

# Functional Materials with Shape Memory Effect at Nanoscale of Dimensions

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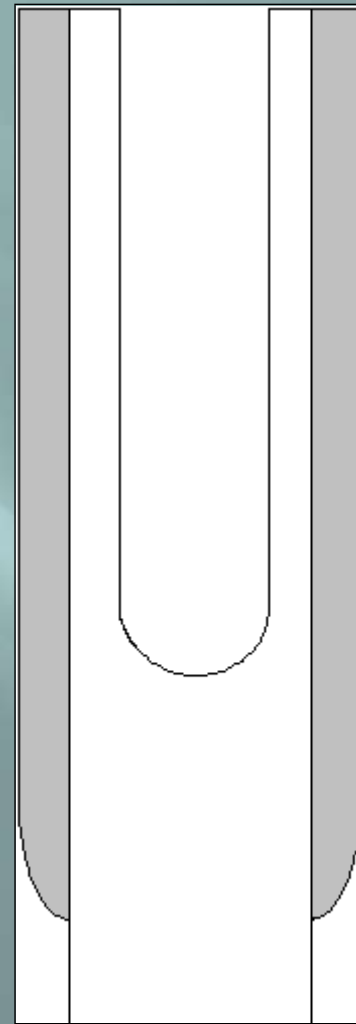
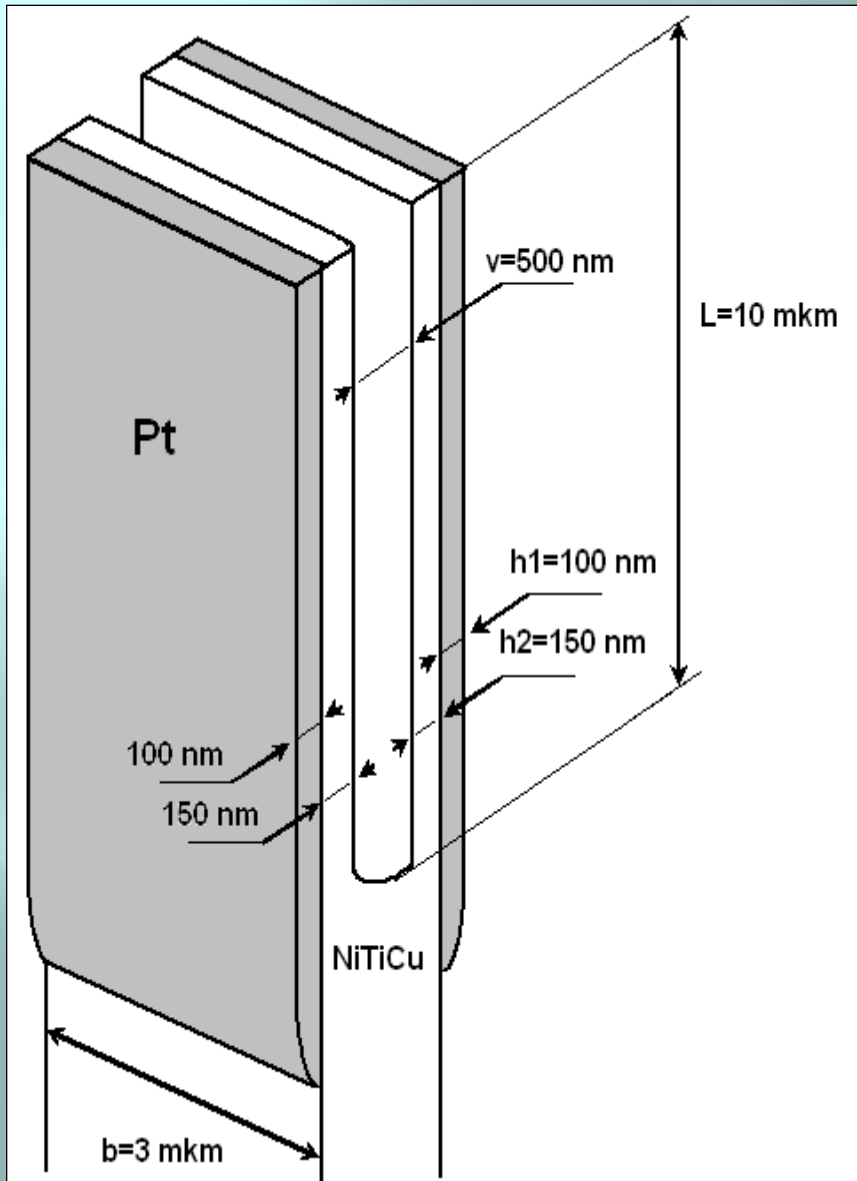
***in collaboration with:***

***National Research Nuclear University "MEPhI", Moscow***

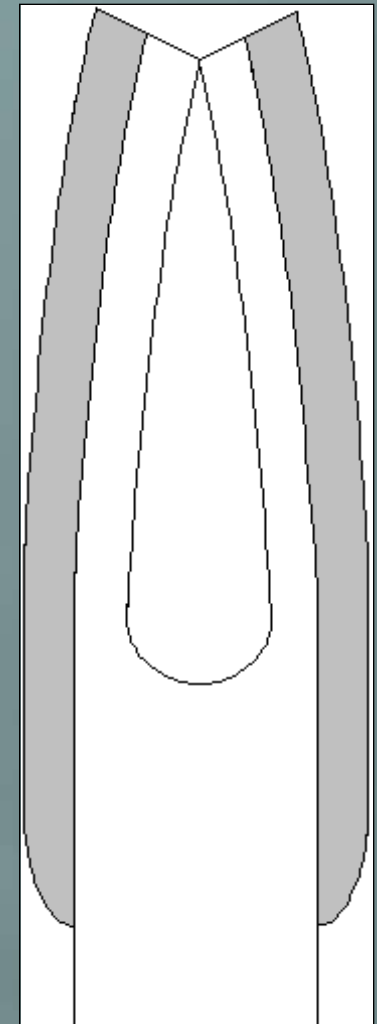
***A.F. Ioffe Physico-Technical Institute of the Russian Academy of Sciences,  
Saint-Petersburg***



# Nanotweezers project



$$T < T_m$$

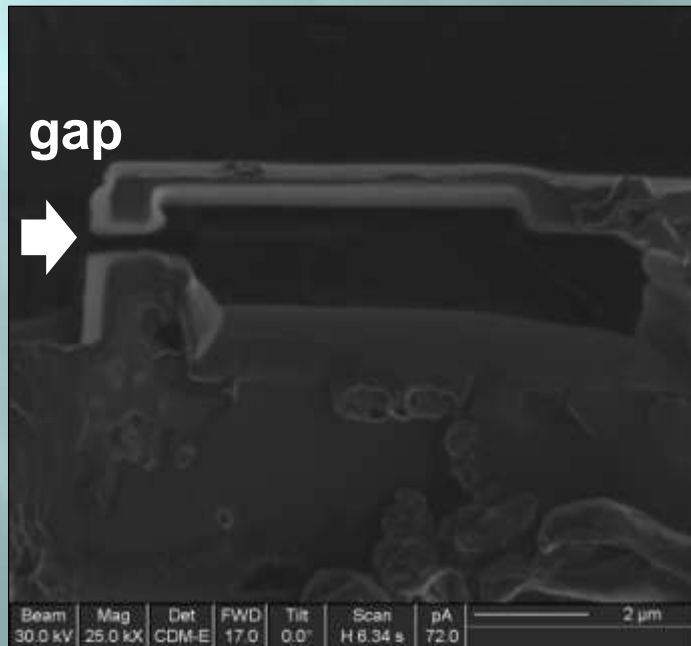
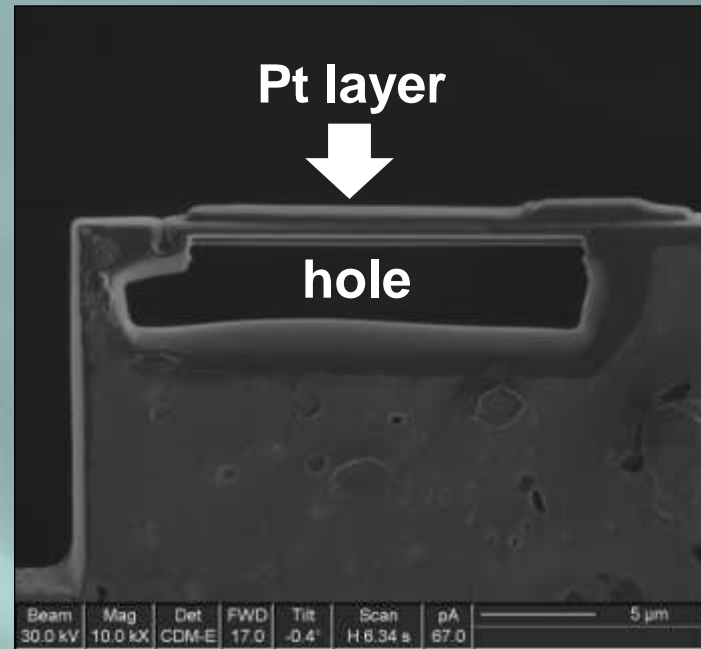
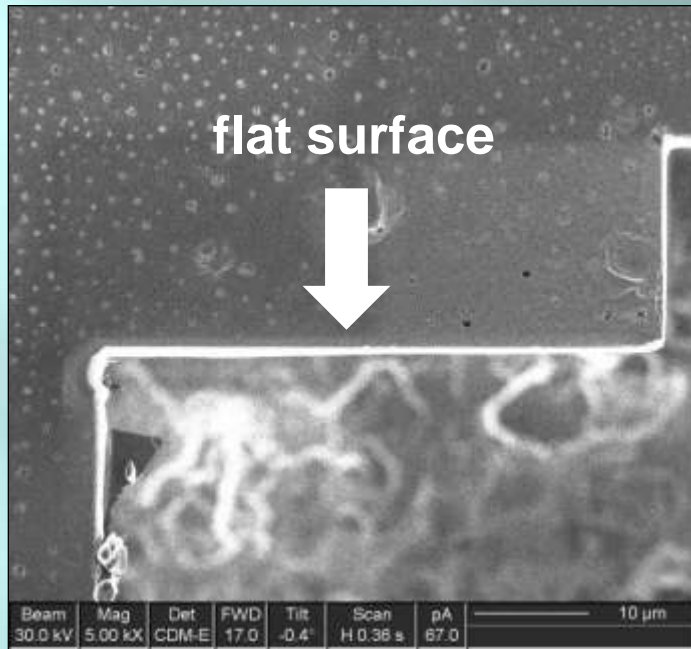


$$T > T_m$$

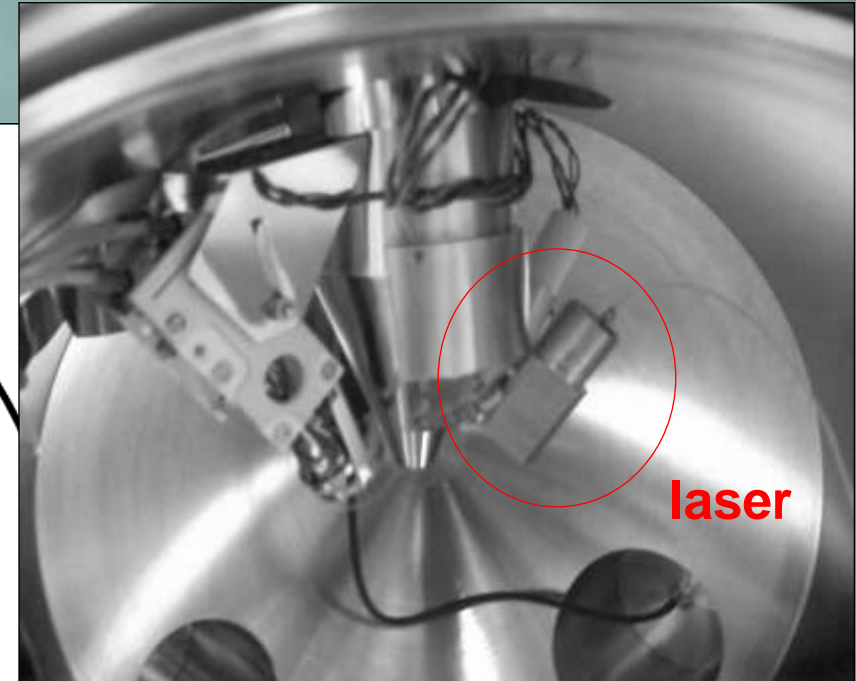
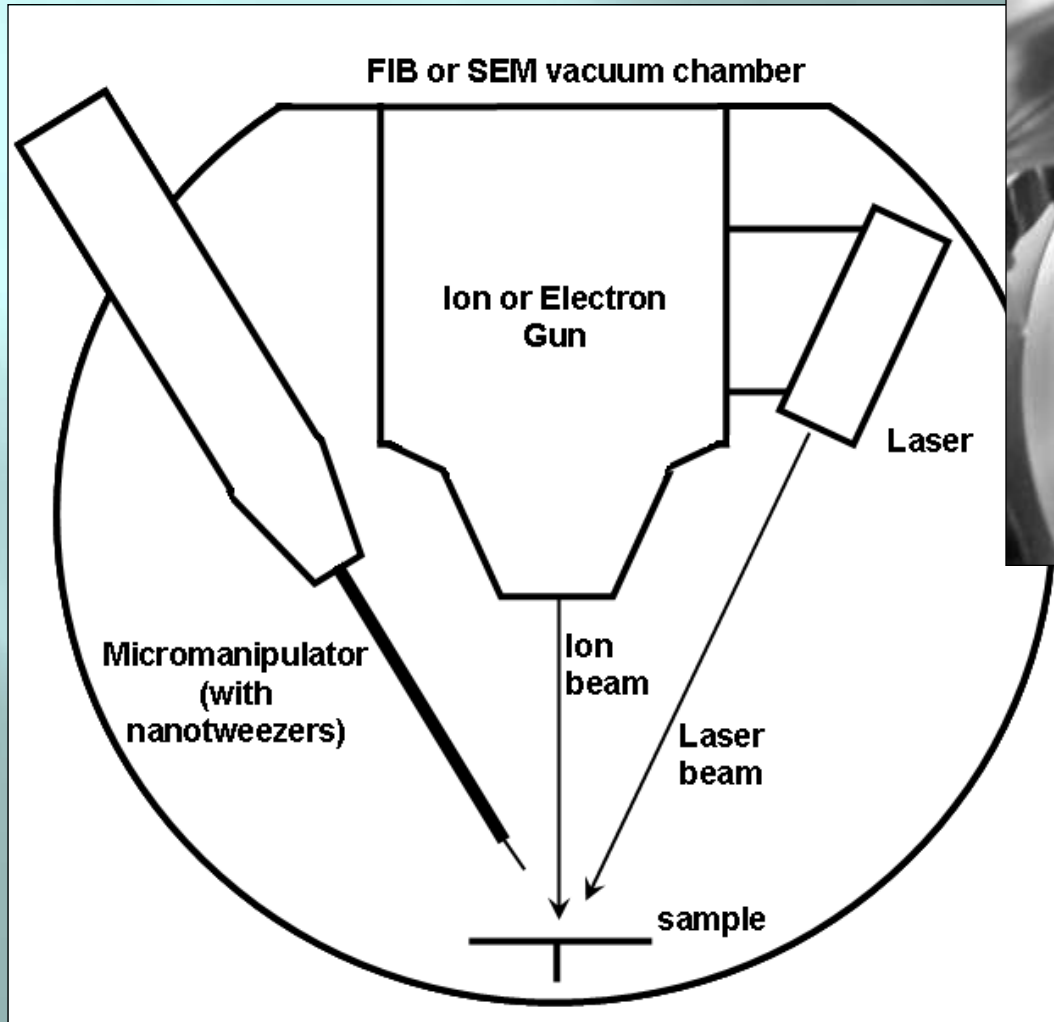
# Advantages of the scheme:

- **Giant relative deformations: 1 - 10 %.** Thus record small dimensions are enough for manipulation.
- **Simple manufacturing techniques: standard processes.**
- **Possibility to make a submicron size actuator, thus the size of grasped object will be down to 10 nm.**
- **Possibility to supplement the standard micromanipulators, like Kleindiek® or Omniprobe®.**
- **Convenient work temperature range : 40 - 60 °C.**

# Fabricating the nanotweezers by FIB

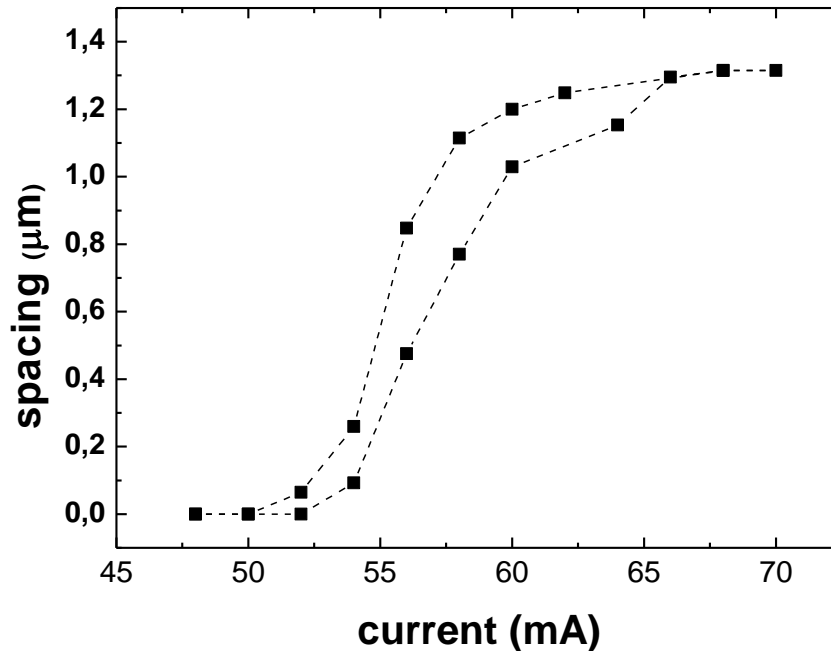
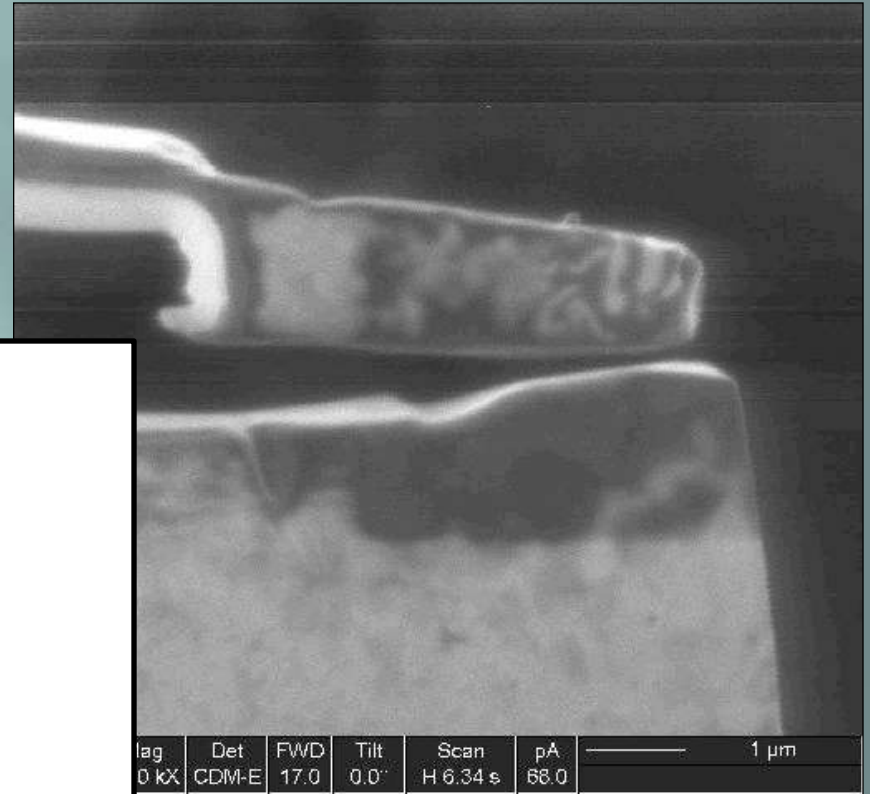
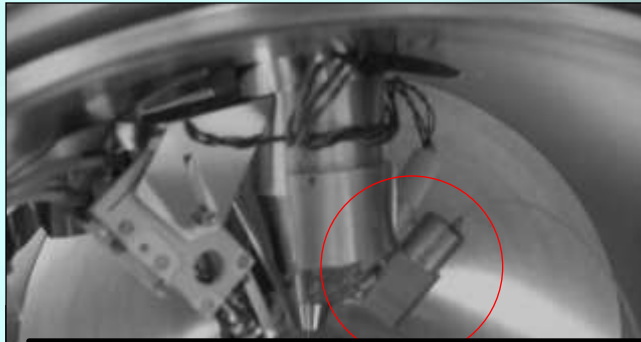


# Heating control of nanotweezers by semiconductor laser in FIB vacuum chamber



# Nanotweezers prototype made by FIB

## Control system integrated in the vacuum chamber



*dimensions 12x3x1 microns*

*grasped objects < 1200 nm*

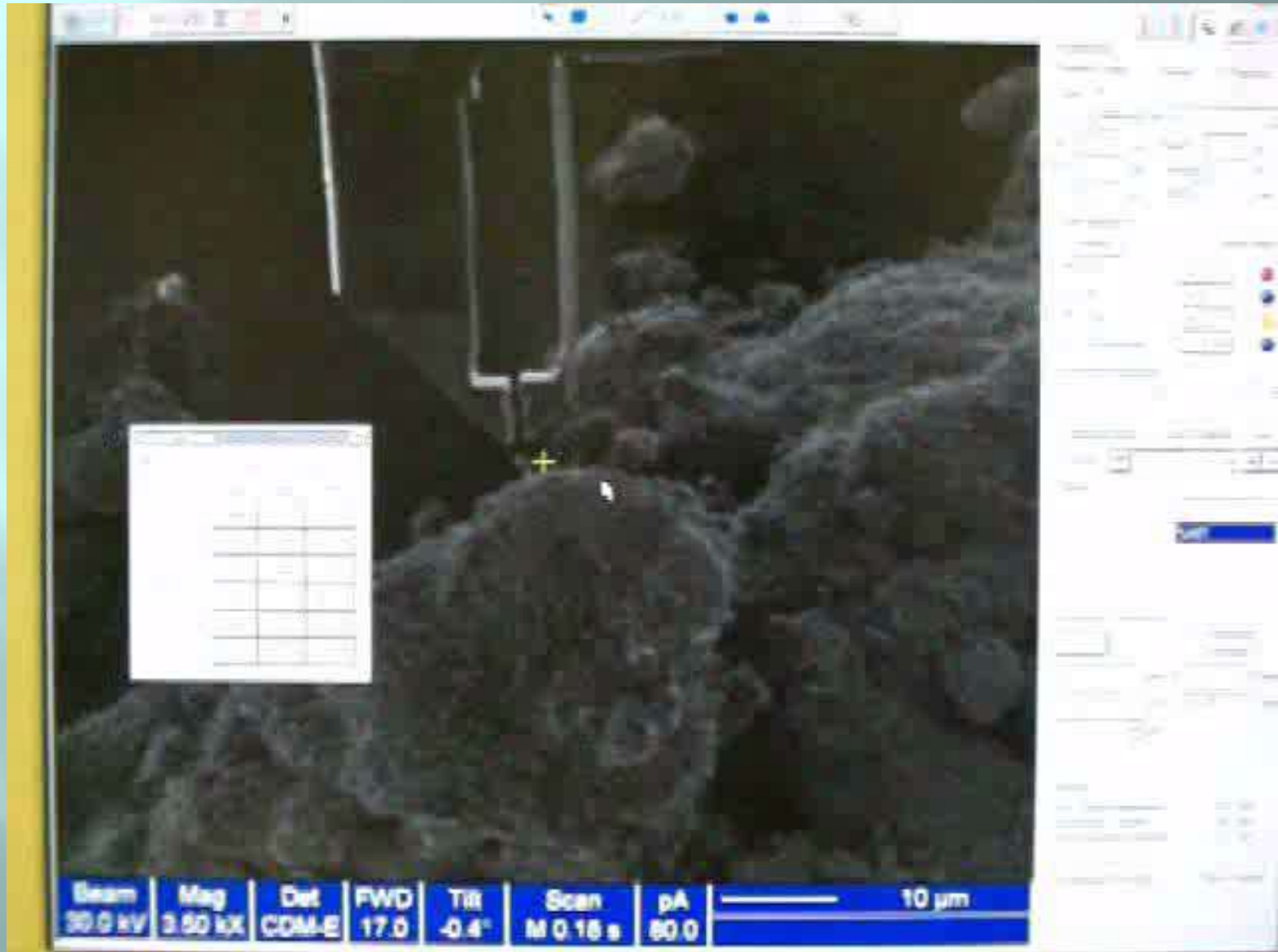
[smwsm.org//II/micropincer.html](http://smwsm.org//II/micropincer.html)

# Switching time of Nanotweezers prototype

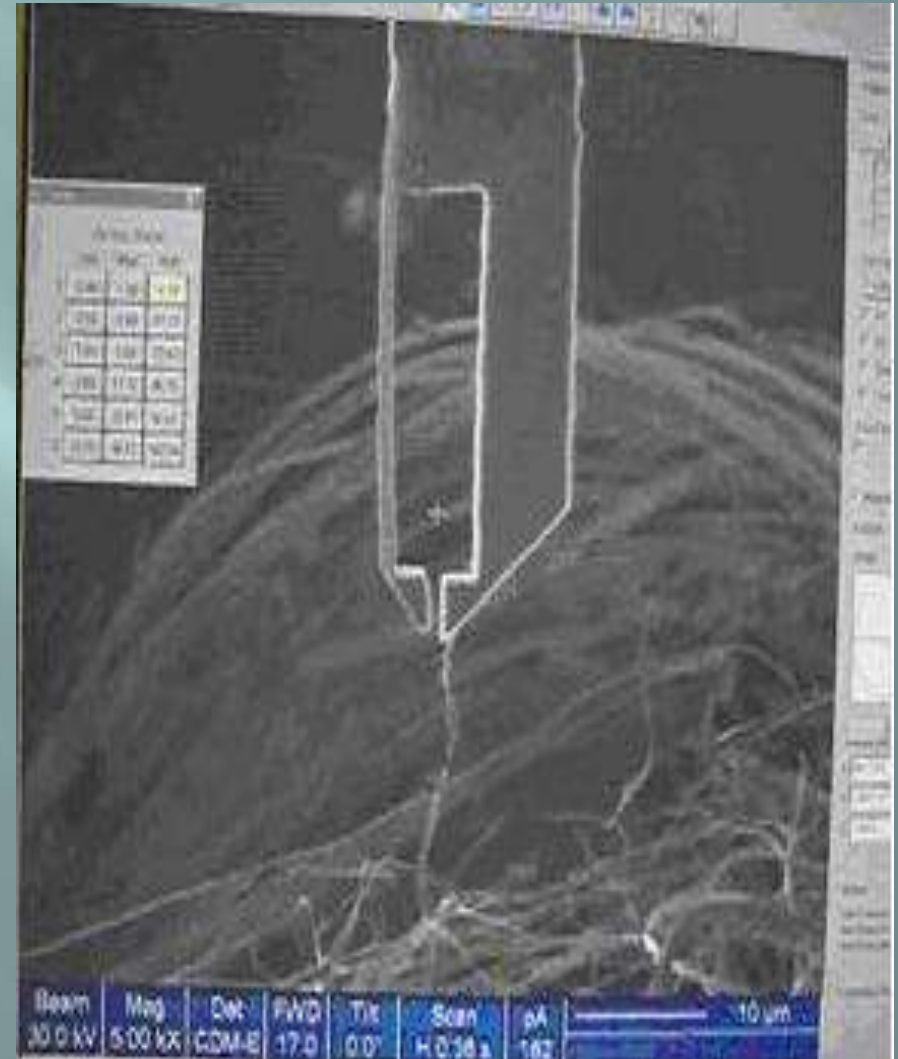
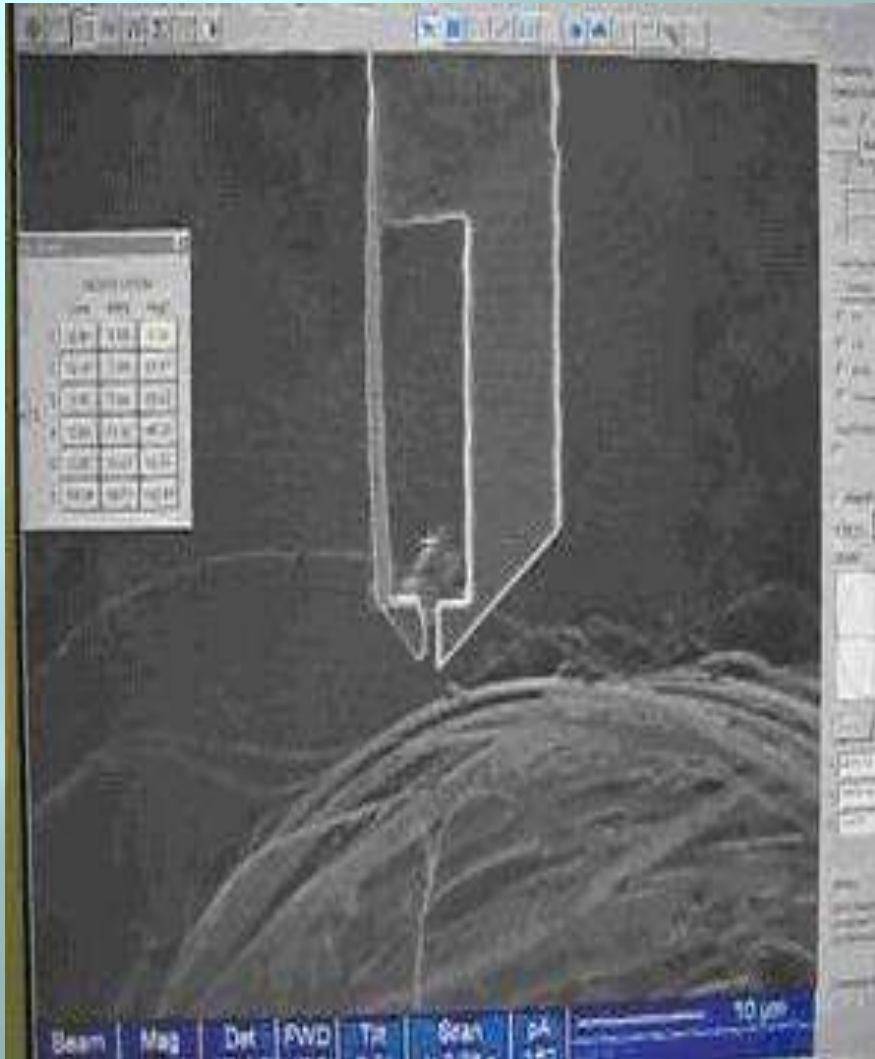


Time of switching ~ 200 ms

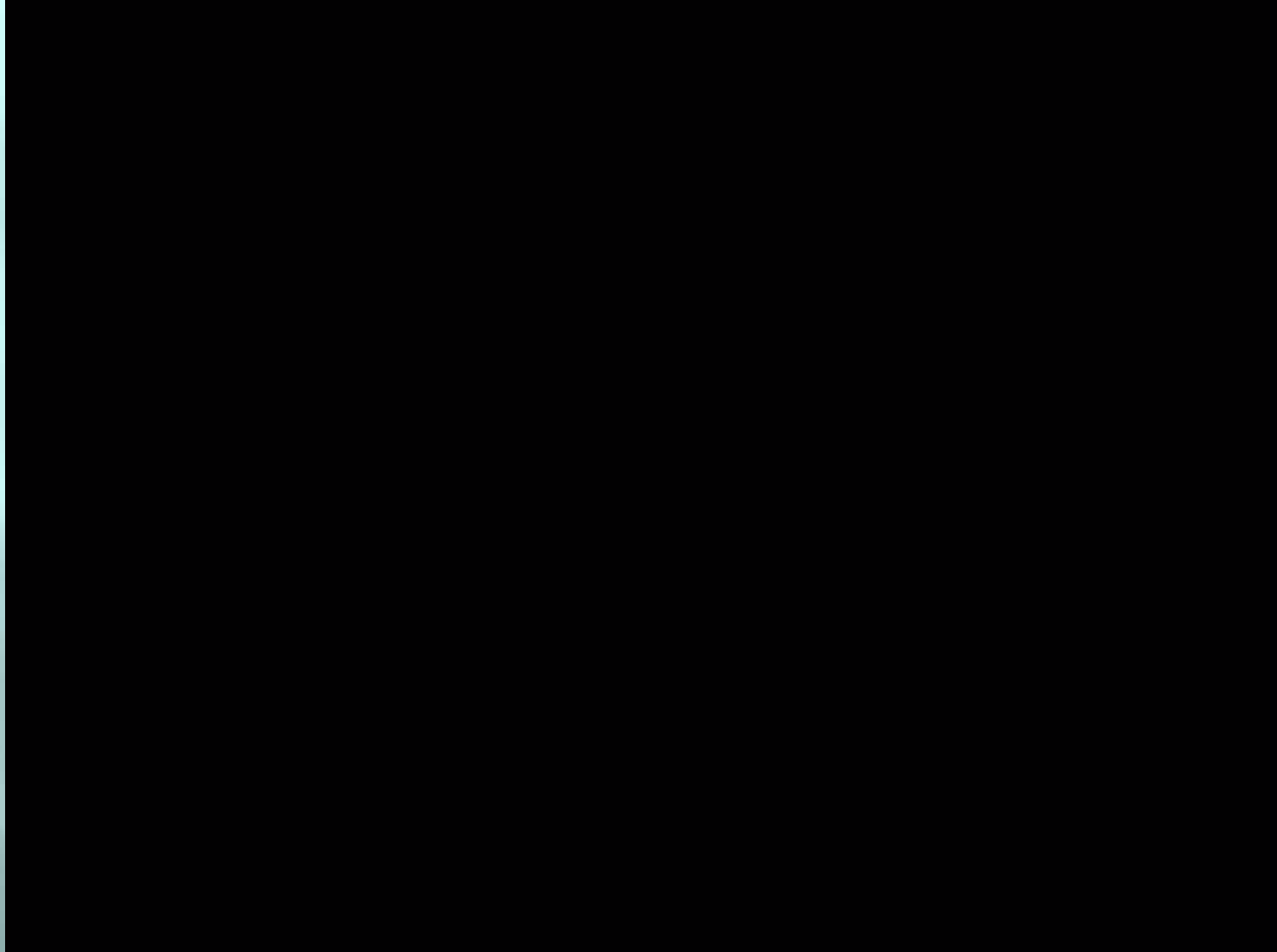
# Manipulation with CNT sample



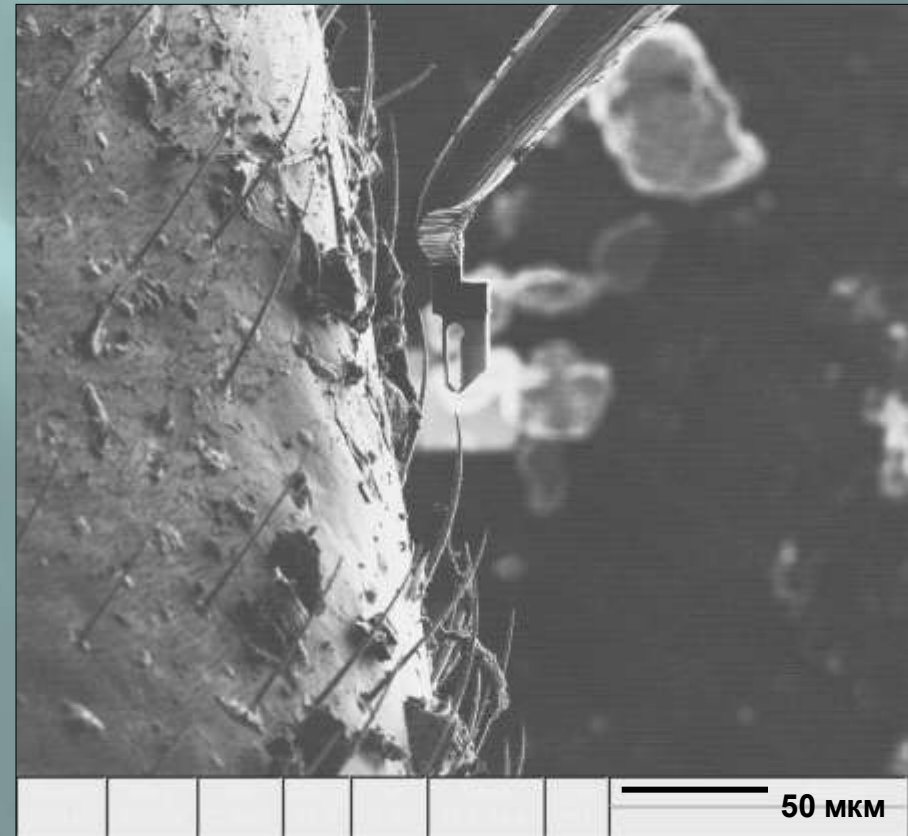
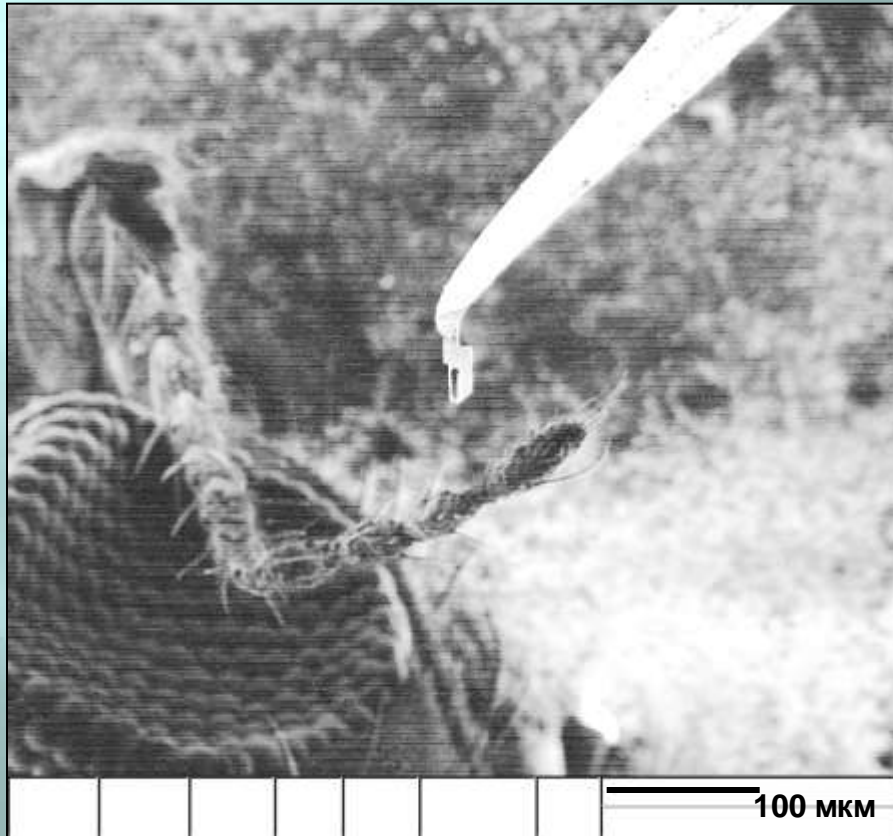
# Manipulation with Ta<sub>3</sub>S whiskers



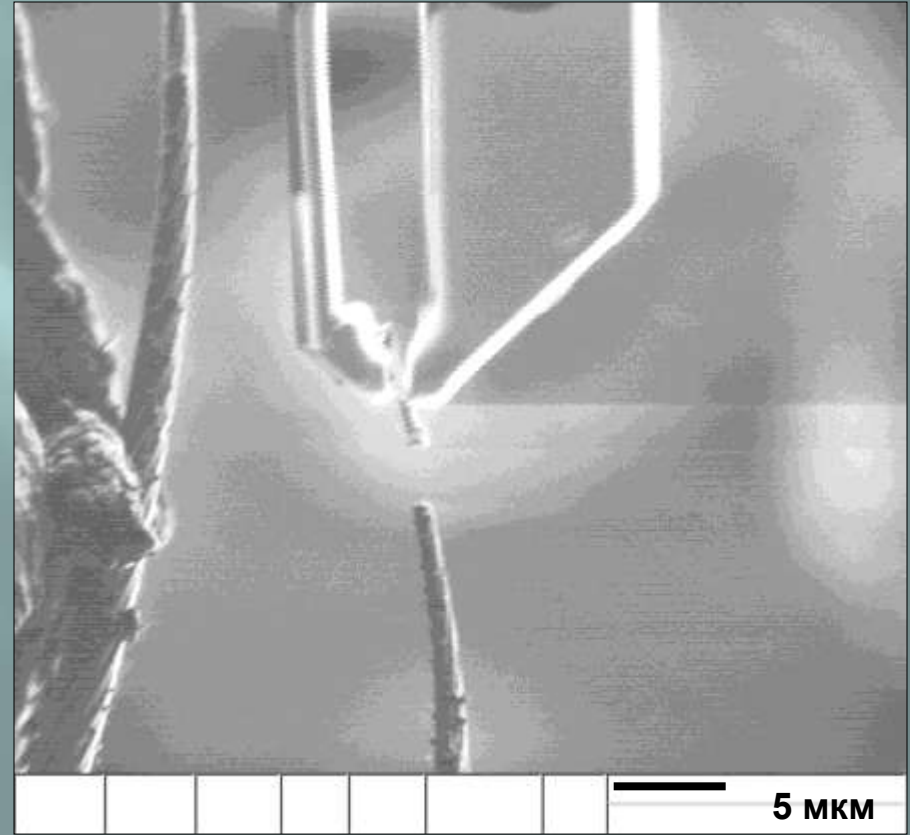
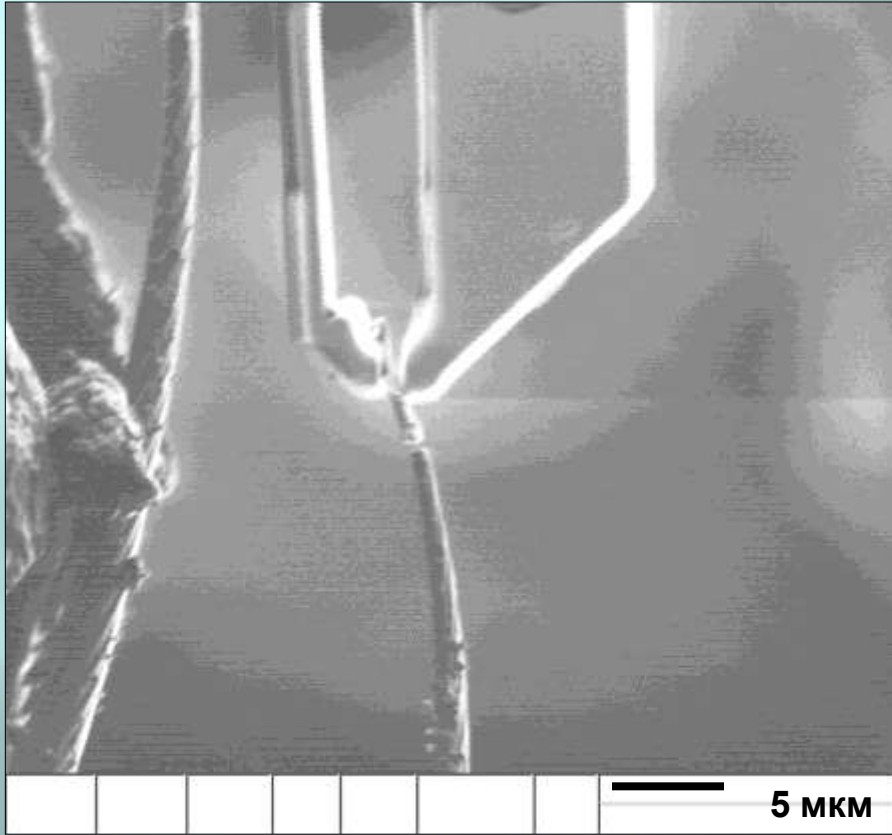
# Manipulation with biological microobject. Part of *Culex pipiens*



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# Conclusion

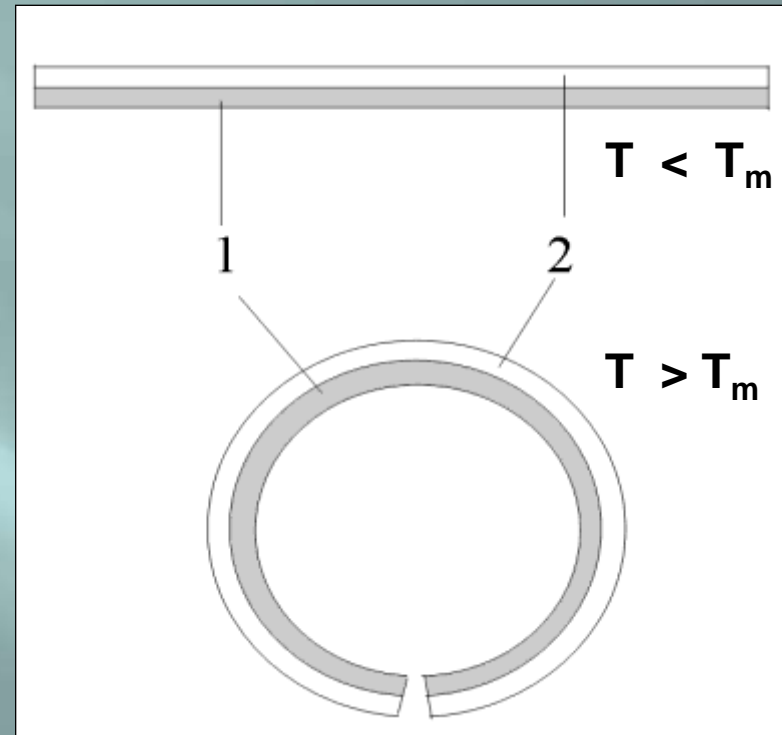
- **The prototypes of nanotweezers were created by Focused Ion Beam technique. The control is carried out by a beam of semiconductor laser in the environment of scanning electron/ion microscope. The smallest overall dimensions of the nanotweezers are 1x1x0,14  $\mu\text{m}$ .**
- **Reversible bending strain of up to 1 % was observed on micron and submicron scale for fabricated composites.**
- **The proposed scheme can be applied in designing of other types of nano-instruments for micro- and nanotechnology, microbiology and microsurgery.**

*We are currently developing a nano-instrument system for capturing, moving and storing the micro- and nano-objects.*

# Action principle of new composite actuator

1. shape memory layer
2. elastic layer

**SME:** giant pseudoplastic deformation up to 10 %

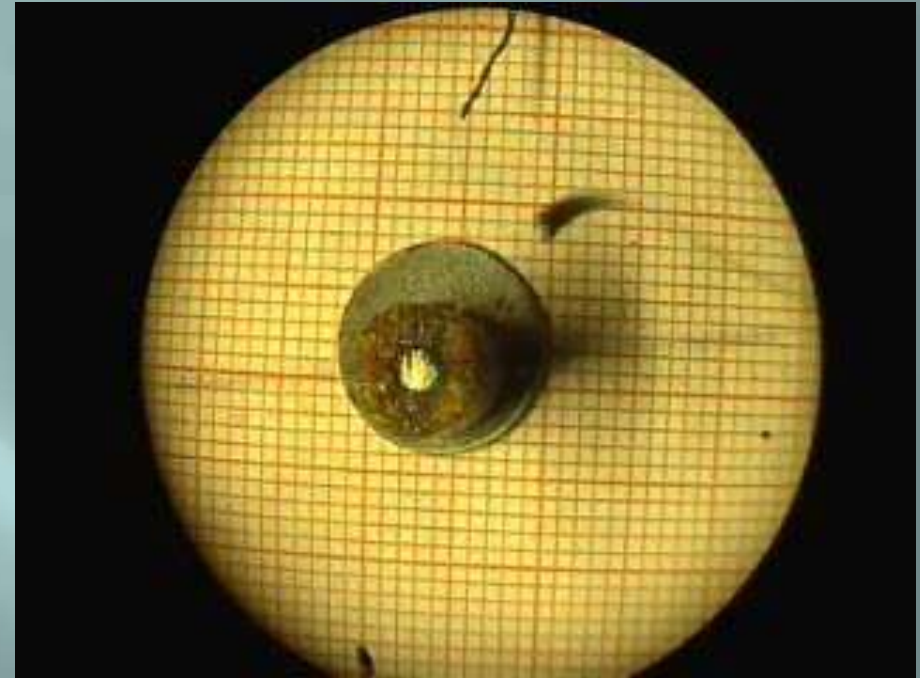


The result is the *reversible giant bending strain (up to 10 %)* of composite, using only “one-way shape memory” effect.

Bending deformation is *2-3 orders higher* than in a usual bimetallic plate.

The control can be carried out by a thermal field or by magnetic field (for ferromagnetic alloys).

# Model of new composite actuator



**Shape memory composite  
controlled by uniform heating**

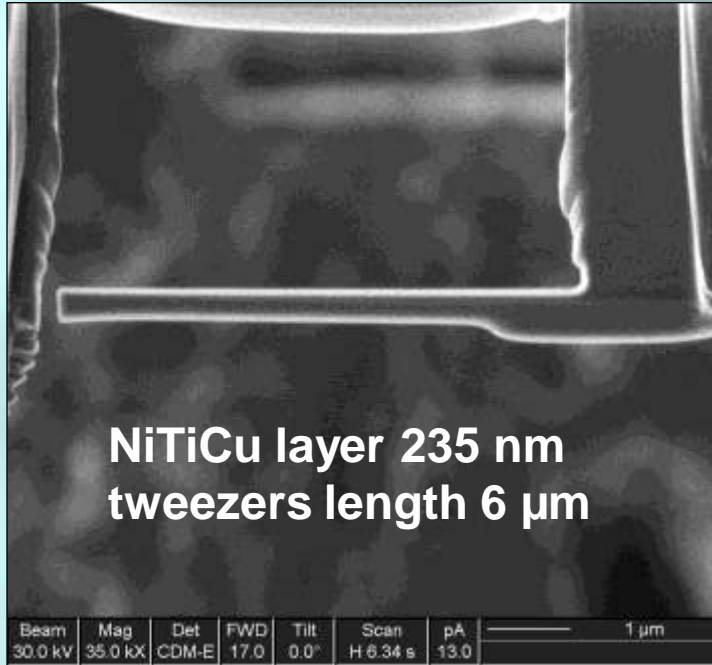
**30  $\mu\text{m}$  NiTiCu / 30  $\mu\text{m}$  steel  
(gluing)**

**“Spider leg” manipulator**

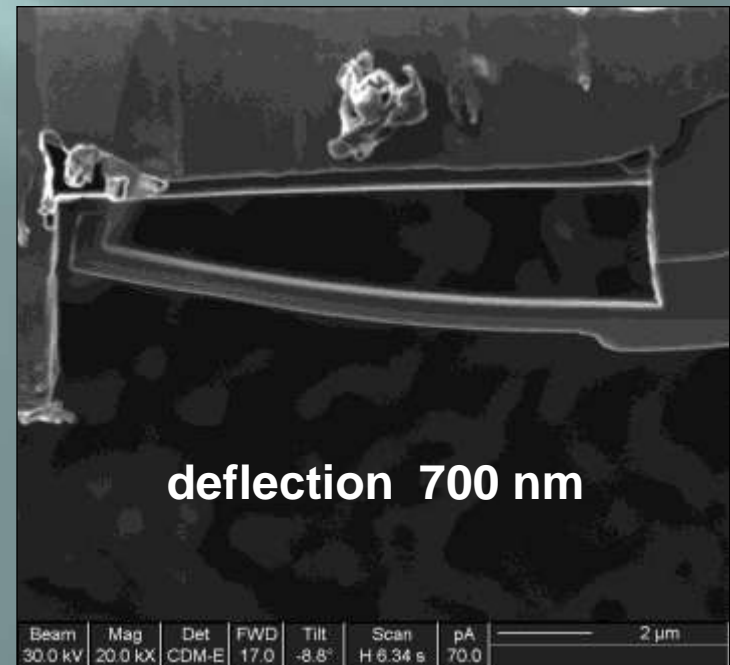
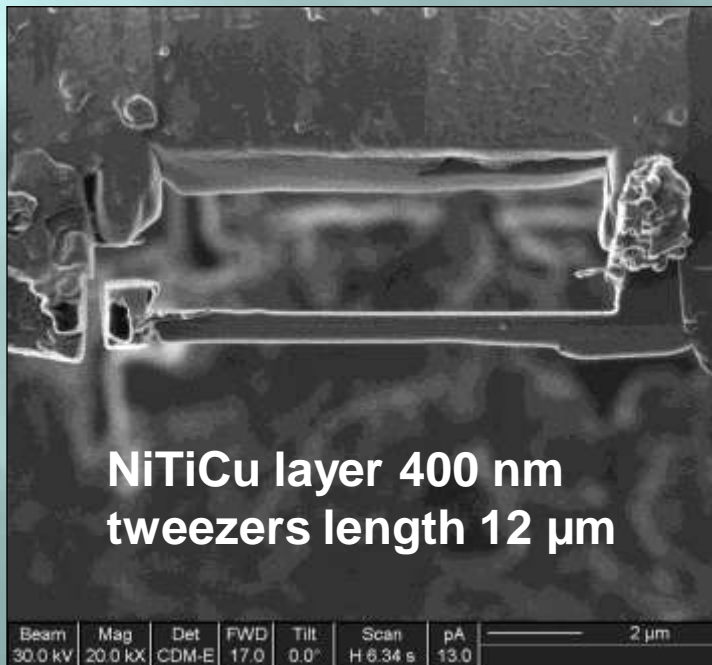
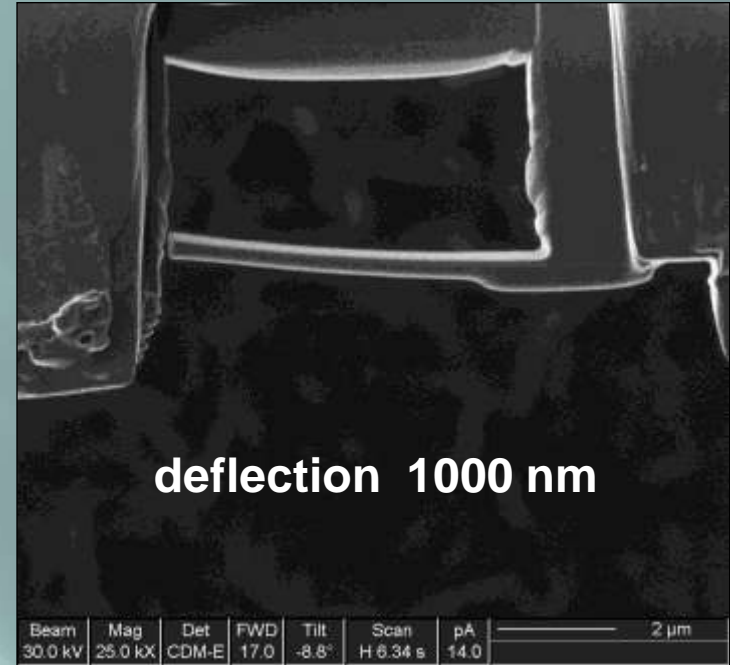
**30  $\mu\text{m}$  NiTiCu / 30  $\mu\text{m}$  Ni  
(galvanic deposition)**

**reversible bending deformation about 1 %**

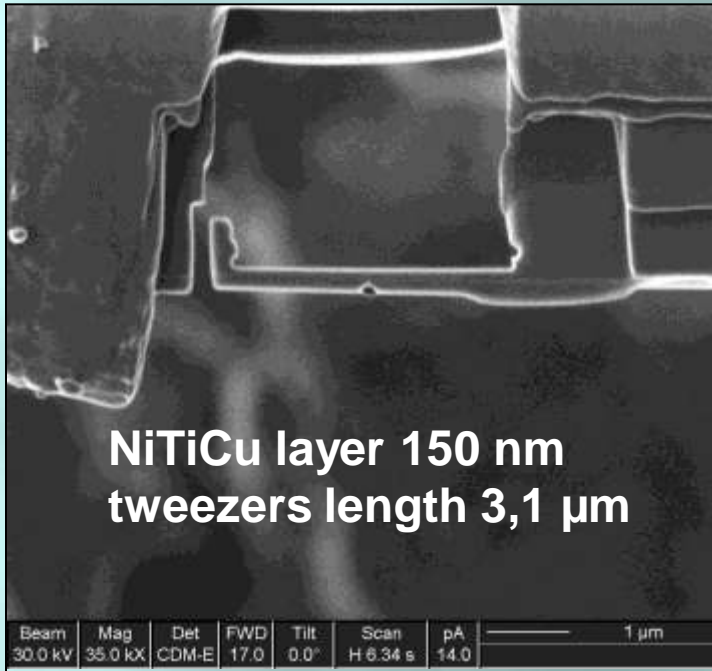
**without heating**



**while heating**



**without heating**



**while heating**

