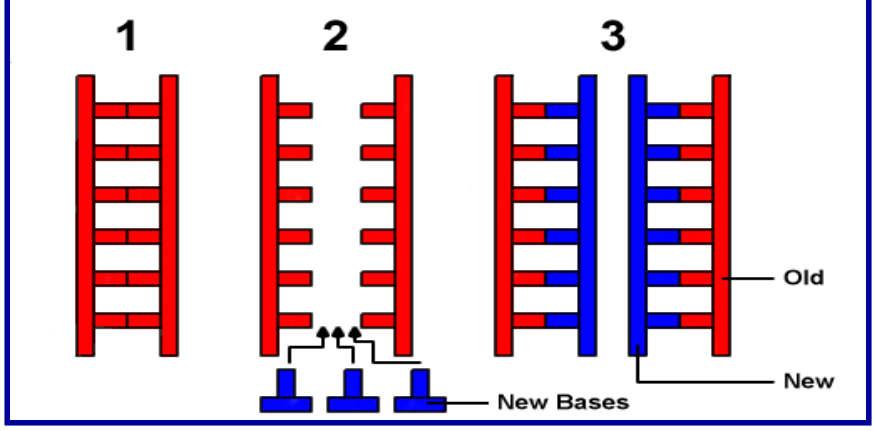
1962: Nobel Prize in Physiology and Medicine

"For their discoveries concerning the molecular structure of nucleic acids and its significance for information transfer in living material"

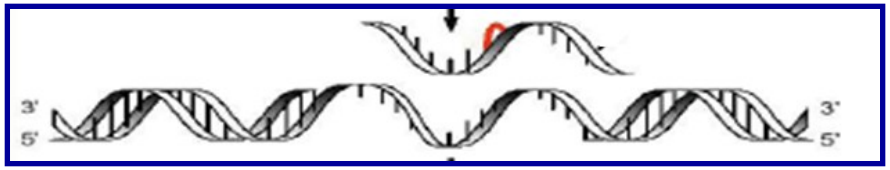
J. D. Watson & F. H. C. Crick *A Structure for Deoxyribose Nucleic Acid. Nature,* **171,** 737-738 (April 25, 1953).
M. H. F. Wilkins, A.R. Stokes and H. R. Wilson. *Molecular Structure of Deoxypentose Nucleic Acids Nature,* **171,** pages 738-740(1953)
R. Franklin and R. Gosling. *Molecular Configuration in Sodium Thymonucleate Nature,* volume **171,** pages 740-741, (1953)

Replication





Reparation



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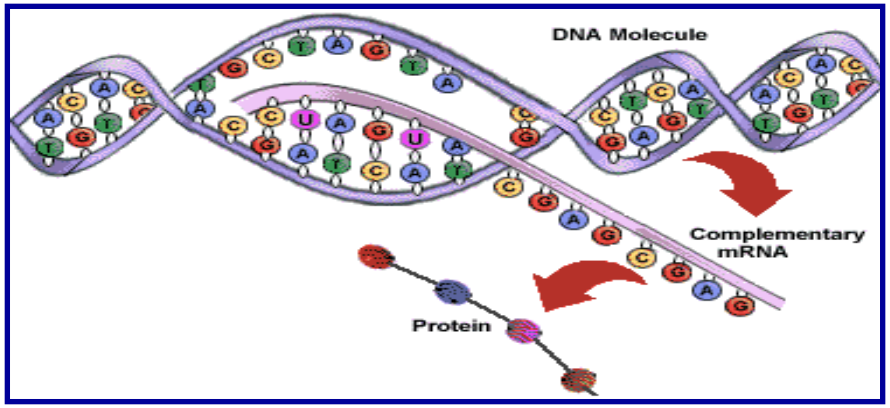

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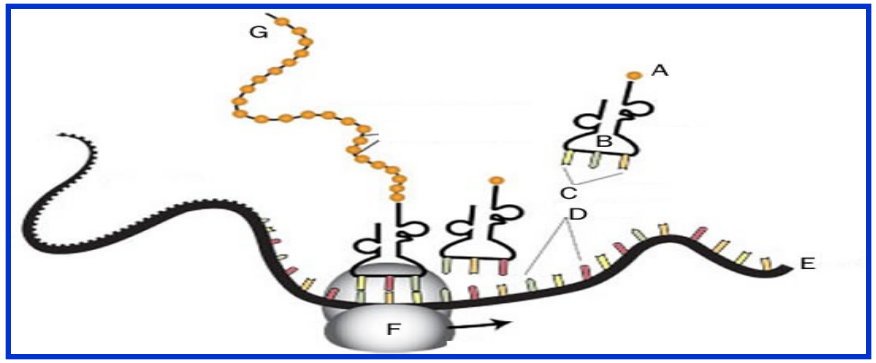
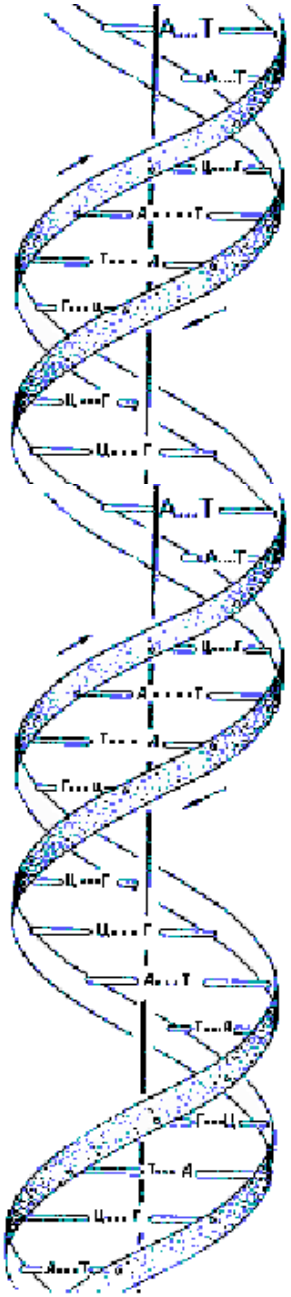


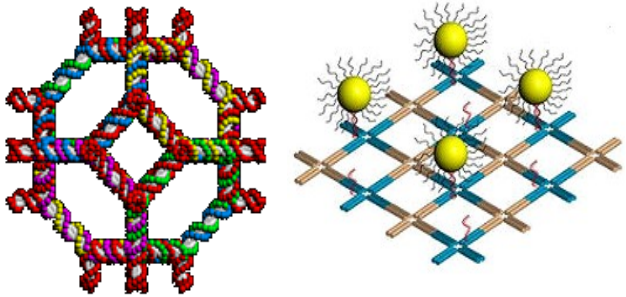


DNA-based nanotechnology - the utilization of unique DNA properties

High specific interactions between complementary nucleic bases

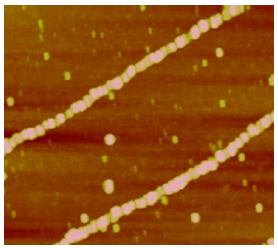
Conformational transitions in tertiary and secondary DNA structures

DNA origami (3D-constructions).



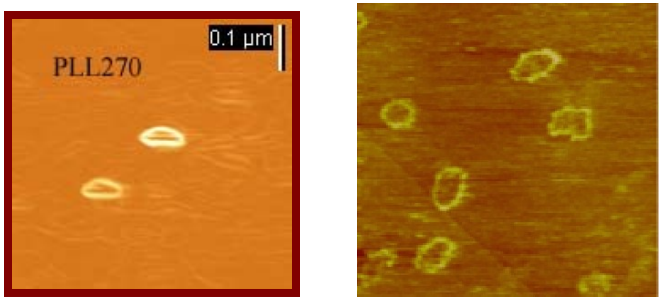
N.C. Seeman

High charge density and exceeding chain rigidity

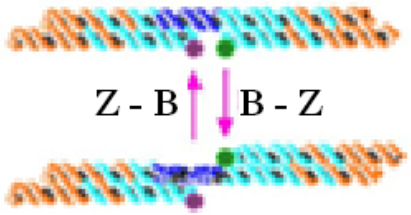


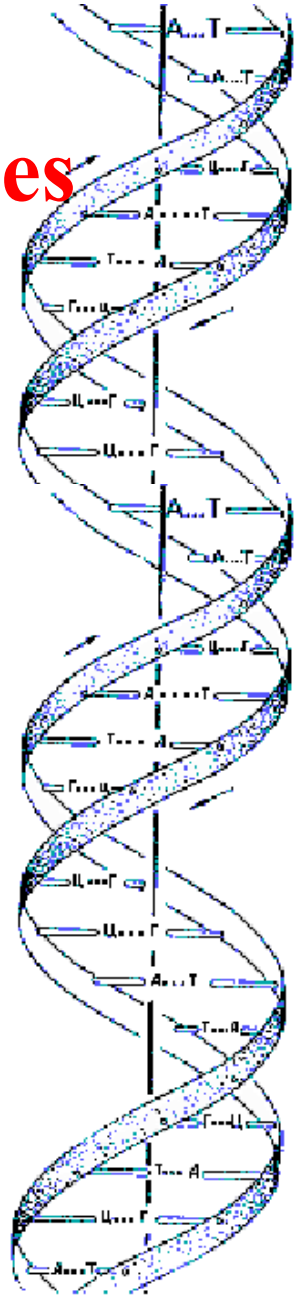
Nanowires

DNA condensation with the formation of ordered structures

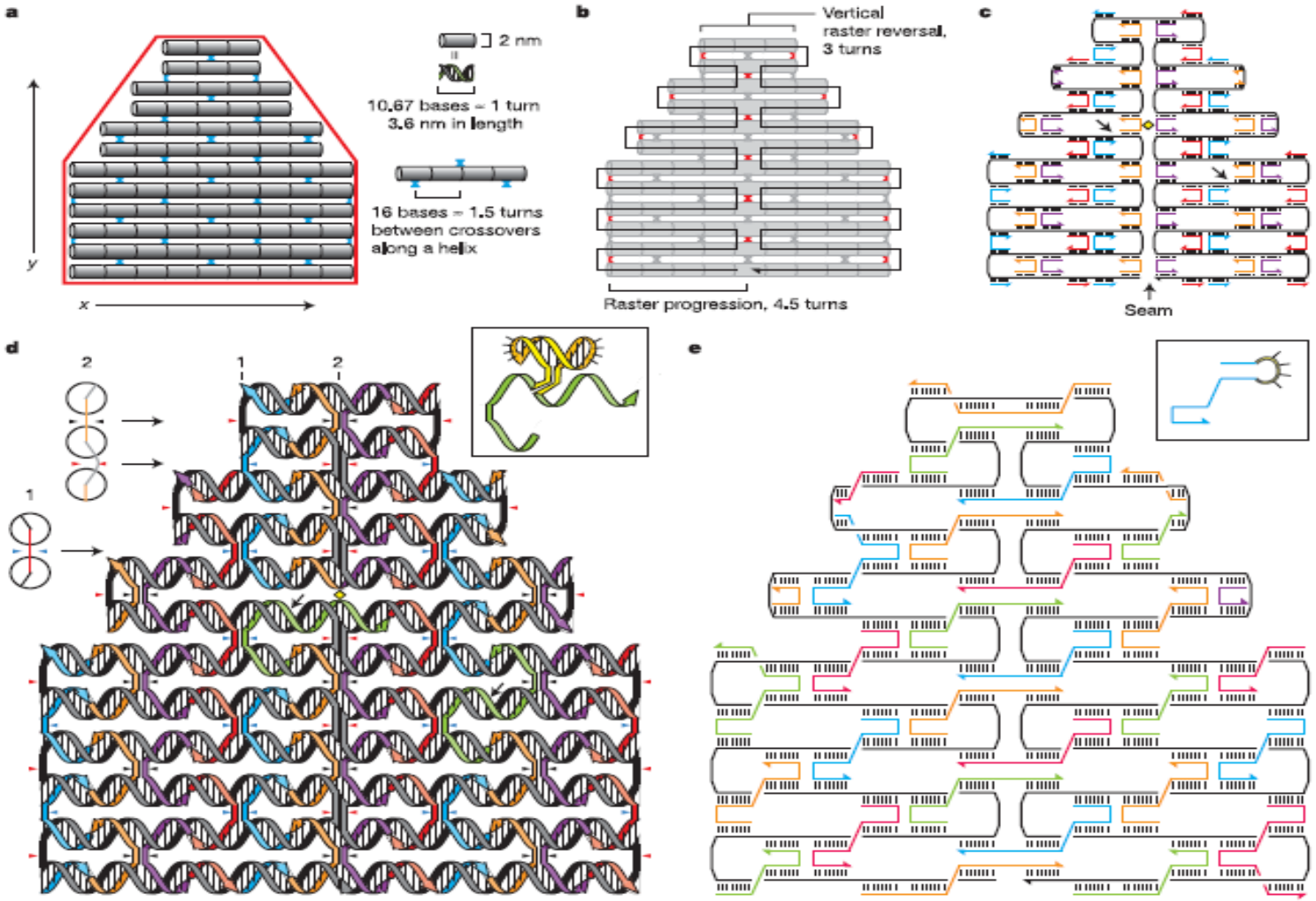


DNA nanomotor (B-Z transition)



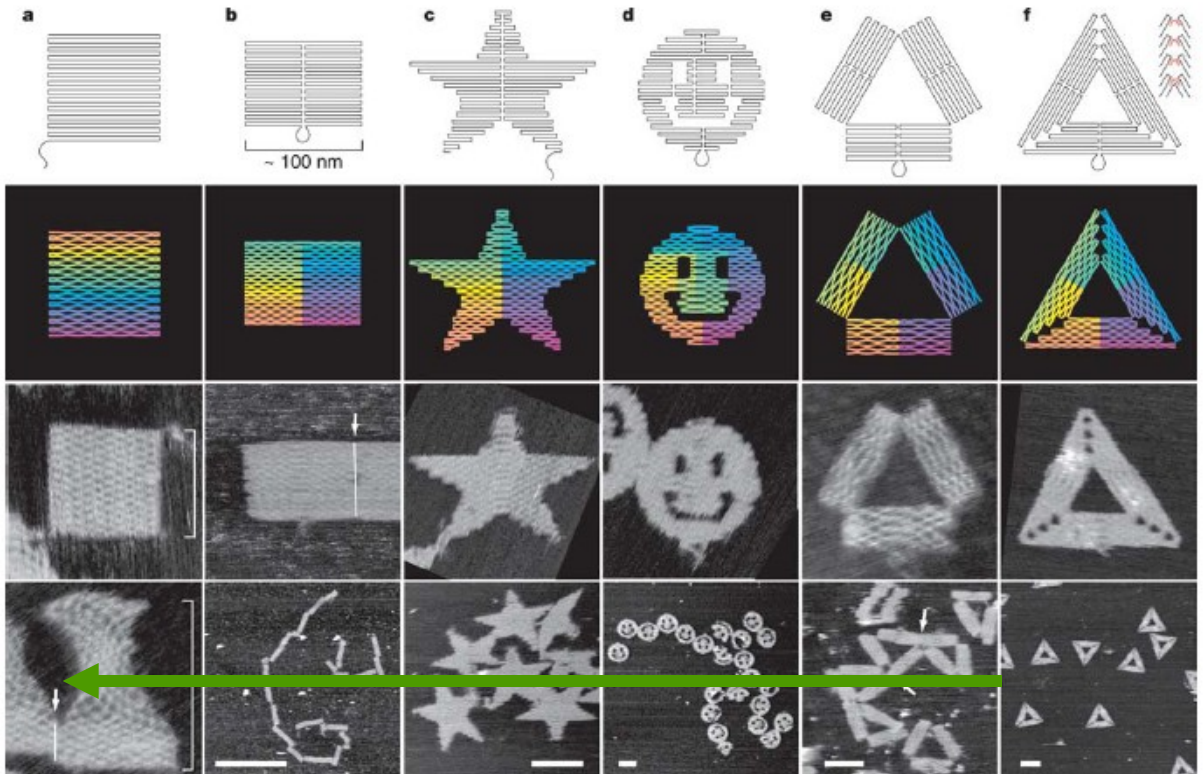


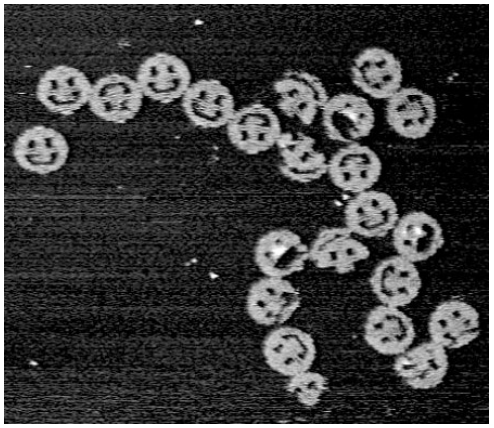
DNA origami



Paul W. K. Rothemund (Departments of Computer Science and Computation & Neural Systems, California Institute of Technology, USA) Folding DNA to create nanoscale shapes and patterns Nature, Vol 440|16 March 2006| p. 297-302

Paul W. K. Rothemund





Nanomanipulation,
2008, 4, No. 4, 447–450
Dielectrophoretic Trapping
of DNA Origami

Anton Kuzyk, Bernard Yurke,
J. Jussi Toppari, Veikko Linko,
and Paivi Torma

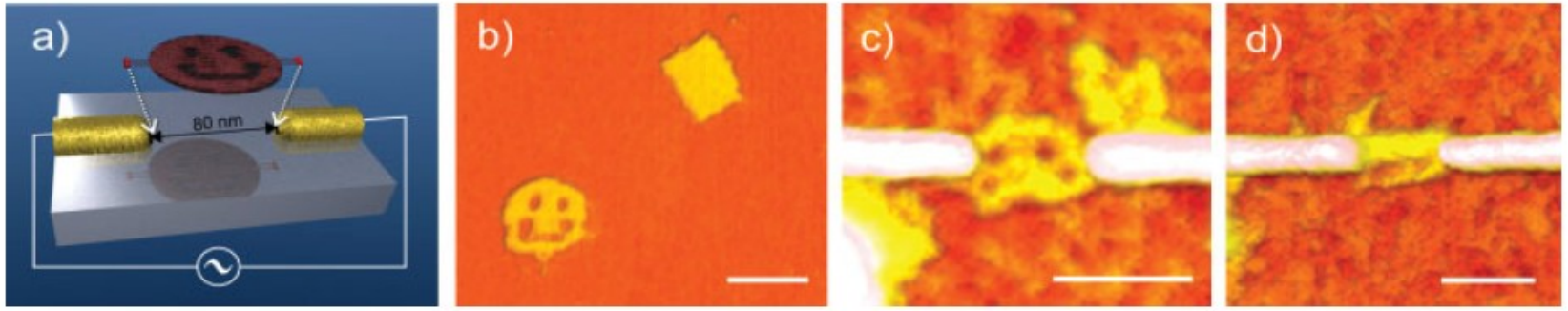
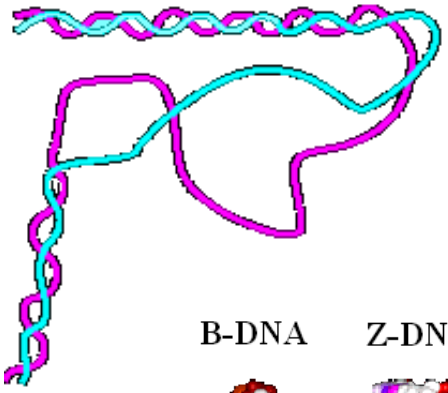
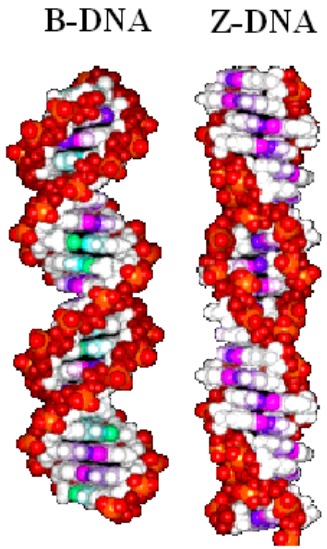


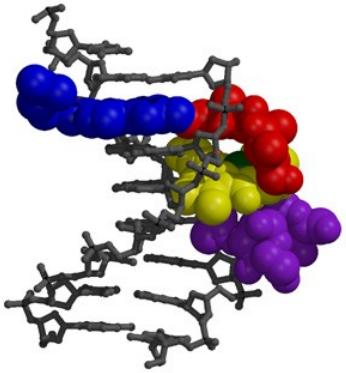
Figure 1. Trapping DNA origami structure with dielectrophoresis. a) Schematic view of the origami trapping experiments. b) AFM image of origami structures used for DEP trapping. The image is taken on a MICA surface using tapping mode AFM in liquid. c) AFM image of a single smiley. d) Rectangular origami trapped with the optimal DEP parameters (on SiO_2 surface, tapping mode AFM in air). The scale bar is 100 nm.

Reversible conformational transitions

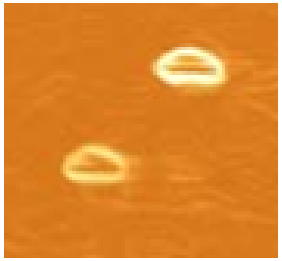
- Melting
- DNA packaging
- DNA bending induced by ligand binding
- B-Z transition (right-left winding)

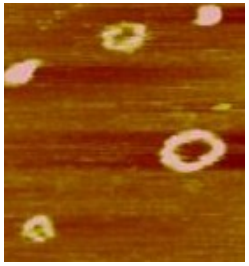


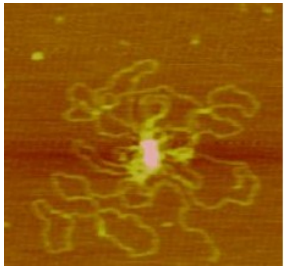




DNA-bleomycin complex

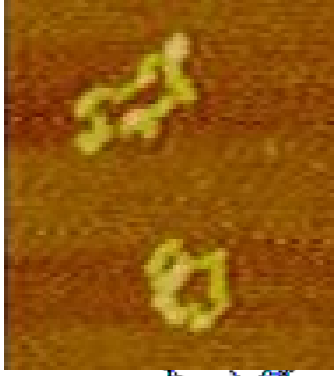


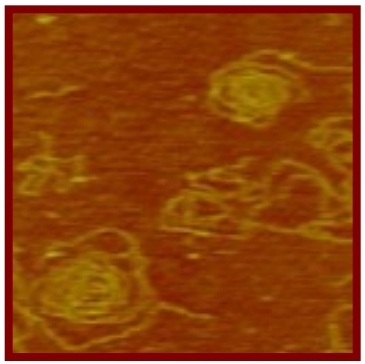


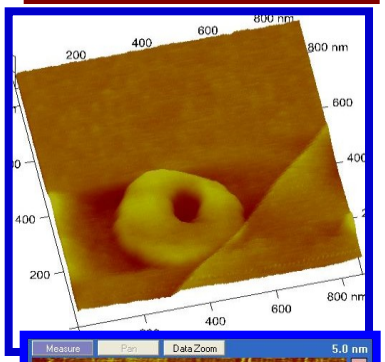


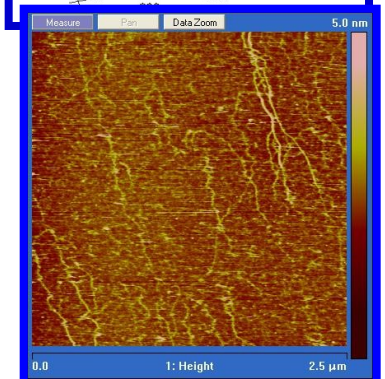
Transformation of DNA tertiary structure can be induced by different procedures:

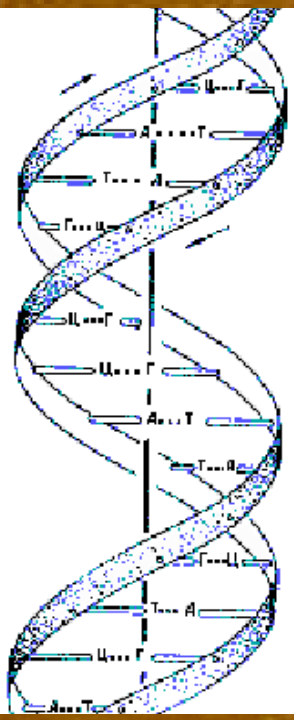
- Phosphate group screening
- Change in DNA charge density (by pH variation, ionic bonds with phosphates)
- Variation in solvent quality (by the addition of alcohol or other poor solvent into DNA-water solution)
- Binding with ligands (alteration in DNA hydrophility, conversion of charge density, decrease of DNA rigidity)
- Intramolecular reorganization via simultaneous influence of counterions and conversion of solvent properties

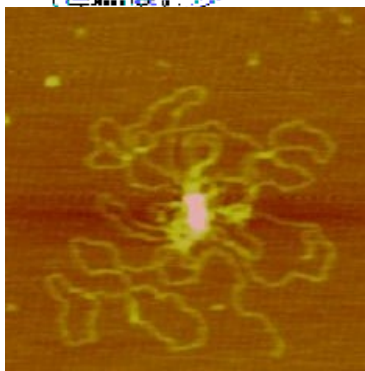




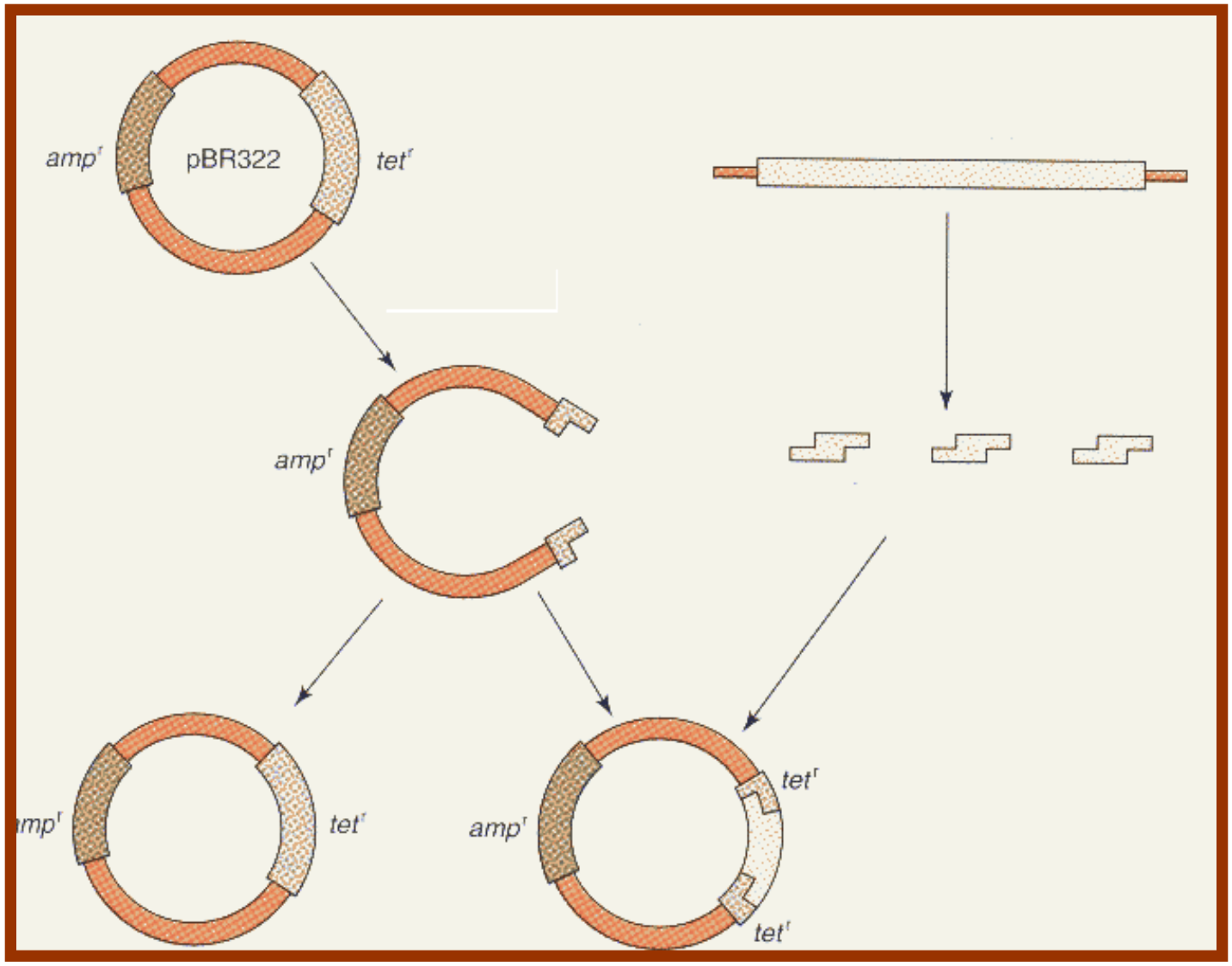


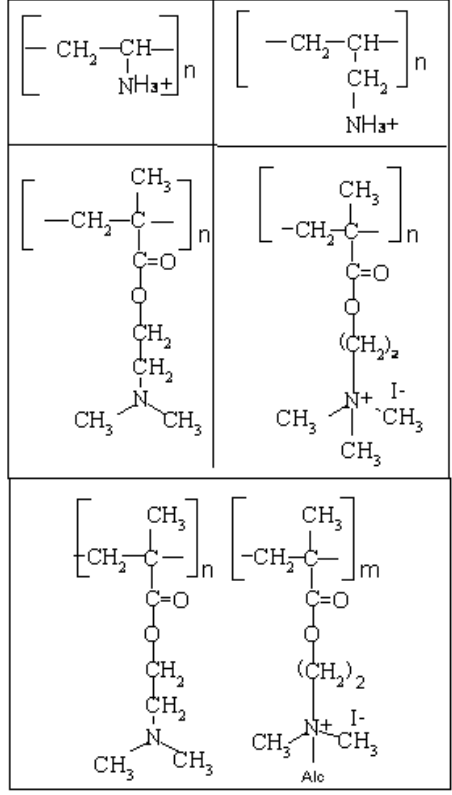


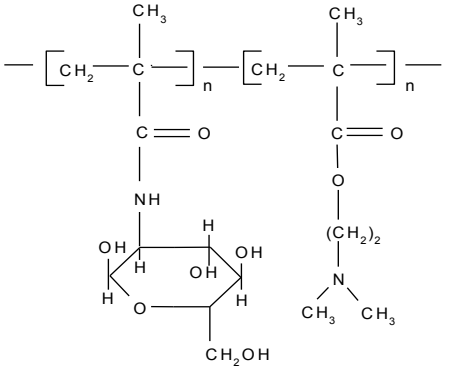




Gene vectors







IMC RAS St.-Petersburg.

Nazarova O.V. Panarin E.F.

Experimental Methods

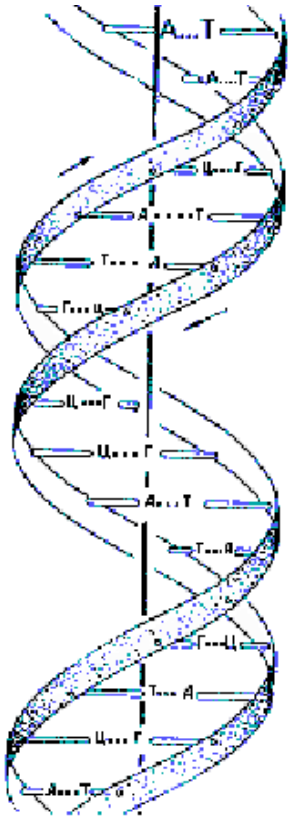
- **ATOMIC FORCE MICROSCOPY**

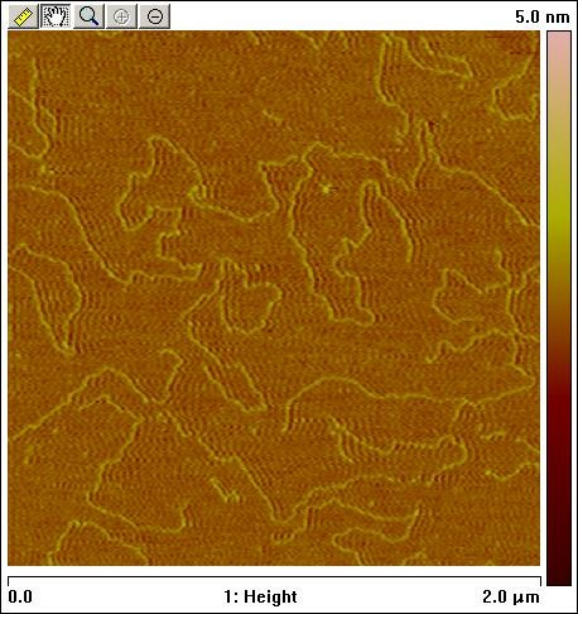
  NanoScope IV, Veeco
- **DYNAMIC LIGHT SCATTERING**

  PhotoCor, Russia
- **CIRCULAR DICHROISM**
- **Mark IV, Jobin Ivon**
- **LOW GRADIENT VISCOMETRY**

  Zimm-Crothers Type
- **DYNAMIC BIREFRIGENCE**
- **SPECTROSCOPY**

  SF 56, Russia

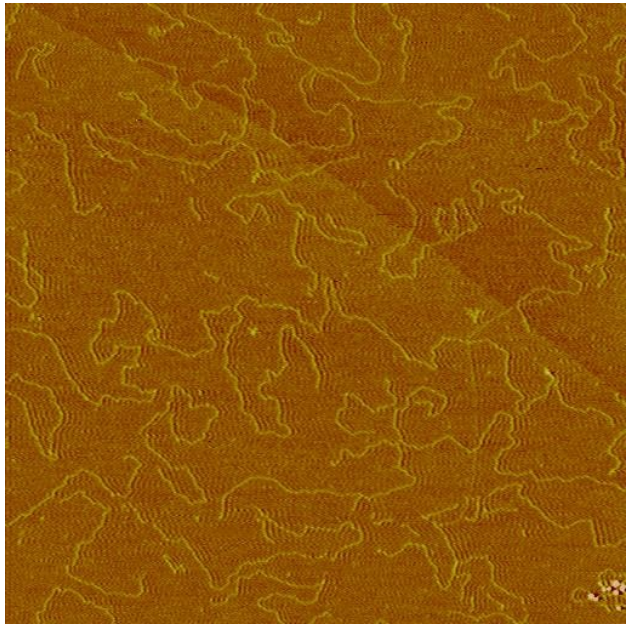


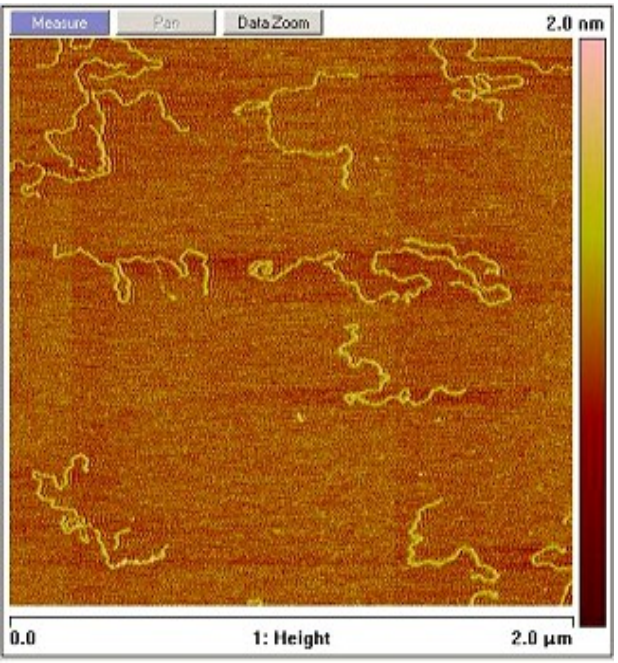


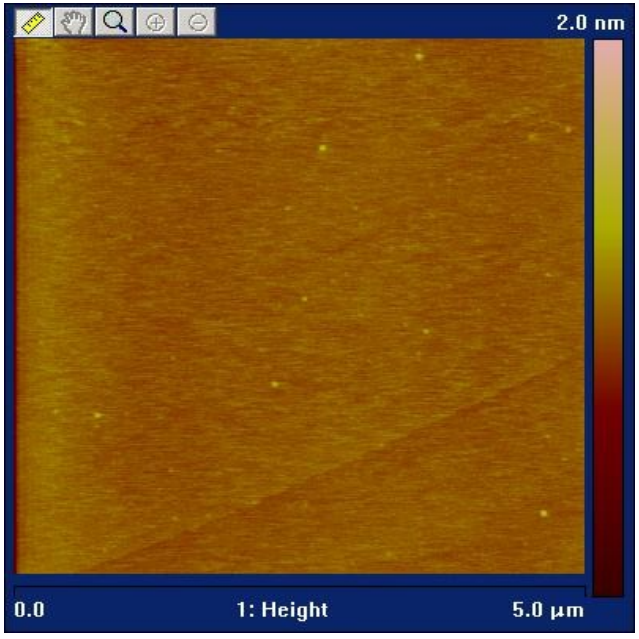
DNA

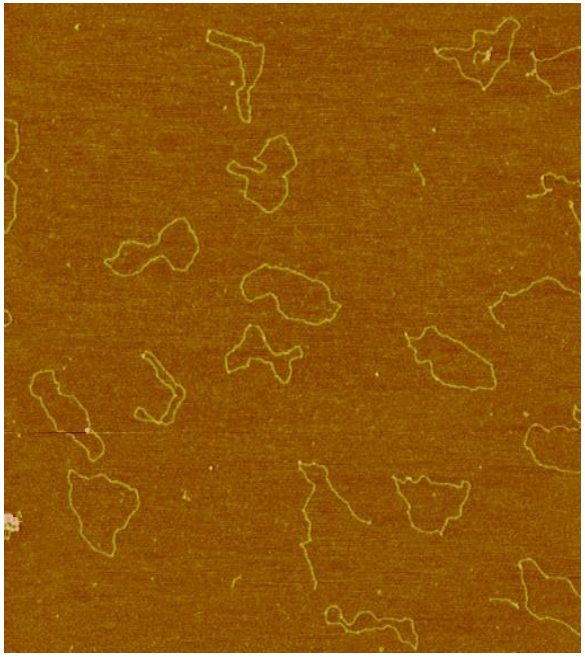
Calf Thymus DNA (Sigma)

pFL 44/EcoI (4,4 kbp)

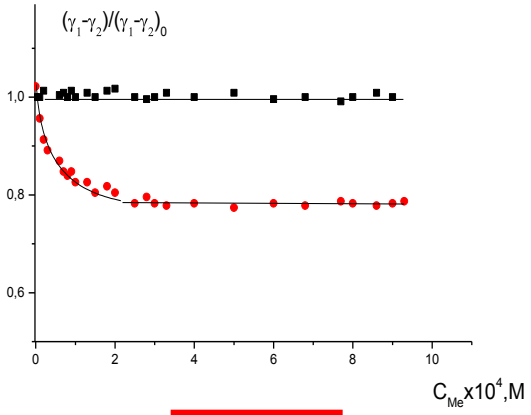




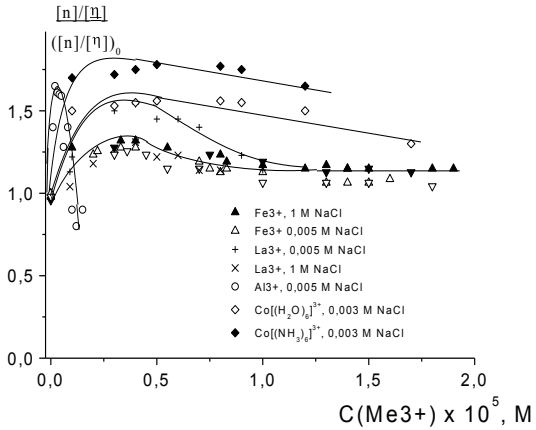




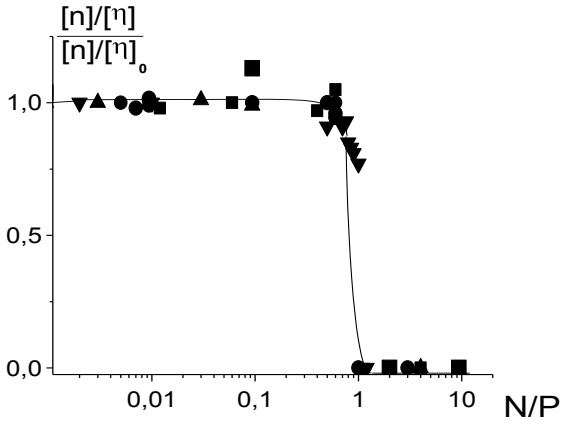
DNA complexes with divalent, trivalent and multivalent ions



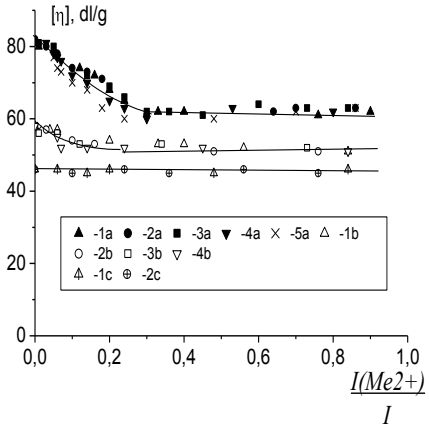
Me2+

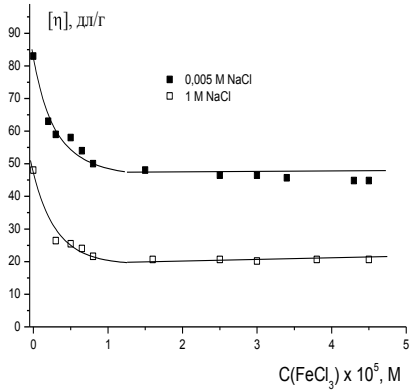


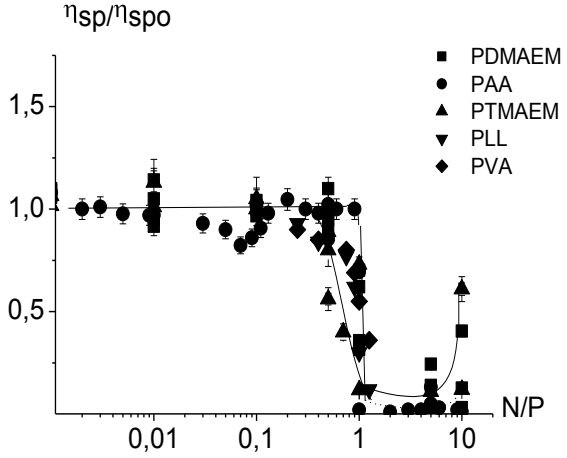
Me3+



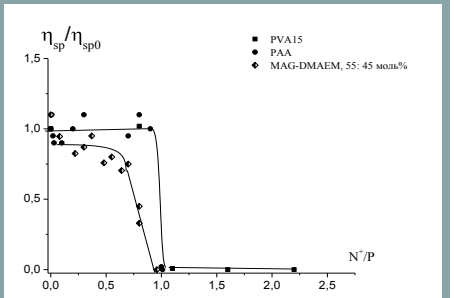
polycations

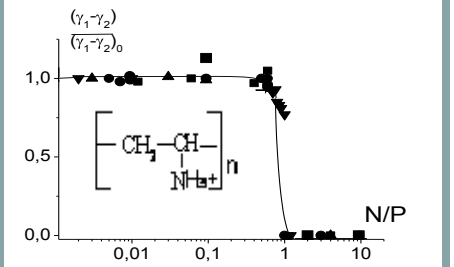


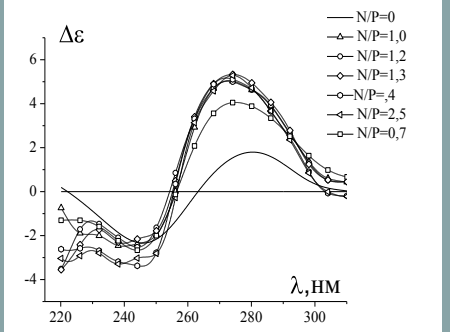


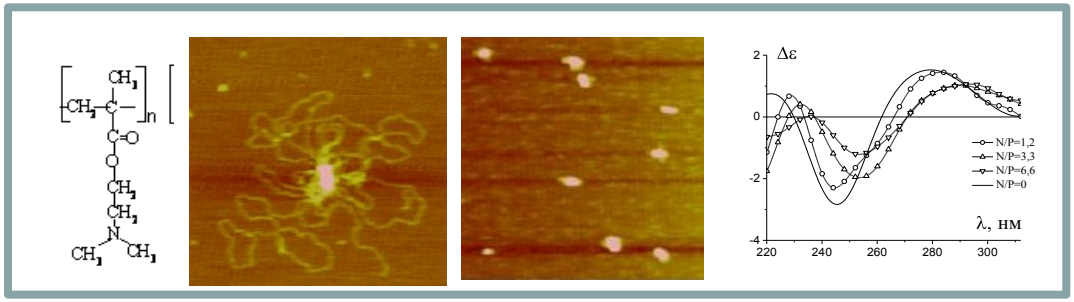


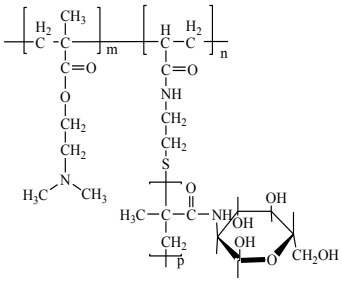
DNA complexes with polycations

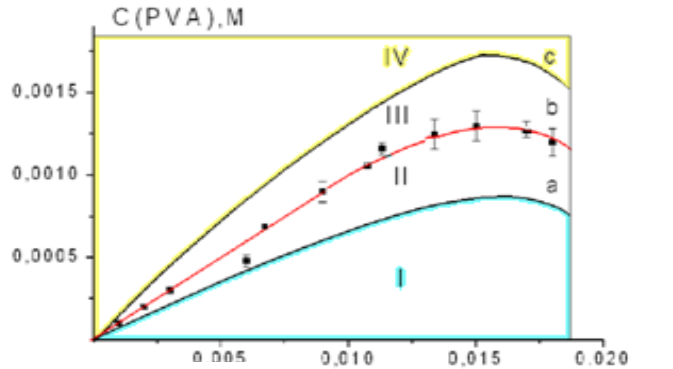




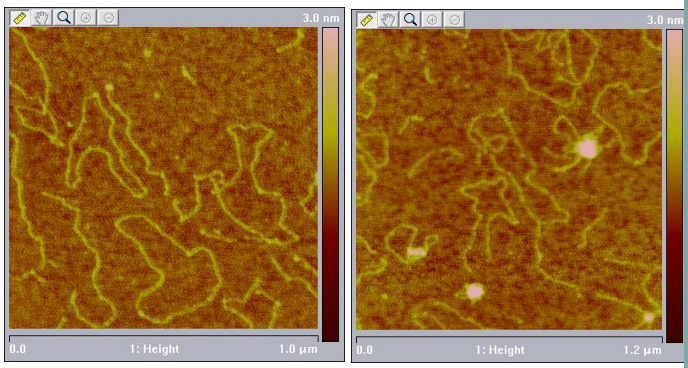




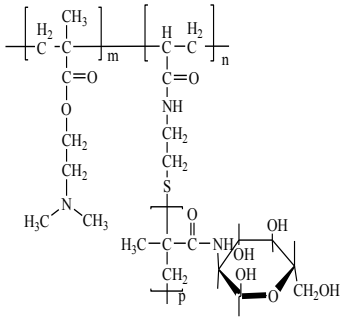


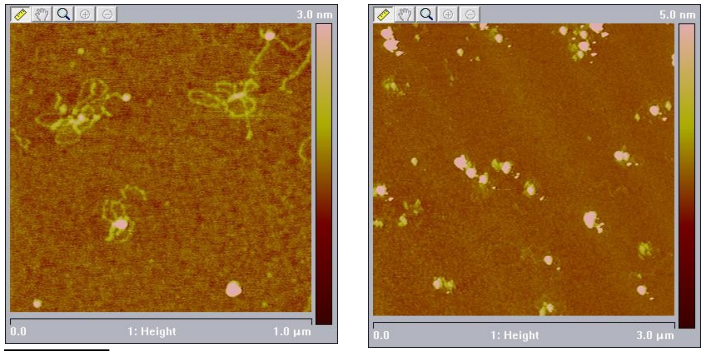


D=115 20 nm

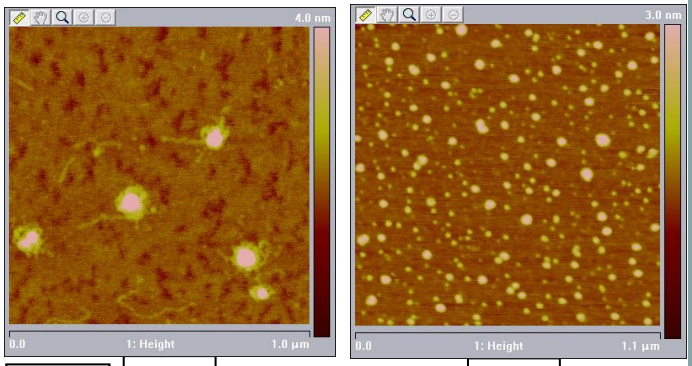


N+/P 0 DNA pFL 44 0,7

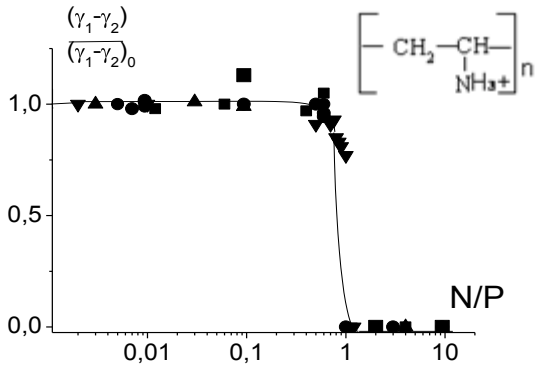


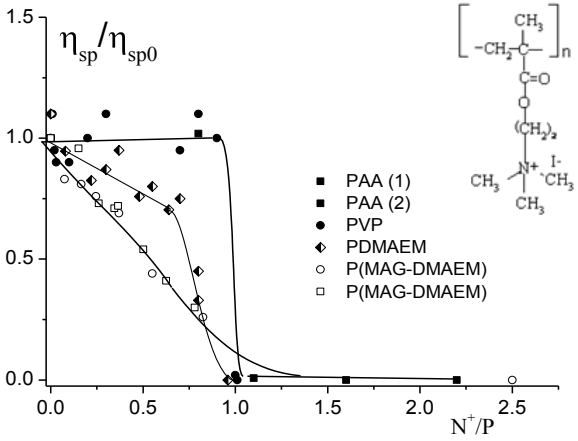


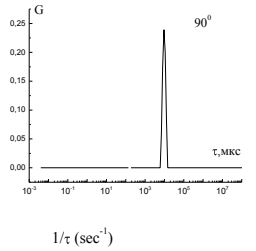
N+/P 1 2

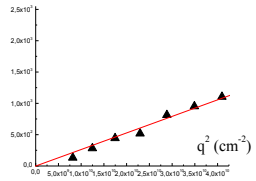


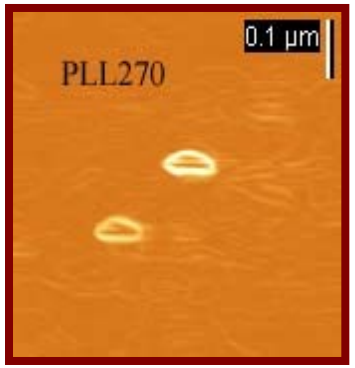
N+/P 1 1,4

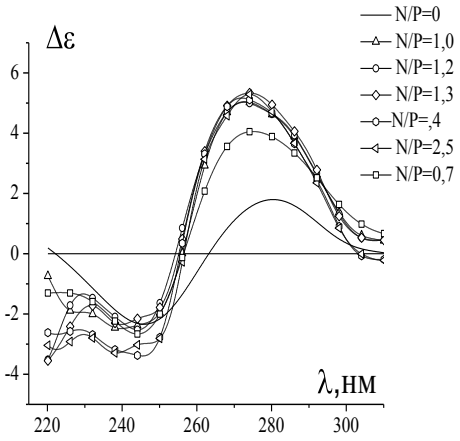


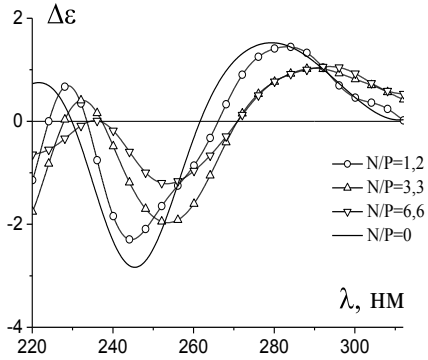


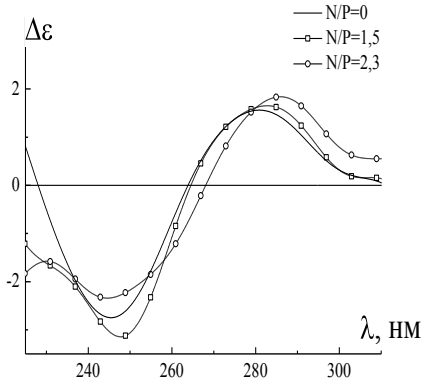


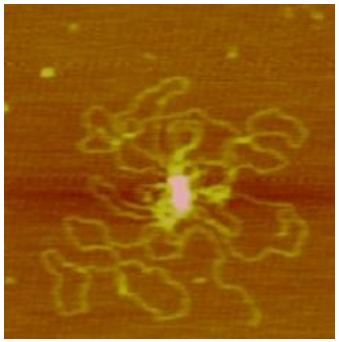


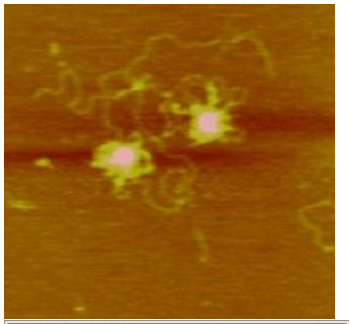


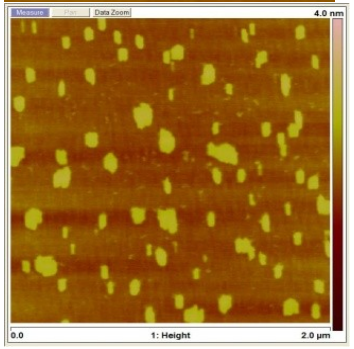












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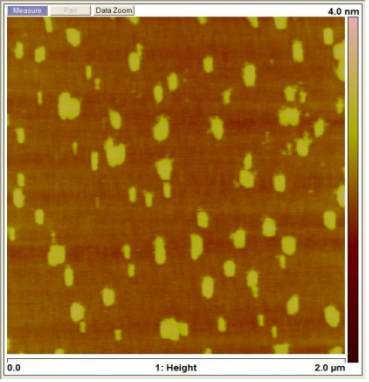
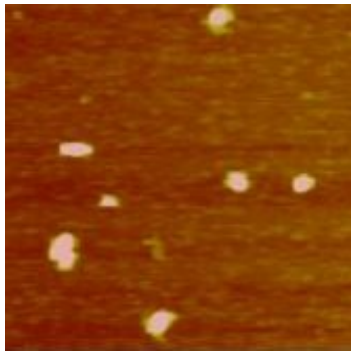
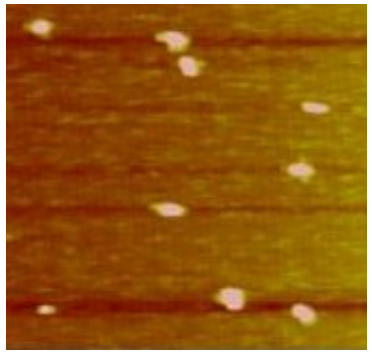


N+/P= 1

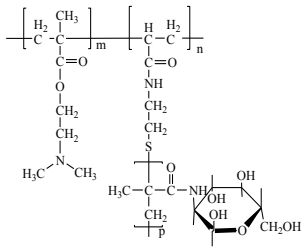


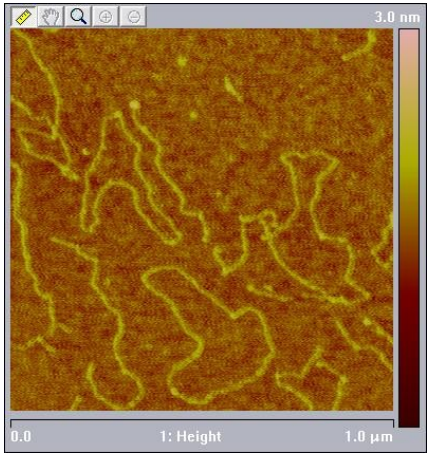
N+/P= 2

(1 µm)



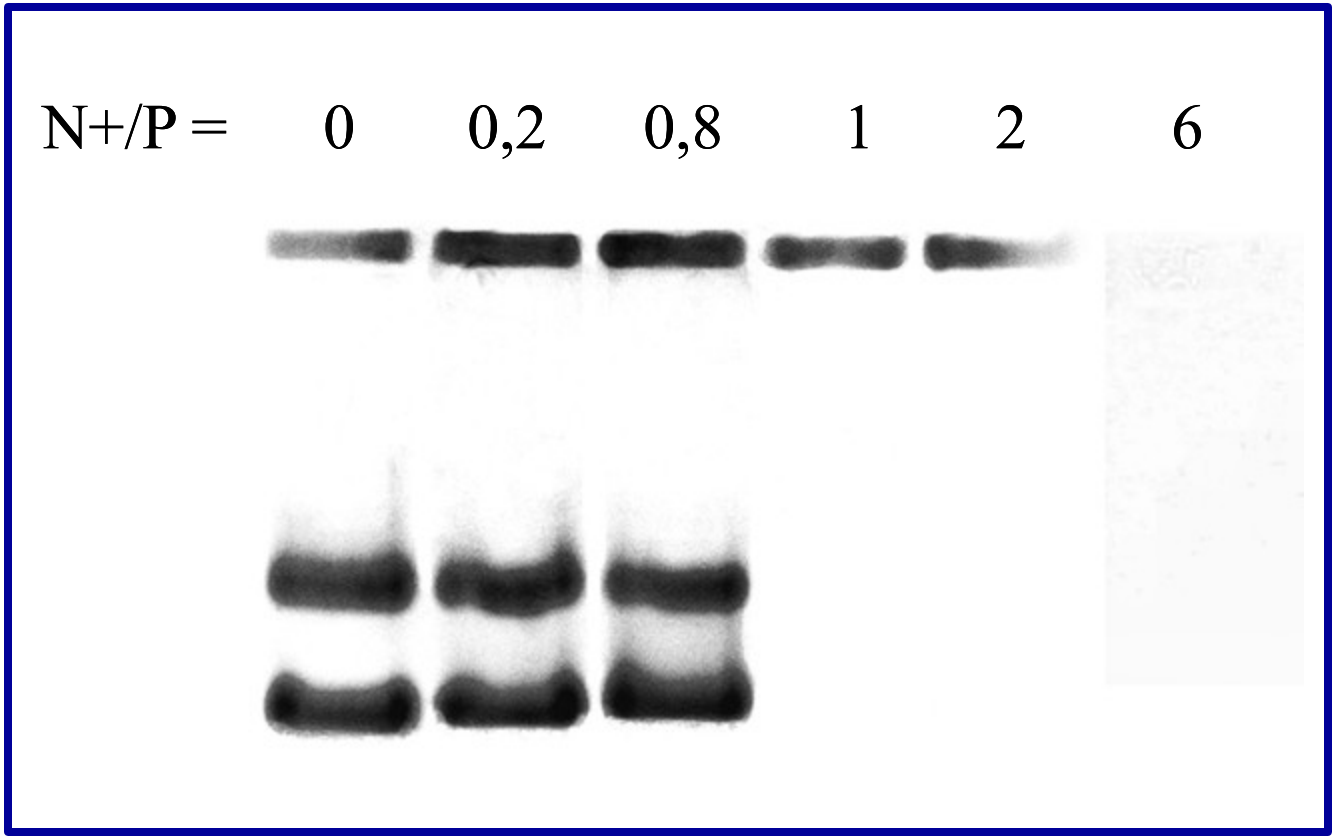
N+/P= 2

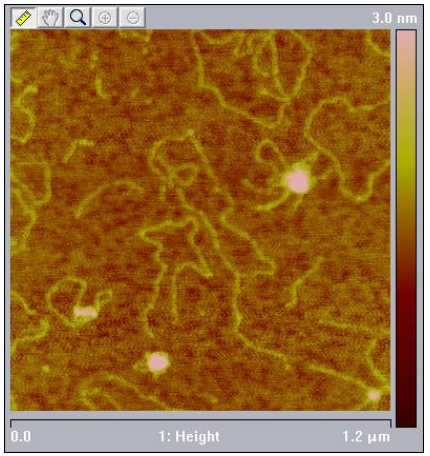


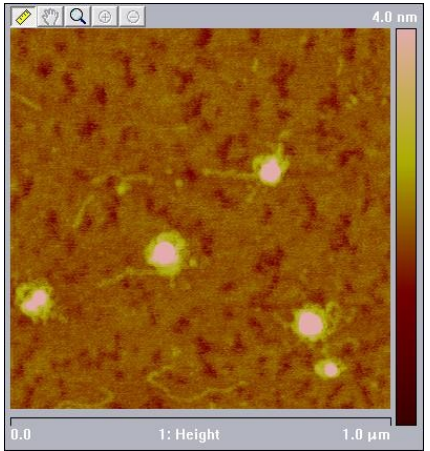


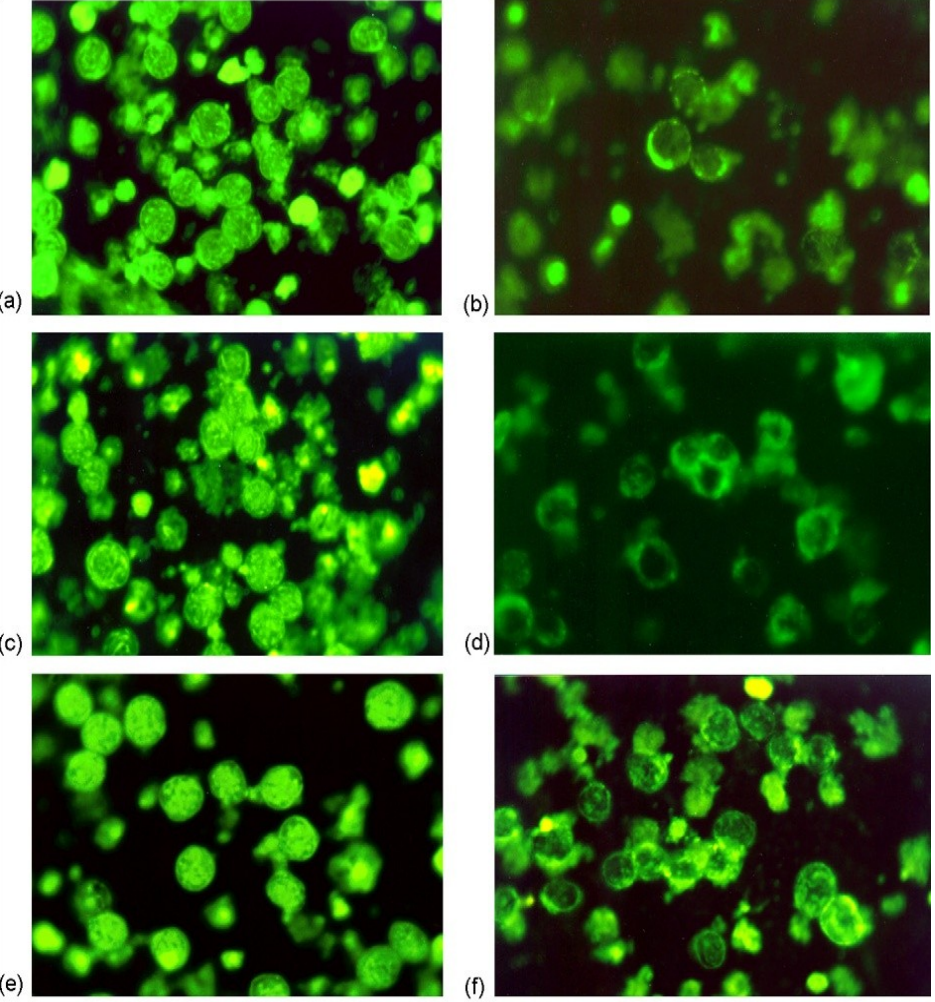
Block (1,2) and graft (3) copolymer (MAG_DMAEM) + DNA in 0.005 M NaCl

C_{DNA}=0.0001%, N/P= 2 , D = (110 ± 20) nm

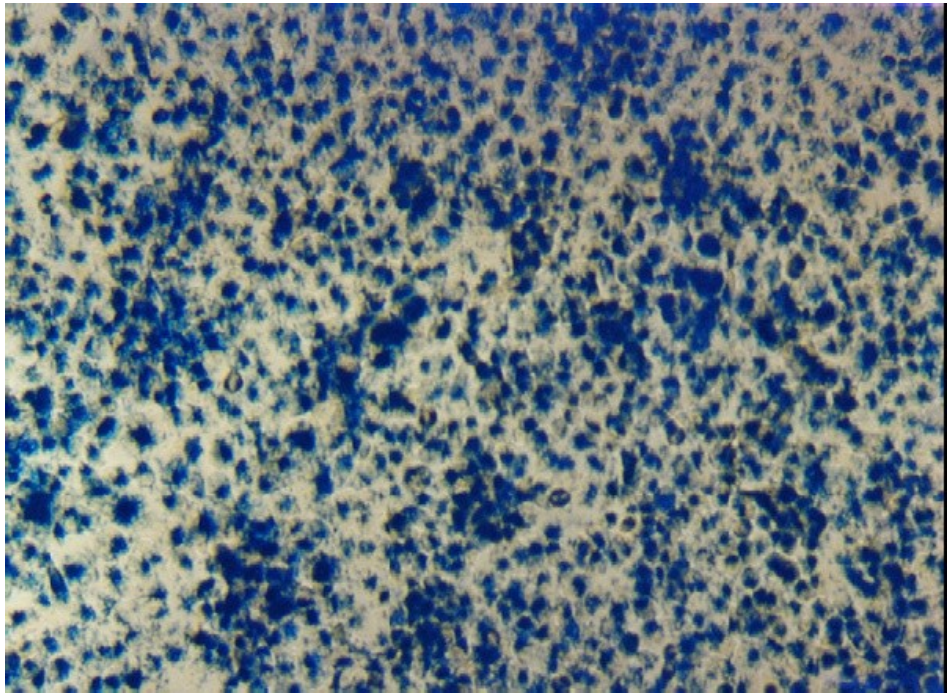




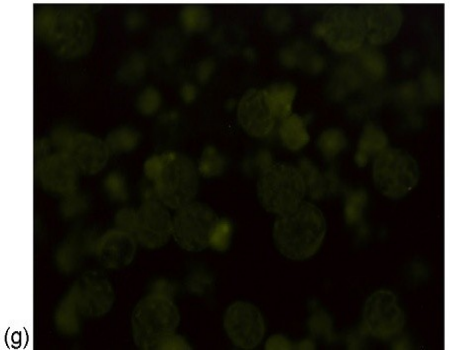




Cell lines Jurkat (I), U-937 (II), T-98G (III) with FITC-oligonucleotides
(a), (c), (e) – PAA
(b), (d), (f) – PDMAEM
(g) – control (without transfection)



T-98G cells after transfection PDMAEM+(DNA with β-Gal) after reaction with X-Gal (1:360)



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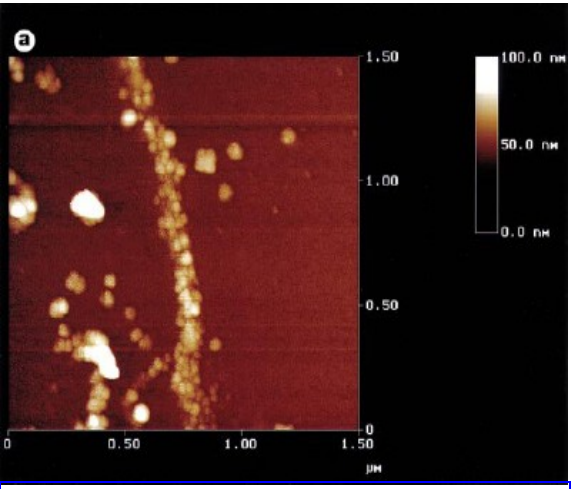
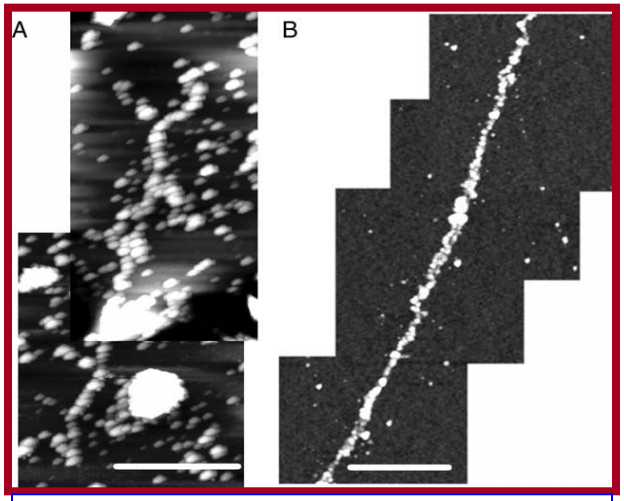
Conclusions (part 1)

- Gene vectors can be formed at definite relation of polycation/DNA concentration (N/P)
- DNA condensation is realized at N+/P>1
- DNA-polycationic gene vectors (D=120 nm) can penetrate into cell and can provoke the protein production
- AFM and Dynamic Light Scattering belong to rare appropriate methods for the monitoring of condensed DNA structure.
- AFM images correctly reflect DNA conformation in complexes with polycations

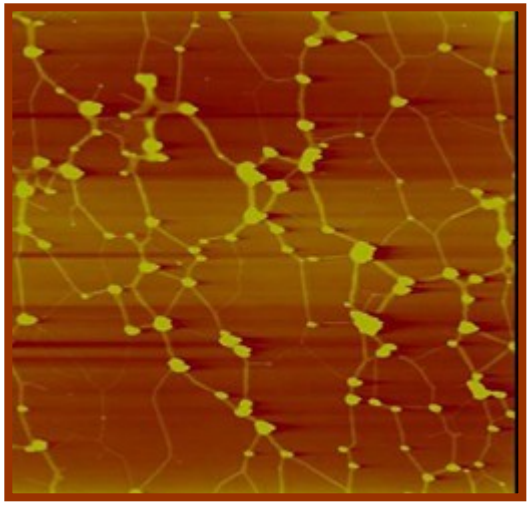
DNA Nanowires



NATURE |VOL 391 | 1998
Erez Braun, Yoav Eichen, Uri Sivan& Gdalyahu Ben-Yoseph
DNA-templated assembly and electrode attachment of a conducting silver wire

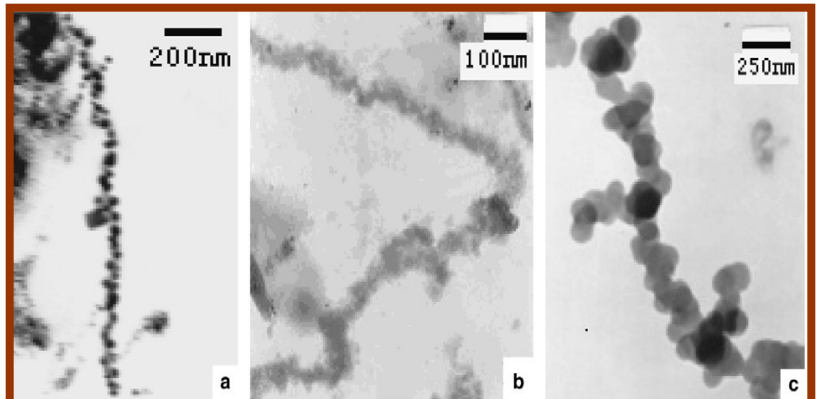


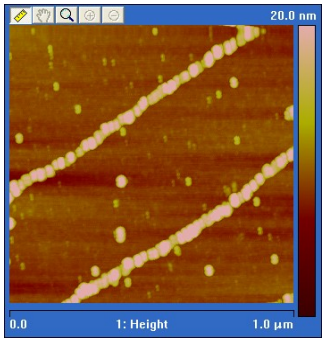
J. Mater. Chem. 14, 611-616 (2004).
Becerril, H.A.; Stoltenberg, R.M.; Monson, C.F.; Woolley, A.T. **Ionic Surface Masking for Low Background in Single- and Double-Stranded DNA-Templated Silver and Copper Nanorods.**



Biophys. Chem. (2009), J. Lu, et al., **DNA-templated photo-induced silver nanowires: Fabrication and use in detection of relative humidity**

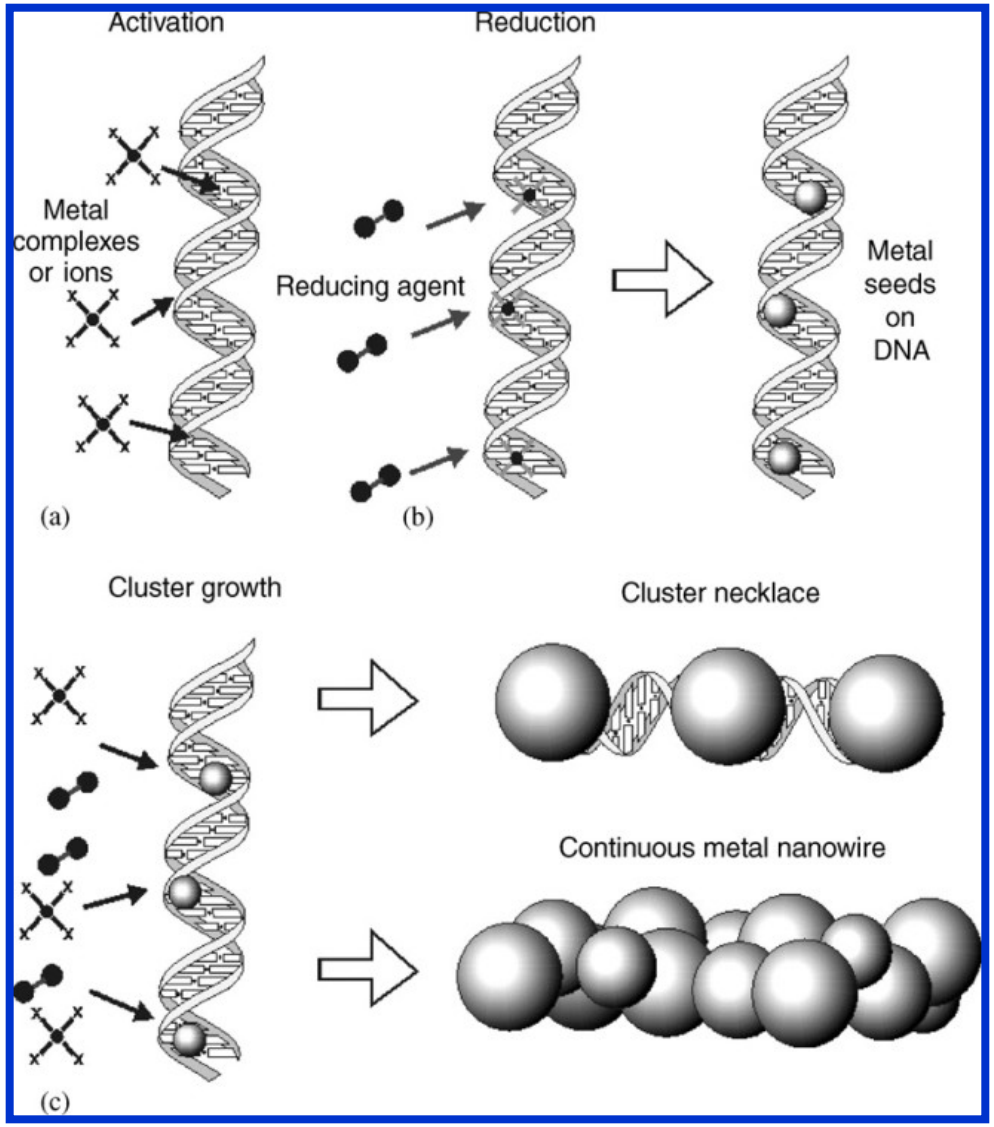
The TEM images of silver nanowires
Materials and Design 28 (2007)
S. Cui et al.
Construction of silver nanowires on DNA template by an electrochemical technique

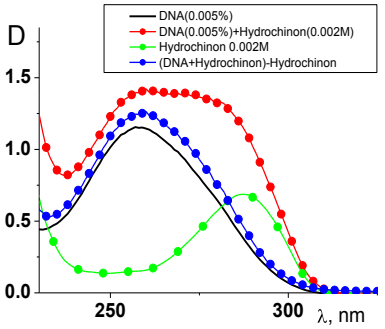


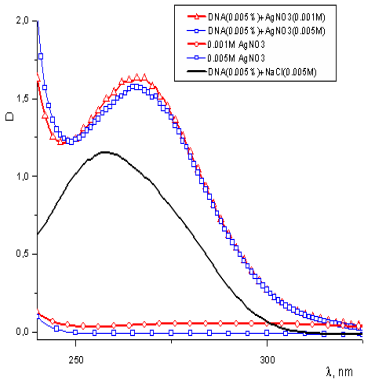


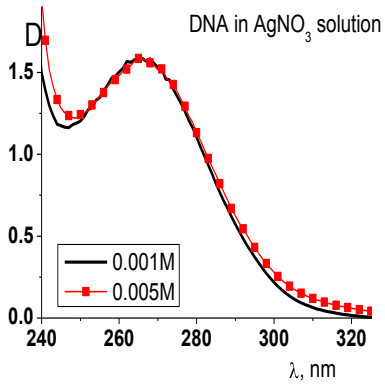
Пучкова О. Стенд.
(Puchkova O. Poster)

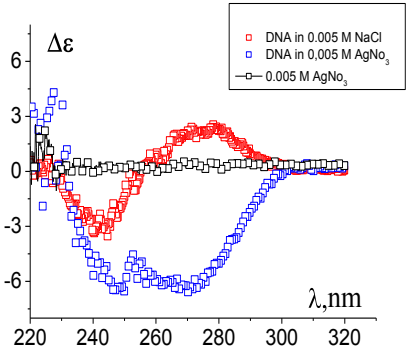
DNA metallization

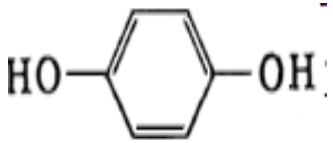




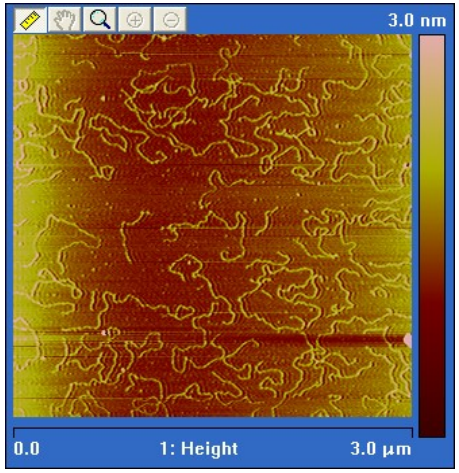


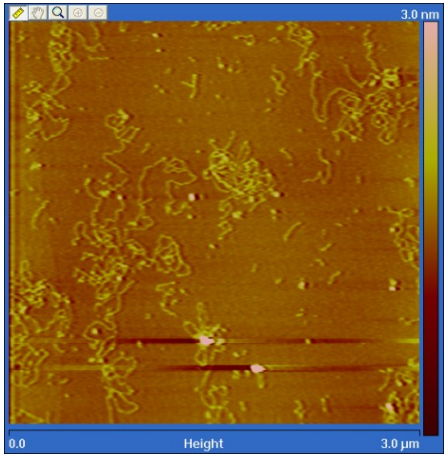


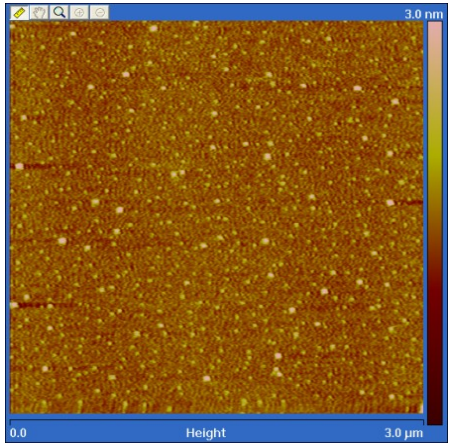


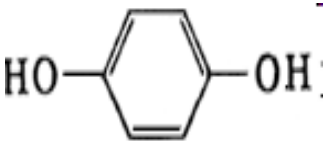


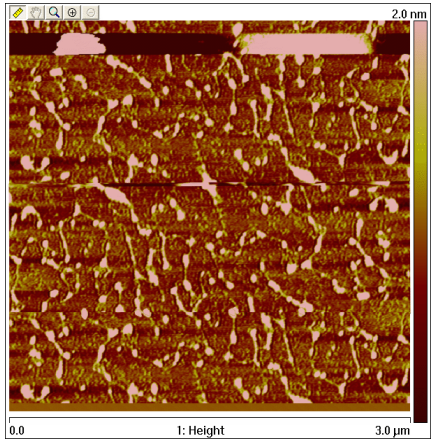
DNA metallization on mica

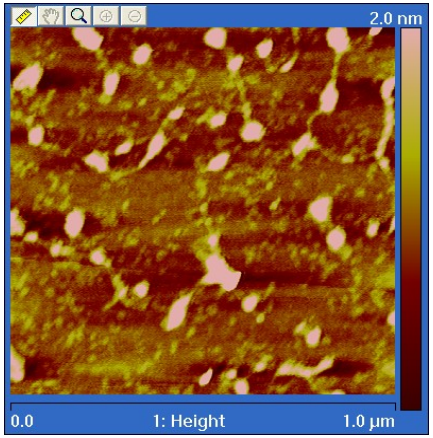


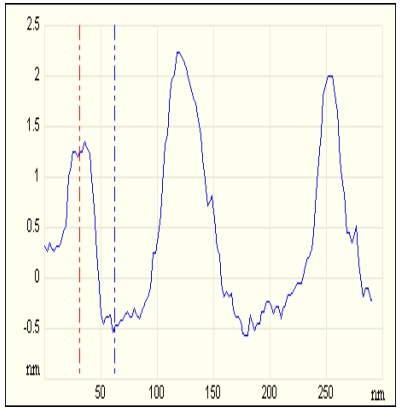


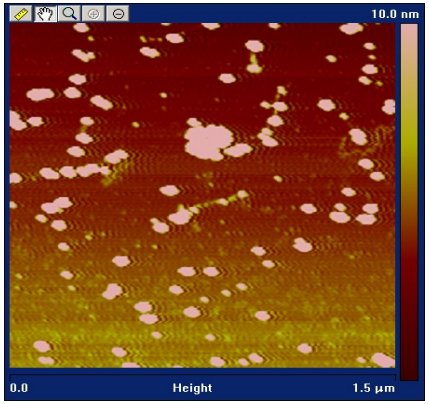


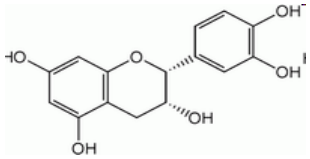


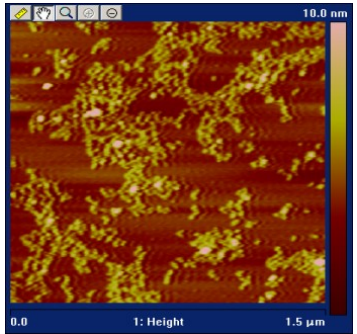


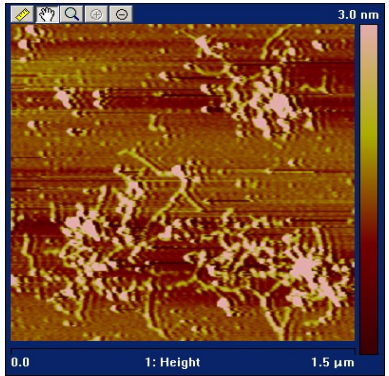


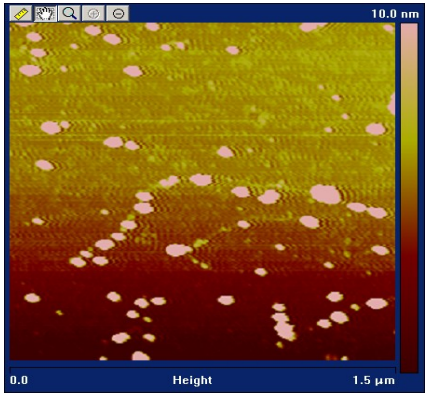






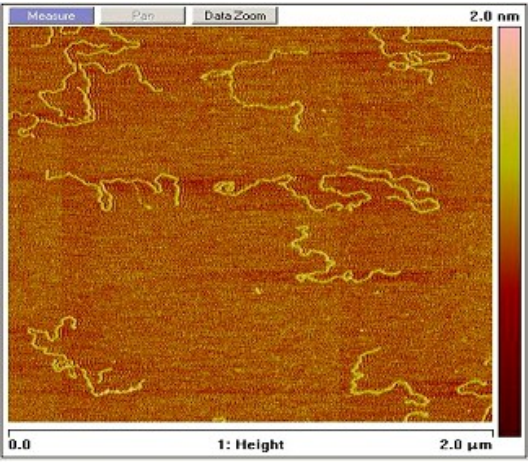


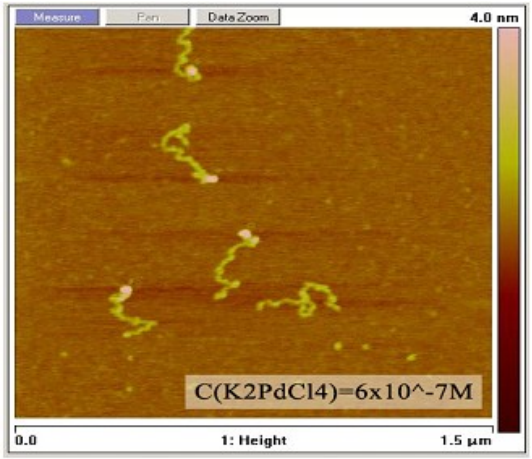


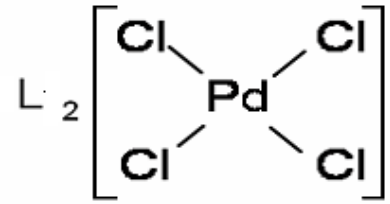


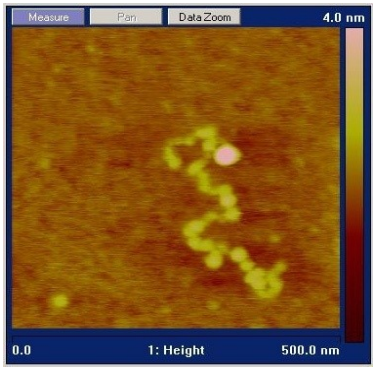
Пучкова Анастасия
Физ. ф-т СПбГУ

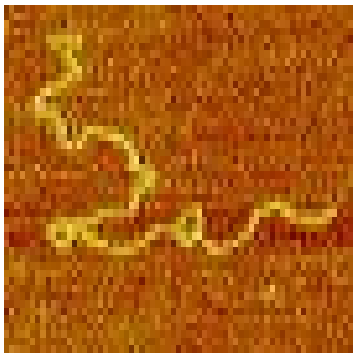
Plasmid DNA pFL 44 / EcoRI MM=4,4 kbp

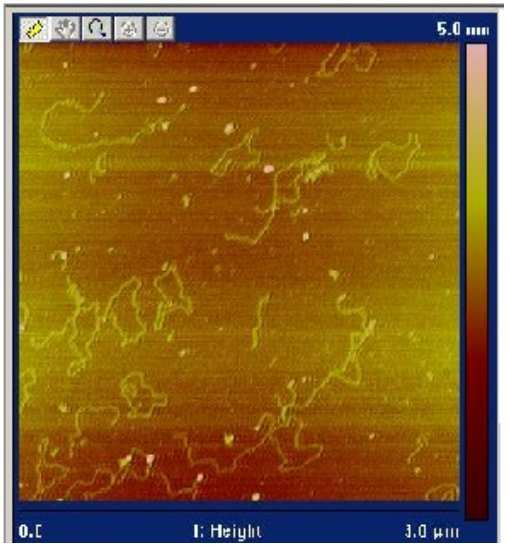


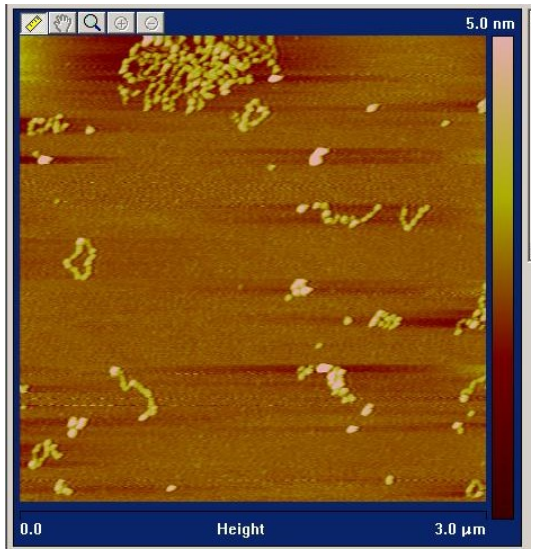


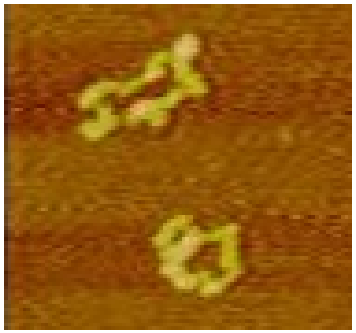


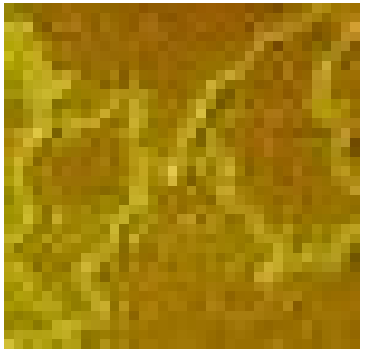


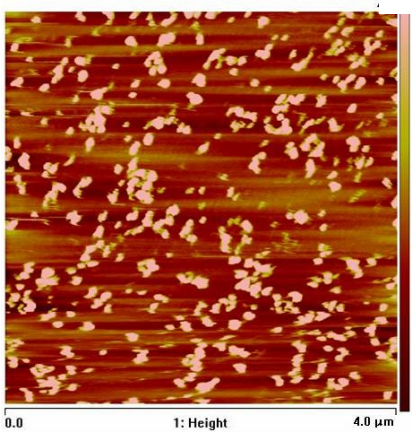




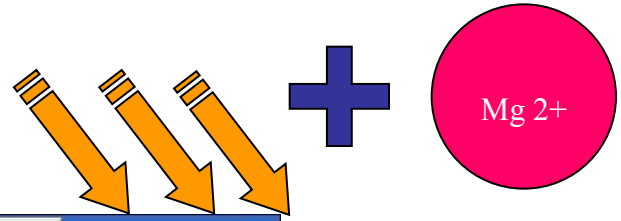




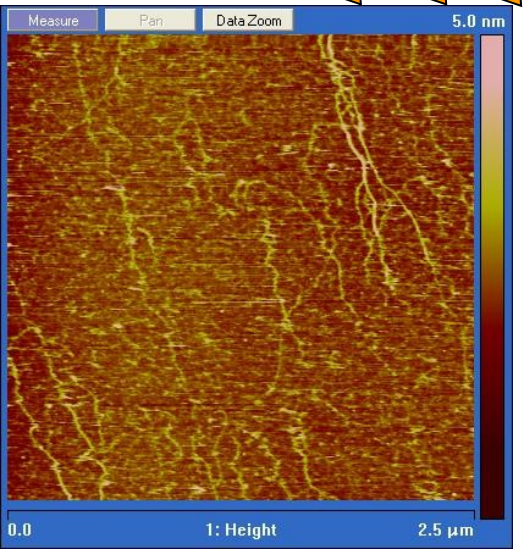


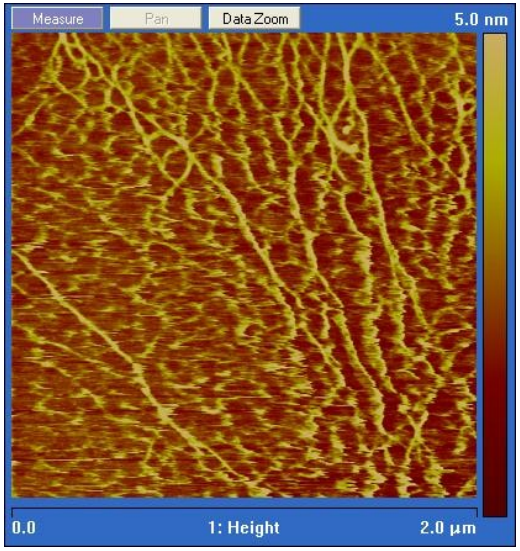


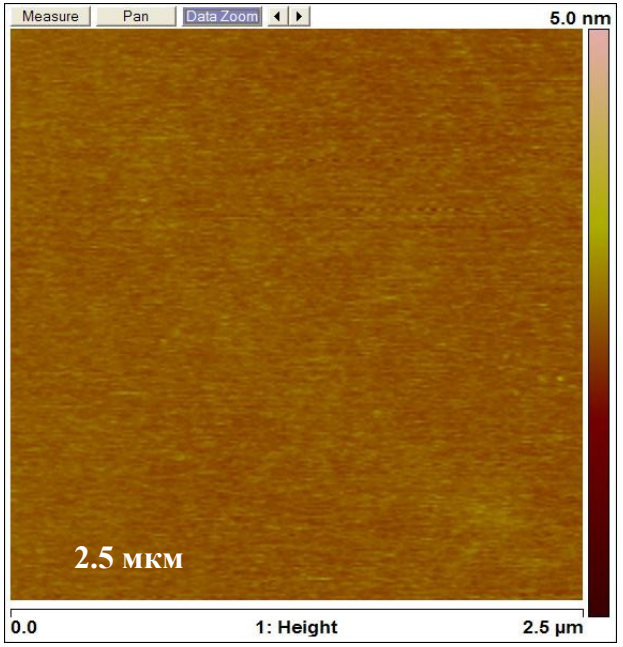
DNA on Silicon Surface



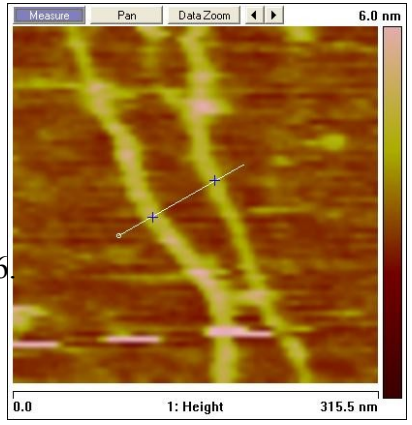
p-silicon

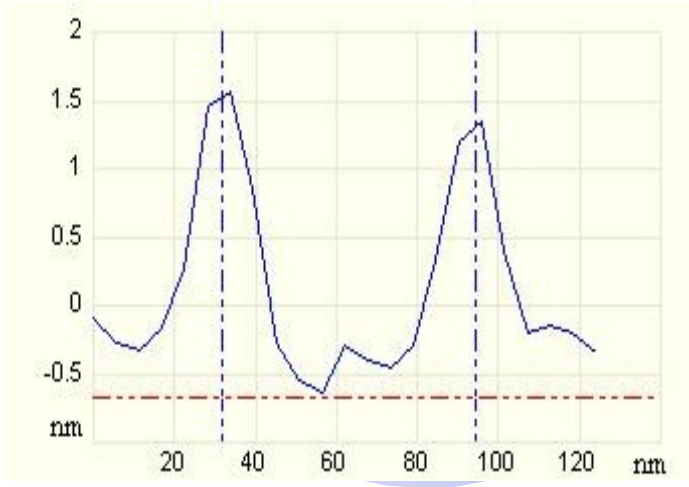






silicon surface





И.Л. Волков, Н.В. Базлов, А.С. Бондаренко, О.Ф. Вывенко, Н.А. Касьяненко.
Светоиндуцированная нековалентная фиксация ДНК и синтеттических полиионов на поверхности монокристаллов кремния, Журнал структурной химии 50, 2009, 999-1006.

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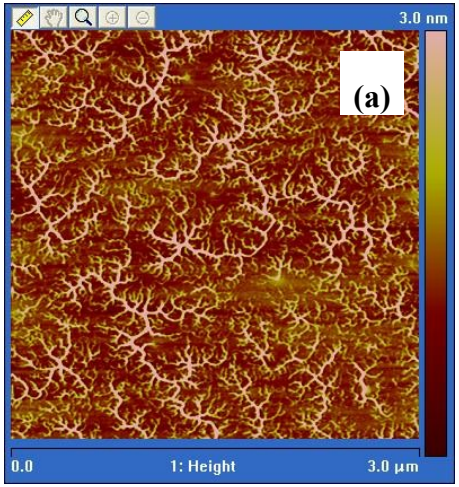
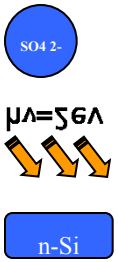
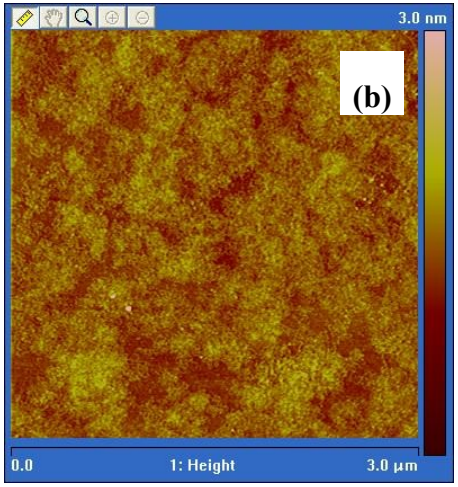
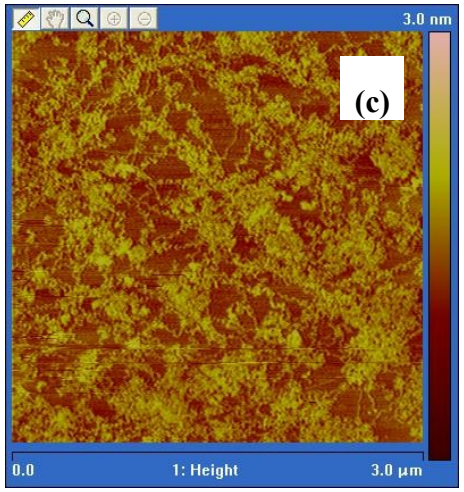
Разработка способа нековалентной фиксации ДНК на поверхности монокристалла кремния, Вестник Санкт-Петербургского университета. Серия 4: Физика, химия, (2009), 3 45-51.

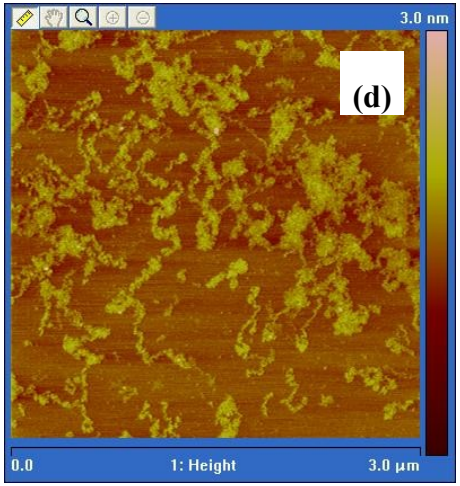
Polycation on mica and silicon surface

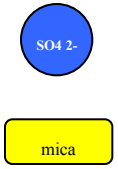


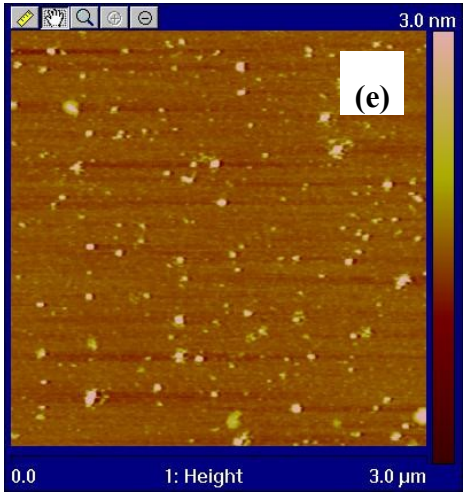


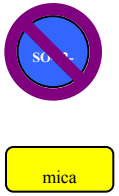


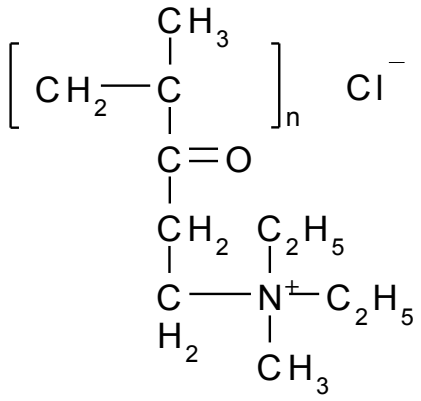








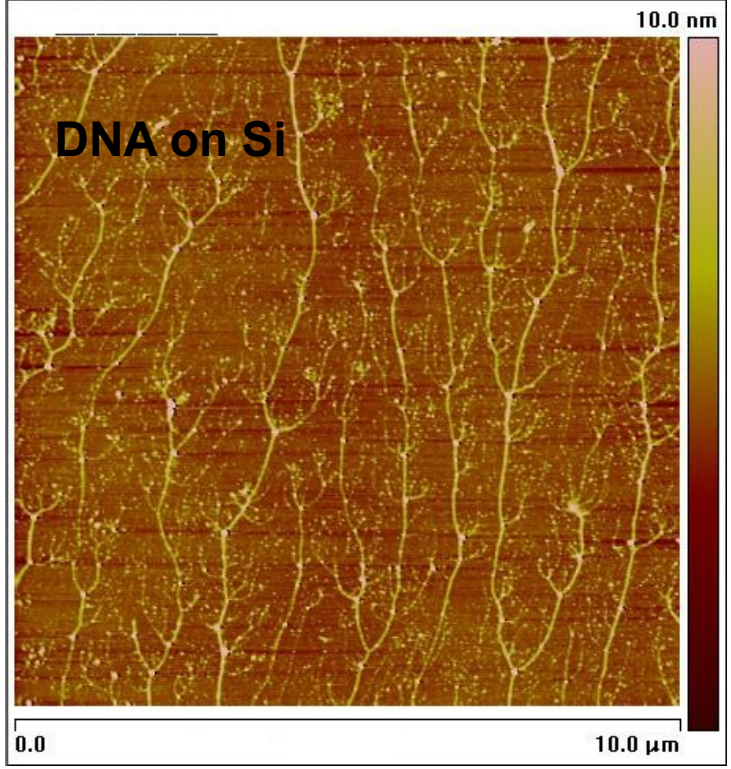


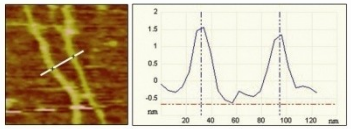


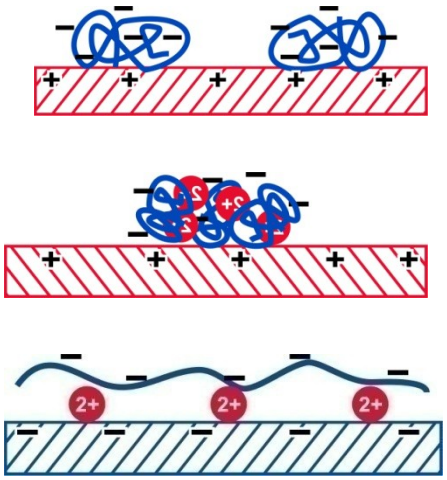
With Na2SO4 on n-silicon (a) and p-silicon (b) with light, on mica (d, e),

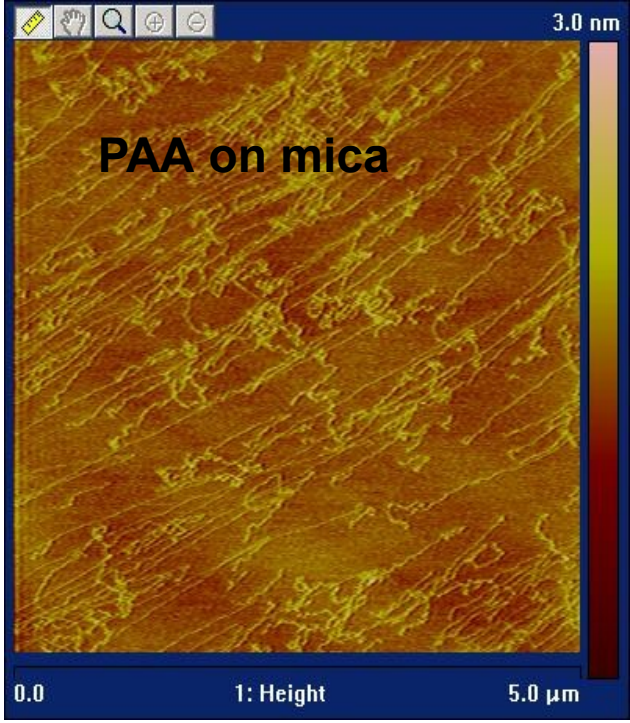
without Na2SO4 on mica (c).

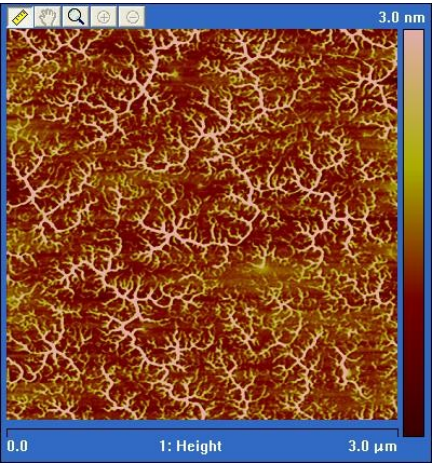
C(Na2SO4)= 5•10^{-4} M (a, b, d, e). C(pol)= 5•10^{-5} M (a, b, c, d). C(pol)= 5•10^{-6} M (d)

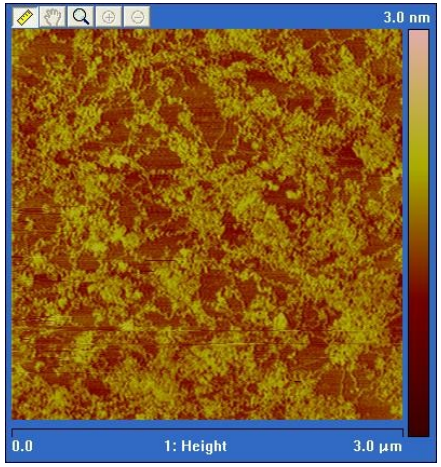

10.0 nm
DNA on Si
0.0
10.0 µm

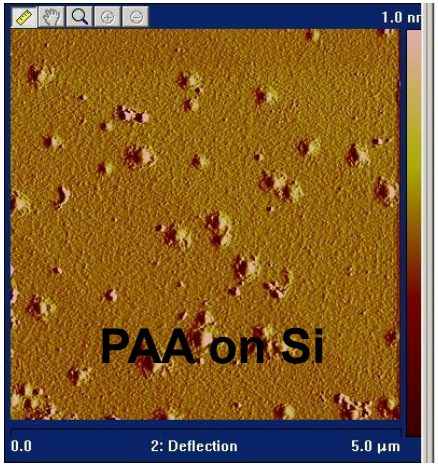


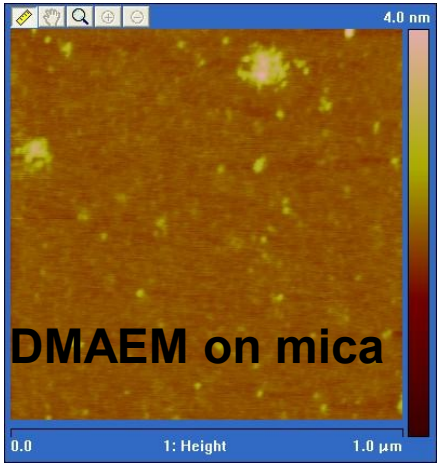



3.0 nm
PAA on mica
0.0
1: Height
5.0 µm


3.0 nm
0.0
1: Height
3.0 µm

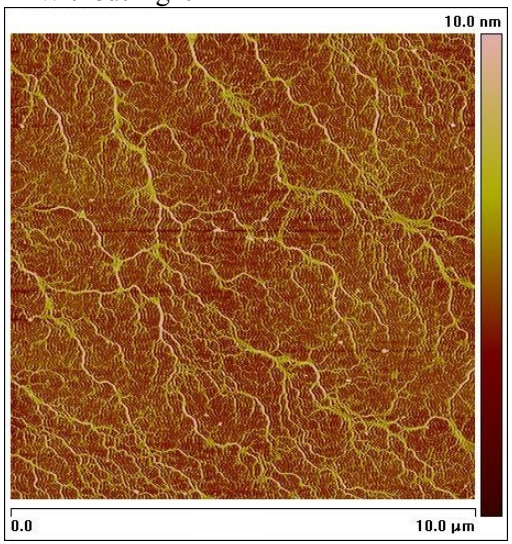

3.0 nm
0.0
1: Height
3.0 µm

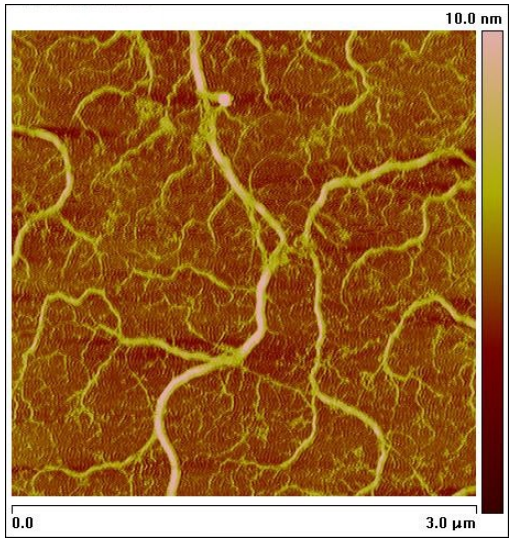

PAA on Si
0.0
2: Deflection
5.0 µm


4.0 nm
DMAEM on mica
0.0
1: Height
1.0 µm

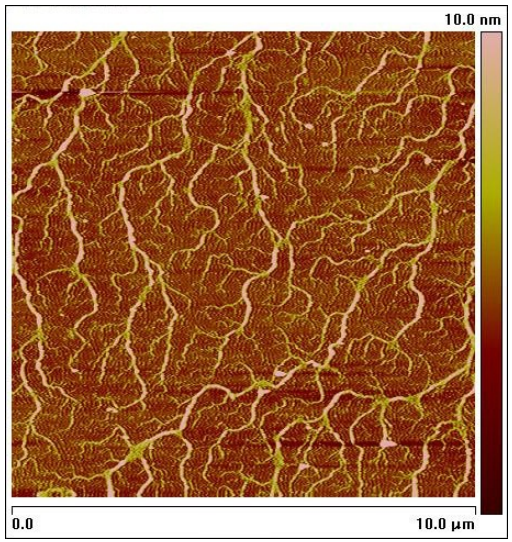
n-Si

Without light



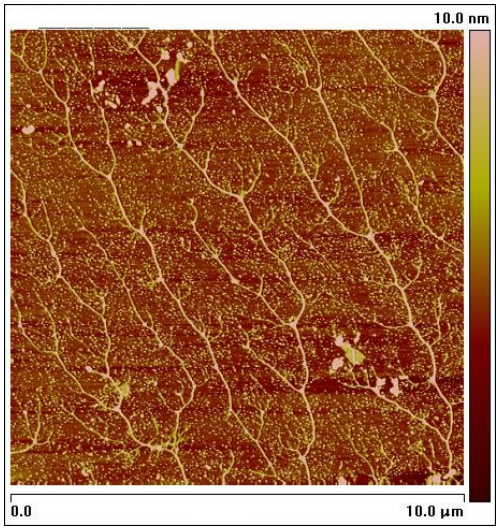


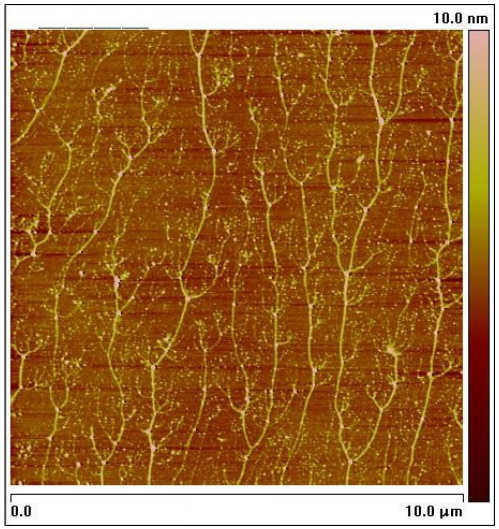
Wiht light (890 nm)



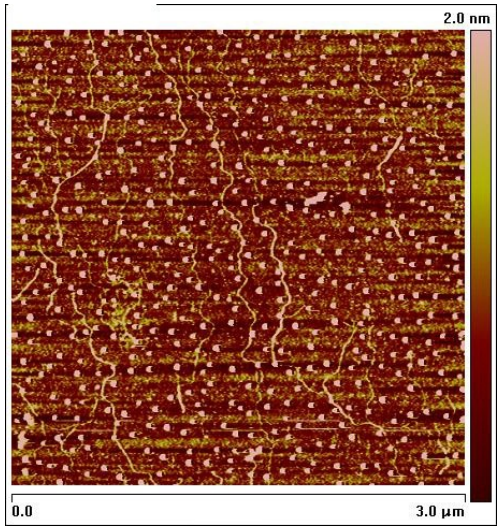
p-Si

Without light





With light (890нм)



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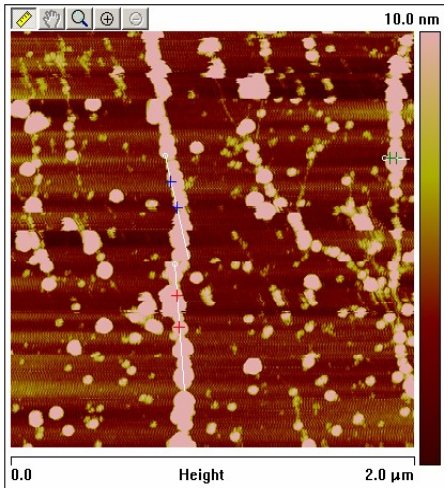
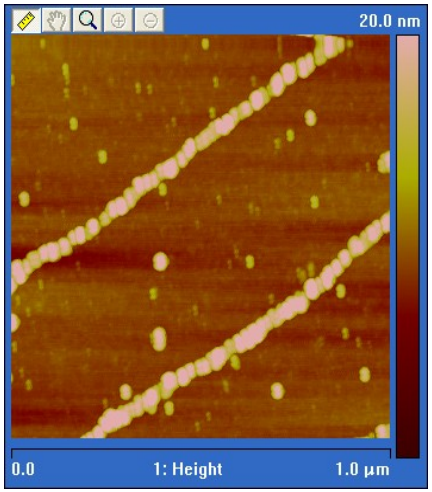
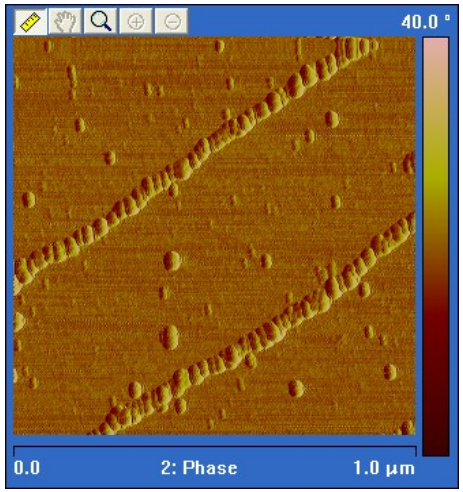
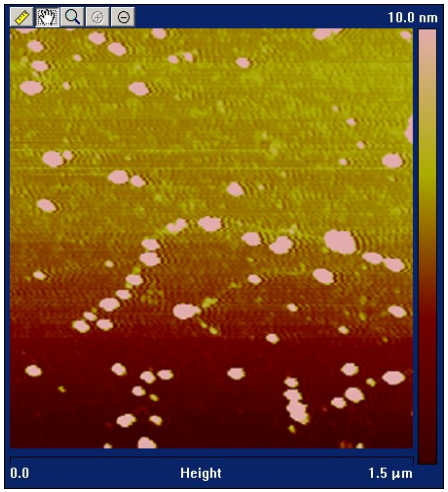
Nanowires on silicon



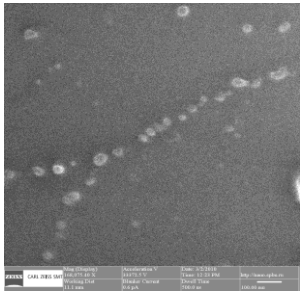


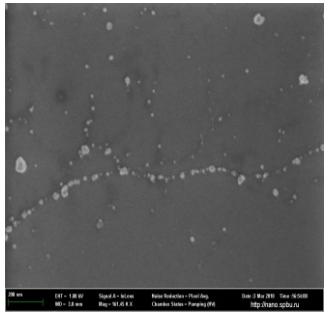


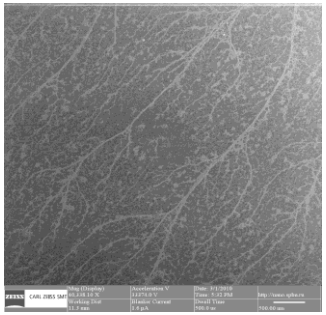


DNA nanowires on silicon

Metallized DNA on mica

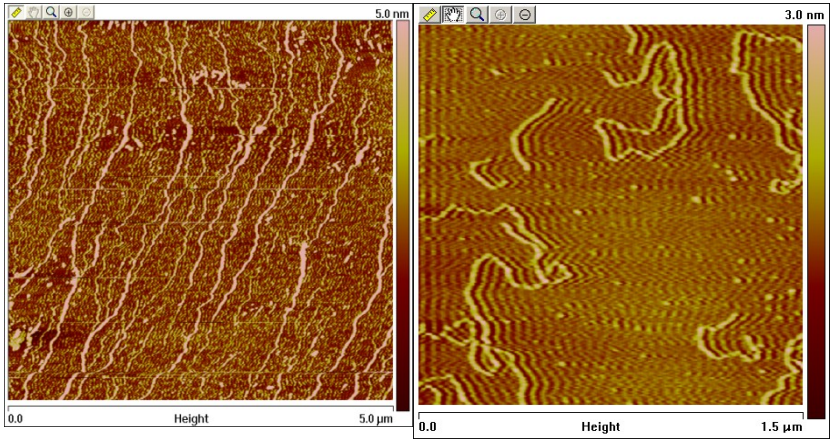






(a) (b) (c)

DNA nanowires on silicon: secondary-ion microscopy, transmission and scanning electron microscopy



AFM image DNA on mica

Transmission electron microscope JEM-2100F (Jeol), Secondary-ion microzonde-microscope IMS7F Cameca, UHV Scanning Tunnel icroscope

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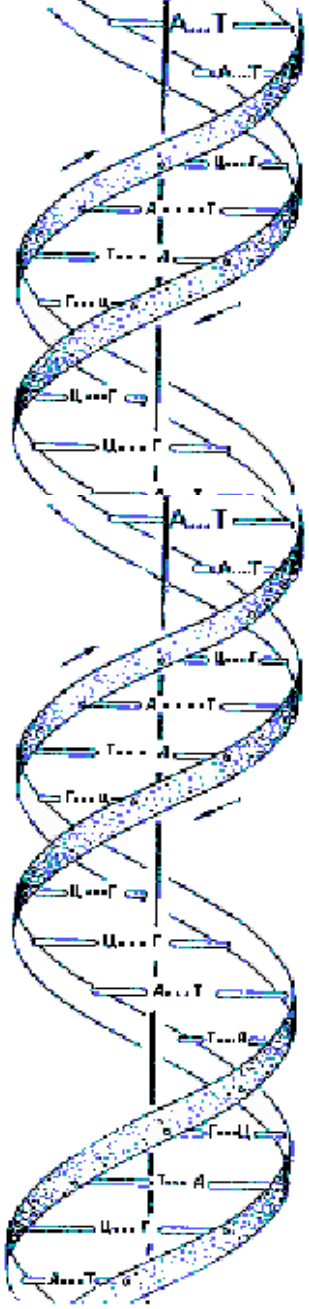
к.б.н. Слита А.В.



Thank you for the attention