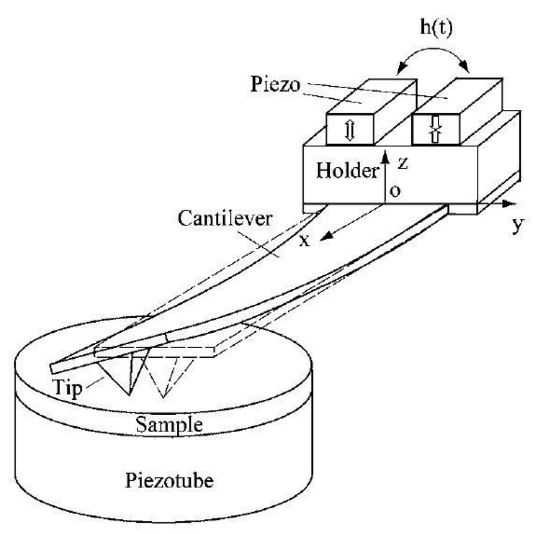
The Conductivity of Metallic DNA investigated by Torsion Tunneling Atomic Force Microscopy

Wei Wang,[1] Dong Xiao Niu,[2] Xinju Yang[1]
[1]Phys. Dept., Fudan Univ., Shanghai, People's Republic of China
[2]Shanghai Institute of Applied Physics, Chinese Academy of Science

By combining torsion tunneling atomic force microscopy (TR-TUNA) with the ultra-thin graphite sheet nanoelectrode method, the conductive properties of silver metallic DNA and copper metallic DNA are investigated, along both the vertical and lateral directions. It is found that the metal clusters attached to the DNA chains enhance the conductivity of DNA significantly, resulting in enhanced conductivity perpendicular to the chain. But due to a "beads-on-a-string" appearance of metallic DNA, electrical transport along the metallic DNA wires is still week.

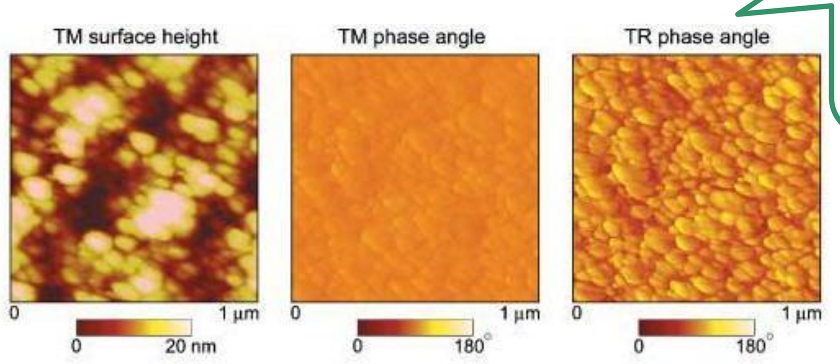
I. Torsion Tunneling Atomic Force Microscopy principle and Sample preparation

TR mode AFM

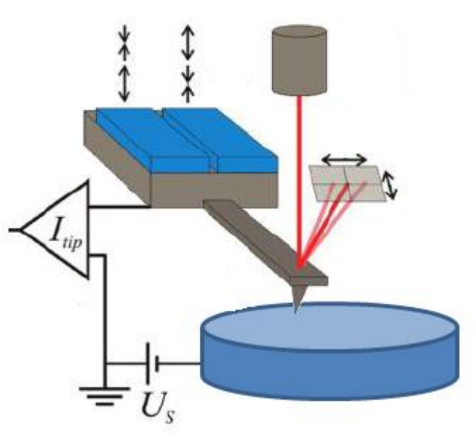


The cantilever is excited at its torsional resonance frequency by two piezoelectric elements attached to the holder. The cantilever undergoes a combination of torsion and lateral bending.

Comparison of tapping mode AFM and TR mode AFM



TR-TUNA mode

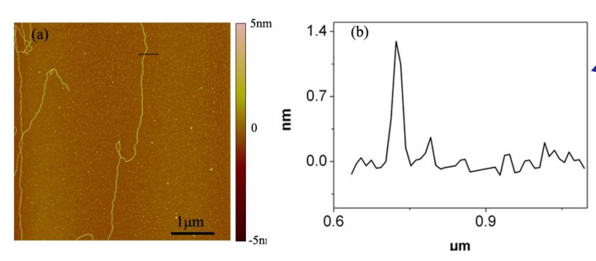


In TR-TUNA mode, a bias voltage (Us) is applied to the sample and the tip sample current is measured (I_{tip}). TR-TUNA mode avoid the damage to delicate specimens due to high lateral forces in traditional contact in conductive scanning force microscopy.

Ultra-thin Graphite Sheet Nanoelectrode

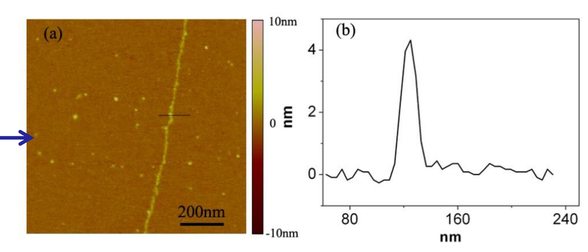
A sheet of sever millimeters wide graphite is cleaved from bulk graphite surface with tweezers. Laying the graphite sheet carefully to a fresh cleaved mica surface, then the graphite sheet we used as electrode.

λ-DNA Metallization

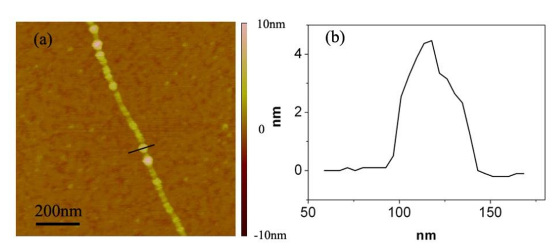


λ-DNA

Cu metallic DNA



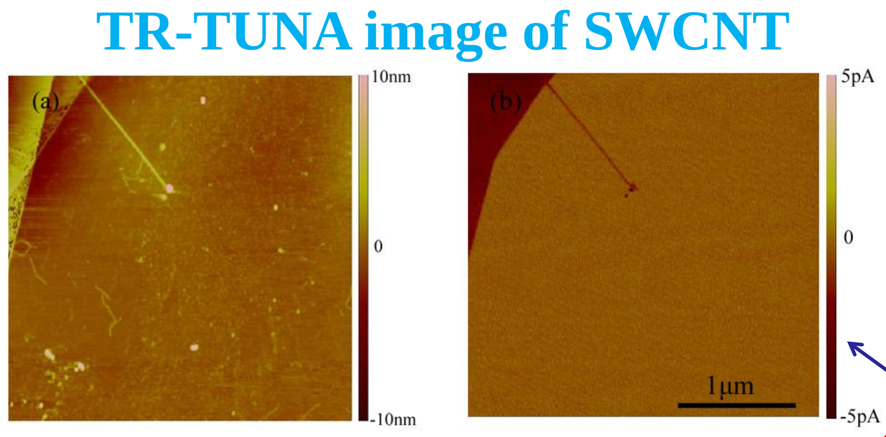
Ag metallic DNA



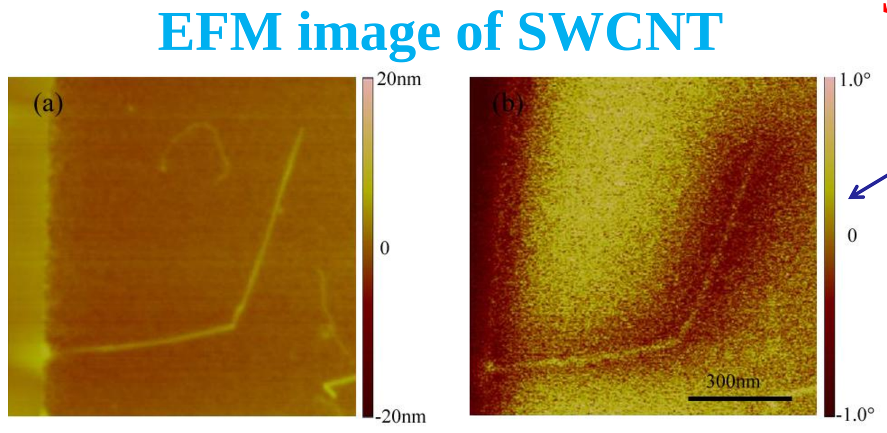
The basic principle of metallic DNA is utilizing reduction reaction to reduce the metal complexes or metal ions fixed to the DNA molecules.

II. Application of graphite nanoelectrode

TR-TUNA image of SWCNT



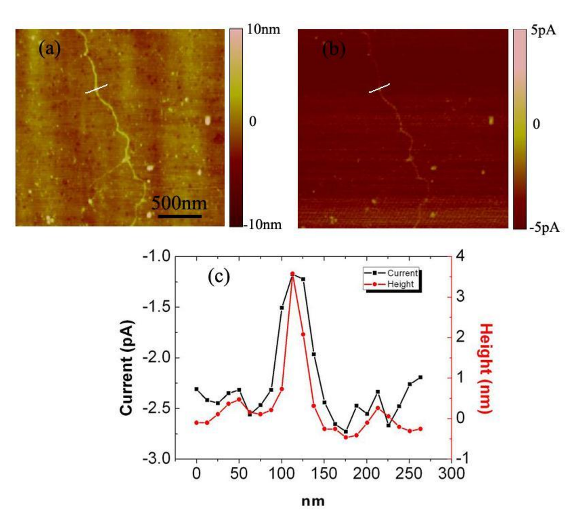
EFM image of SWCNT



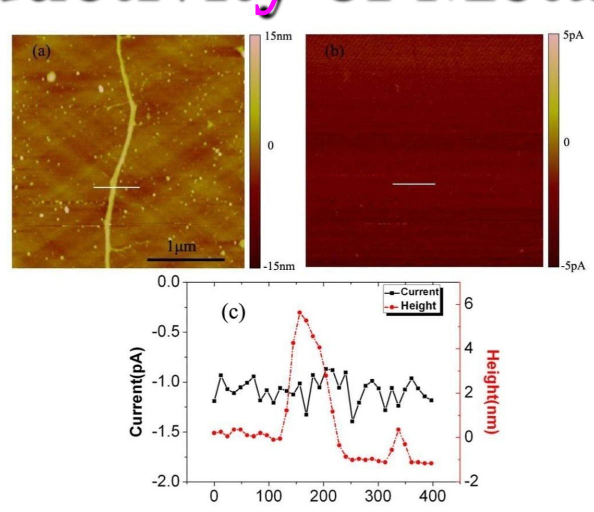
Sample bias: -6.0V

This method is feasible to investigate the conductivity of nanoscale one-dimensional samples.

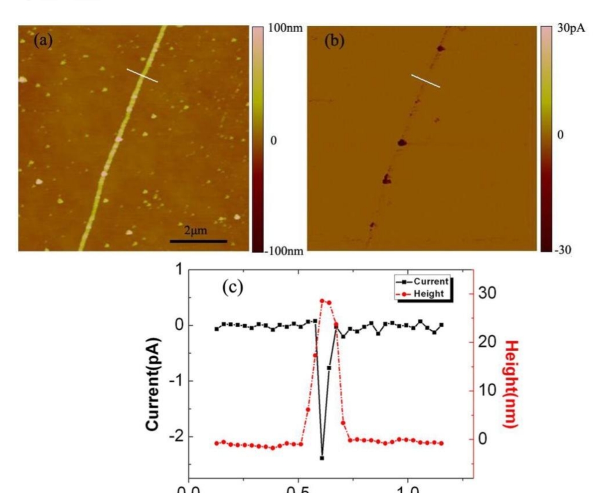
III. Conductivity of Metallic DNA



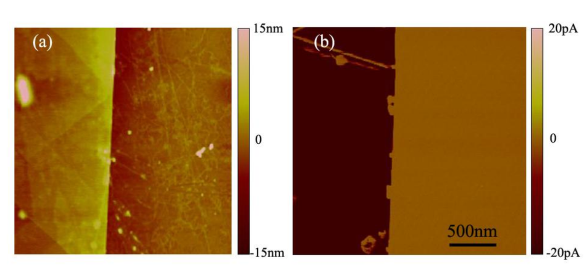
(a)λ-DNA spread on silicon substrate
(b)Current map, sample bias: -9.5V



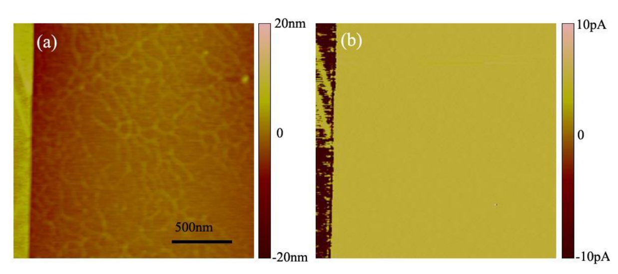
(a)Cu metallic DNA
(b)Current map, sample bias: -8.0V



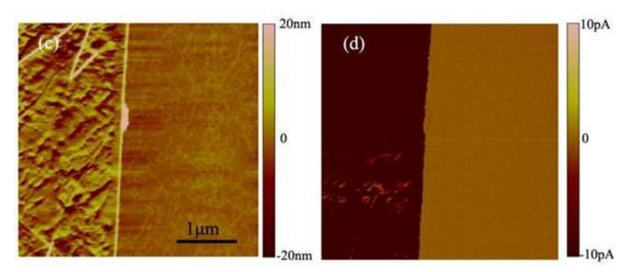
(a)Ag metallic DNA
(b)Current map, sample bias: -9.0V



(a)λ-DNA on mica substrate
(b)Current map, sample bias: -1.0V



(a)Ag metallic DNA
(b)Current map, sample bias: -0.4V



(c)Cu metallic DNA
(d)Current map, sample bias: -1.0V

- Both the lateral and vertical conductivities of DNA are very poor.
- After metallic process, the metal clusters enhance the conductivity of DNA significantly. Good vertical conductance could be measured by TR-TUNA.
- Due to the "beads-on-a-string" structure metallic DNA, electrical transport along the metallic DNA wires is still week.

IV. Conclusions and References

Conclusions: By combining TR-TUNA mode with the ultra-thin graphite sheet nanoelectrode method, the conductive properties of low dimensional soft samples can be investigated, like carbon nanotubes and single biomolecule. With this novel method, the conductive properties of DNA molecule and metallic DNA are obtained.

References: [1] *Weber Stefan A. L., et al. Nano Letters, 2010, 10(4): 1194-1197*
[2] *Monson CF, Woolley AT. Nano Letters, 2003, 3(3): 359-363*