Templating for functional nanodevices

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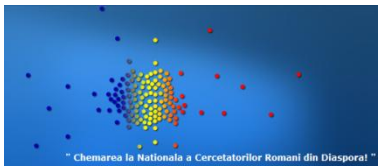


Outline:

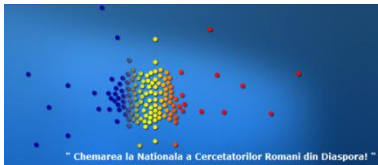
-How to prepare a nanoporous membrane by swift heavy ion irradiation; a single pore membrane for a single nanowire

-How to fabricate metallic tubules

-How to fabricate metallic nanowires

-How to fabricate semiconductor nanowires and devices

-Other templates; other methods of deposition



Necessary for applications: the ability to control the properties of nanoobjects:

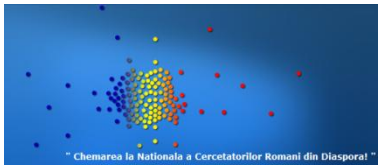
-shape

-composition

-structure

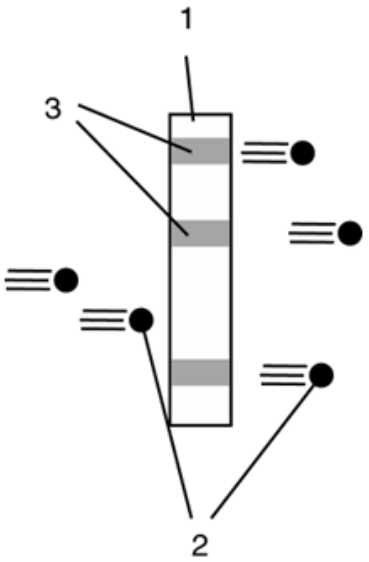
-function

Template replication as a method of fabricating nanostructures allows a precise control of nanostructure's shape by choosing the template with the appropriate shape



How to prepare a nanoporous membrane by swift heavy ion irradiation

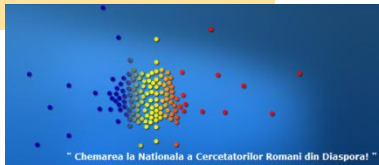
Irradiation



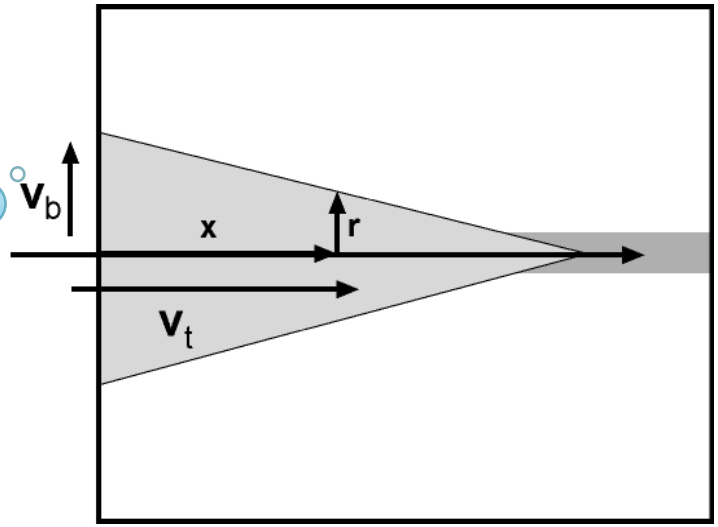
Ions: - **<u>conditions to obtain continuous etchable tracks</u>**

Swift – kinetic energy higher than 4MeV/nucleon
Heavy – Mass>Xe

When passing through the material deposit energy – cylindrical defect zone –possibility of selective etching

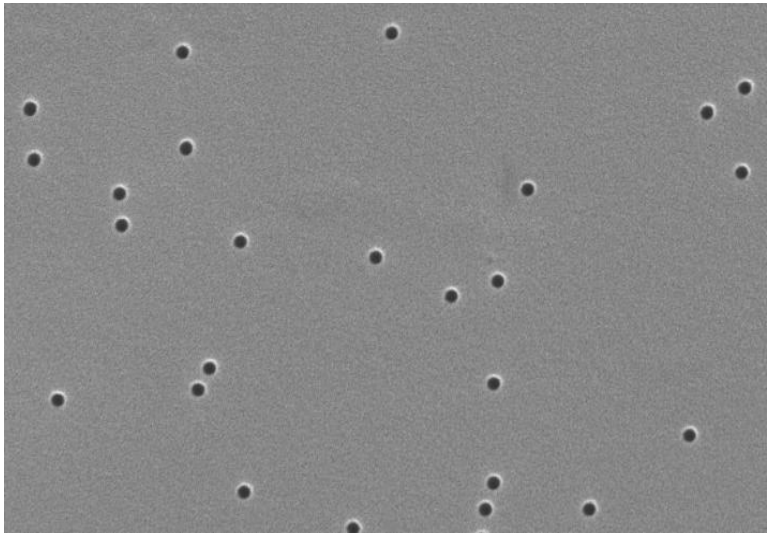


Etching



Nanopore etching

Example of a nanoporous membrane



Example: polycarbonate

Performed with mixtures of NaOH and methanol:

different cone angles can be obtained

There are two important parameters: the rate of etching along the latent track, track etch rate v_t, and the rate of etching of the nonirradiated material, bulk etch rate v_b

Etching result: cones with

Radius

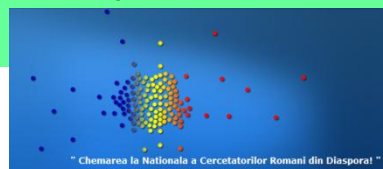
$r(x,t)=v_b(t-x/v_t)$

for $t>x/v_t$

Opening angle

$tga=v_b/v_t$

High selective etching leads to cylindrical pores

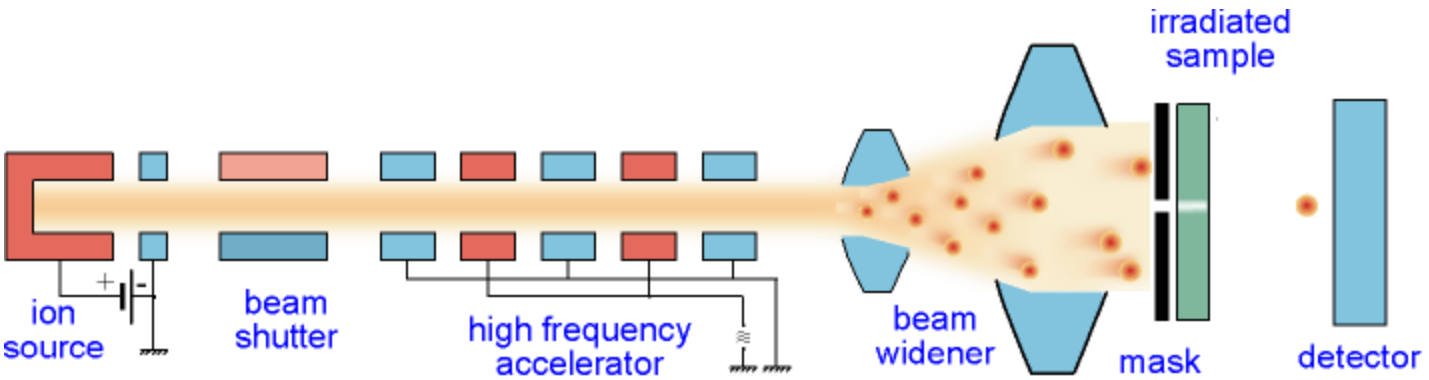


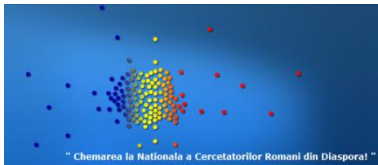
Single ion track membranes for single nanowires

The extreme case of ion track membranes.

Gives the posibility of easily contacting a single nanowire.

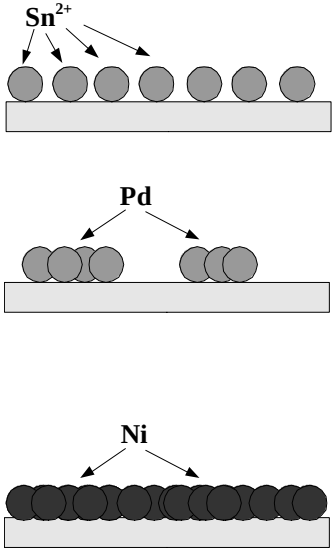
Obtained by etching a polymer foil which has only one ion hit.



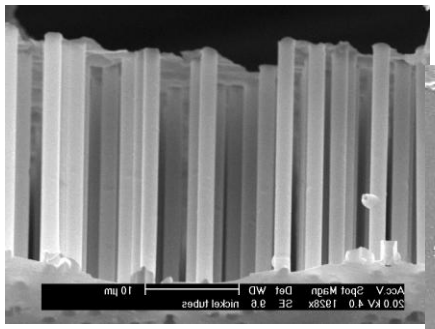


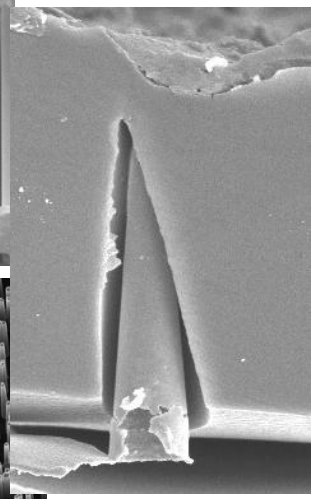
First example:
A metal replica of a porous membrane – metallic tubules

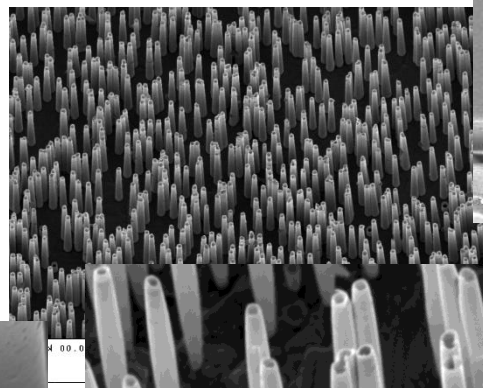
Electroless deposition on micro or nanoporous membranes can be successfully employed for the fabrication of metallic hollow structures namely micro or nanotubes.

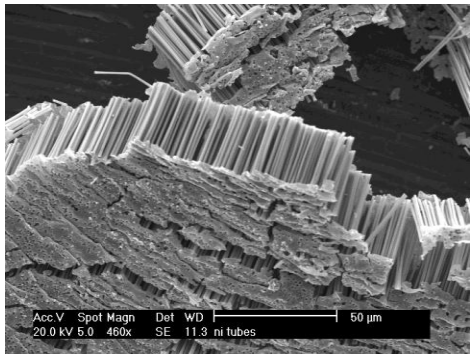


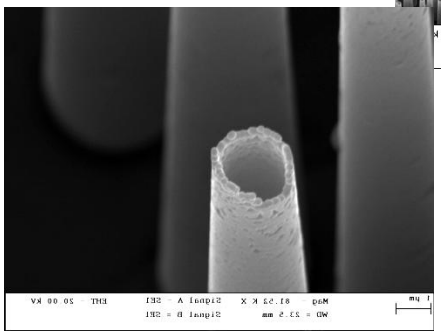
Three steps in electroless deposition: step (1) preactivation with Sn2+ ions, (2) activation with palladium and (3) metal deposition either catalytic on palladium nuclei in the first step or autocatalytic

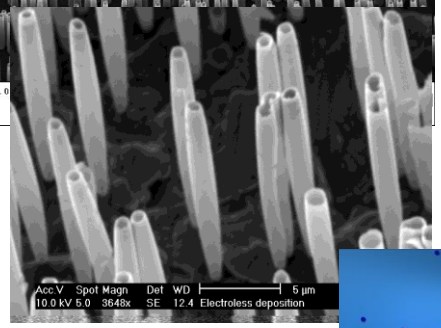


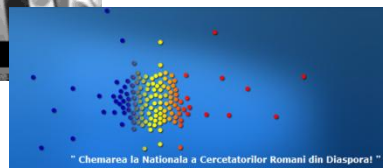






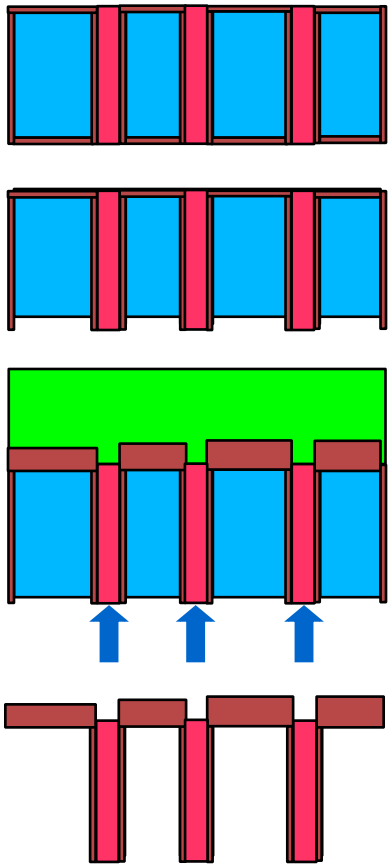




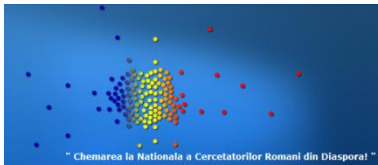


Deposition of self suporting tubules

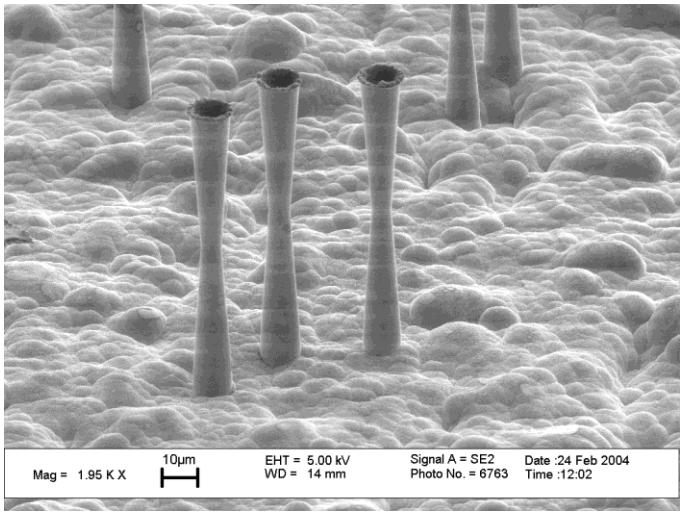
The algorithm employed by us for obtaining the self supporting tubules arrays is presented together with examples of tubules with different morphologies. Thus, by flowing water through the tubules while performing electrochemical deposition, we ensured that these remain opened while the surface layer gets thicker.

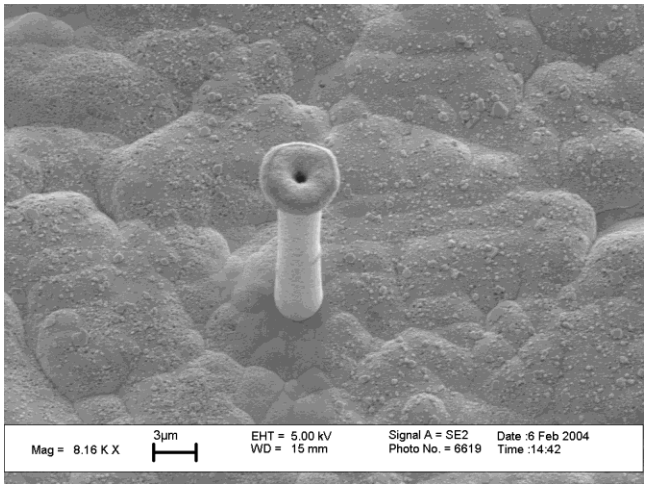


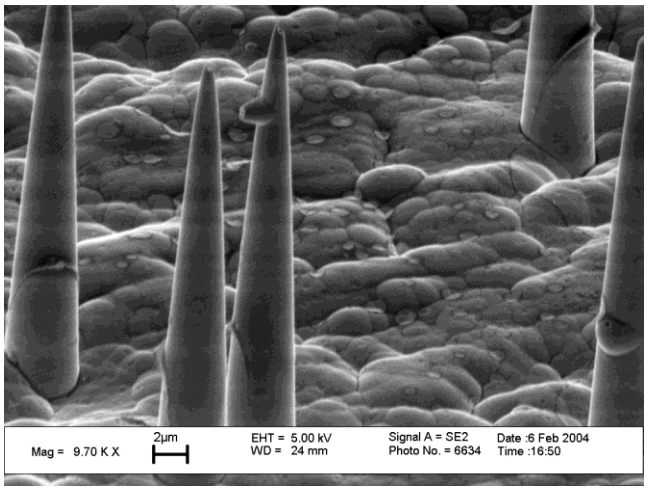
The algorithm for depositing self supporting metallic tubules arrays: (a) electroless deposition of metalls on nanoporous membranes (both surfaces and interior of pores are covered); (b) removal of the metal layer from one surface (either mechanical or chemical); (c) thickening of surface metal layer by electrochemical deposition (arrows show direction of water flow); (d) removal of polymer foil; (e) and (f) SEM micrographs of self supporting double conical or conical tubules arrays obtained by this algorithm.

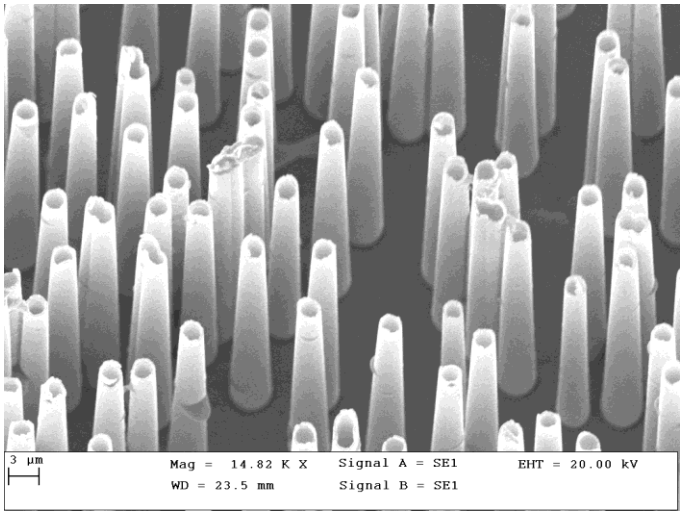


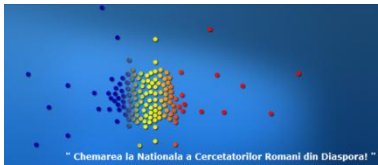
Self – supporting metallic tubules



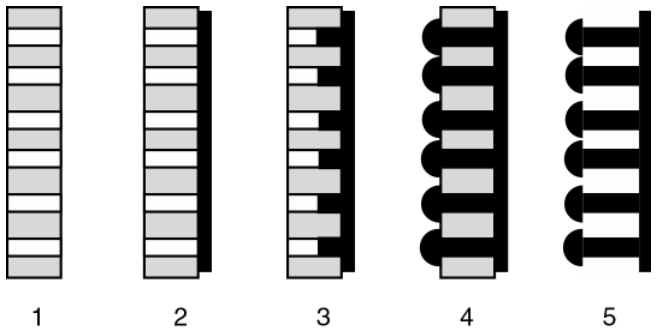


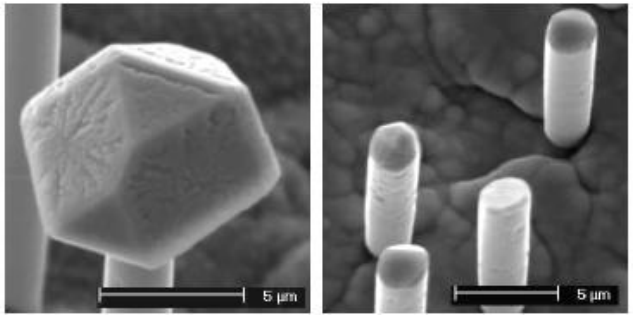


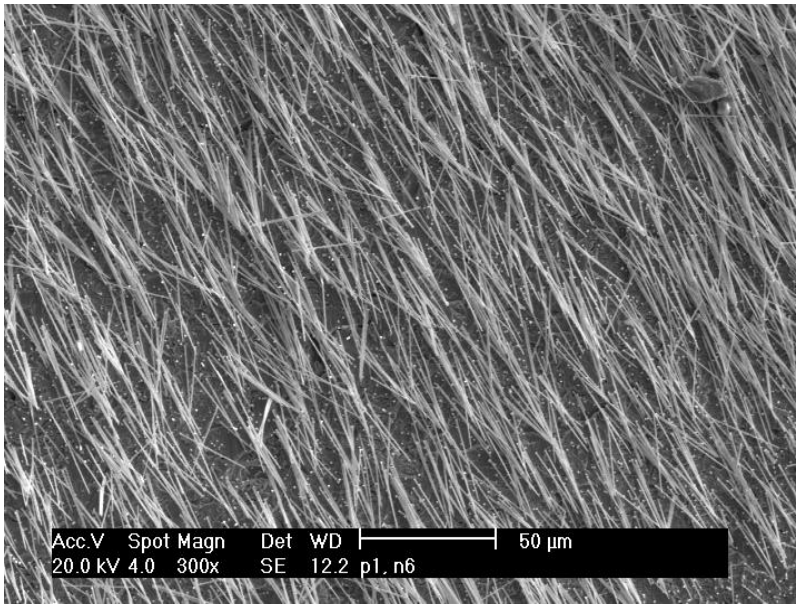


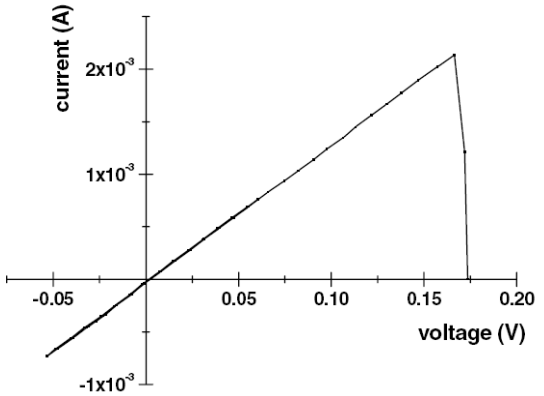


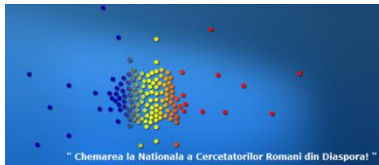
Second example:
A metal replica of a porous membrane – metallic nanowires

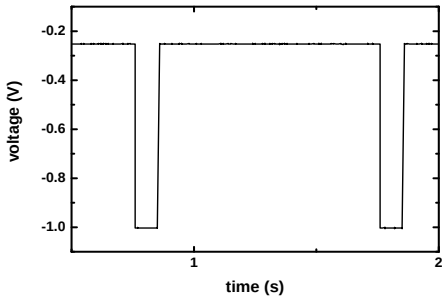


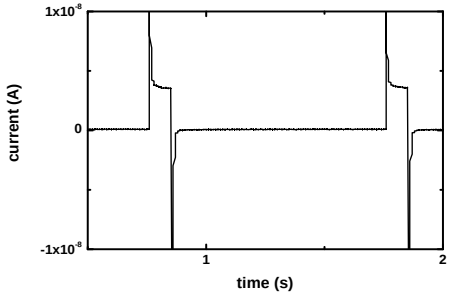


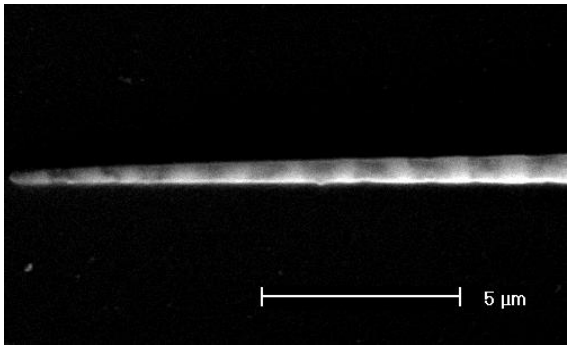


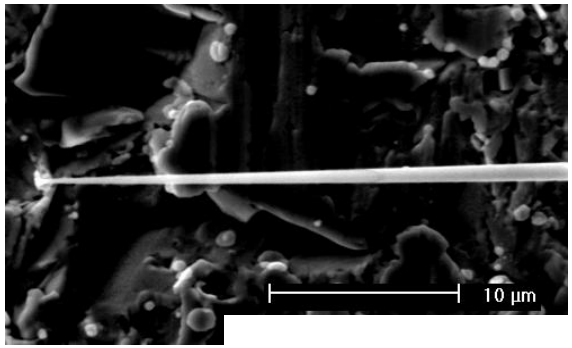




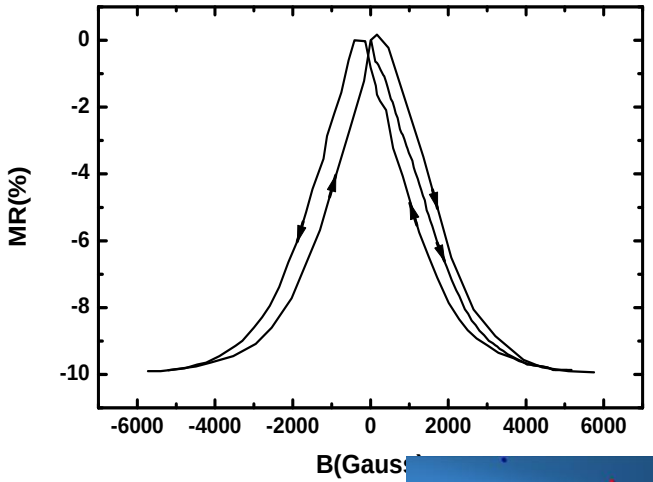


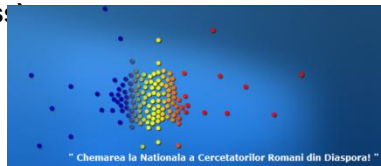






Compositionally modulated nanowires – giant magnetoresistance:
-deposition of multilayers Co/Cu





Third example: Semiconducting nanowires

ZnO electrochemical deposition was employed for fabricating nanowires.

Nitrate bath

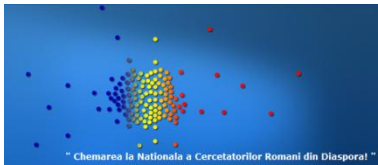
$2e^- + NO_3^- + H_2O \rightarrow NO_2^- + 2OH^-$ (1)

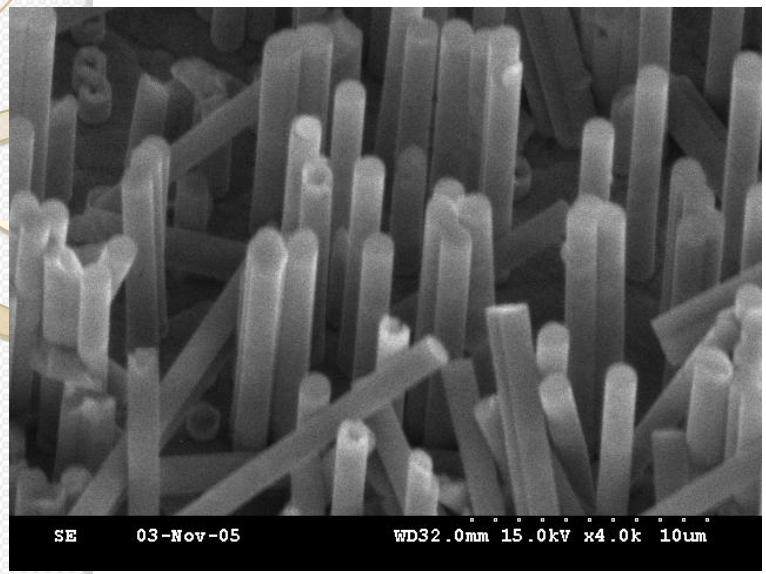
$Zn^{2+} + 2OH^- \rightarrow Zn(OH)_2 \rightarrow ZnO\downarrow + H_2O$ (2)

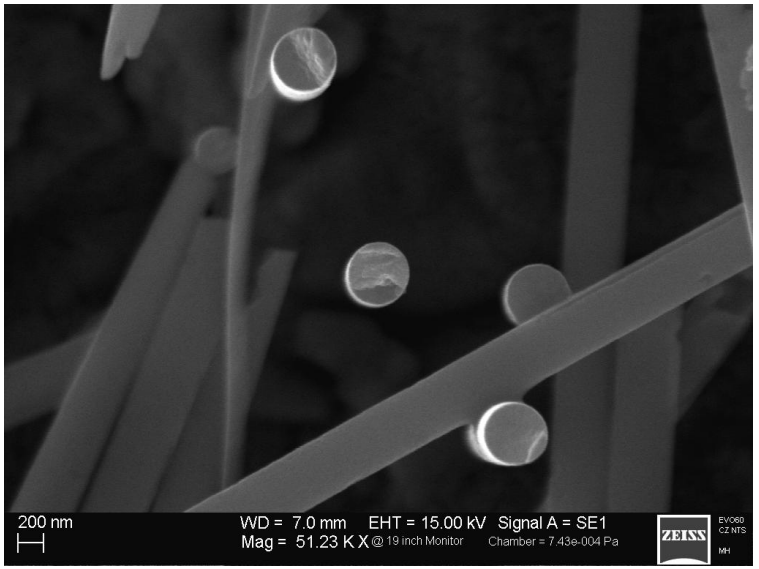
or global reaction:

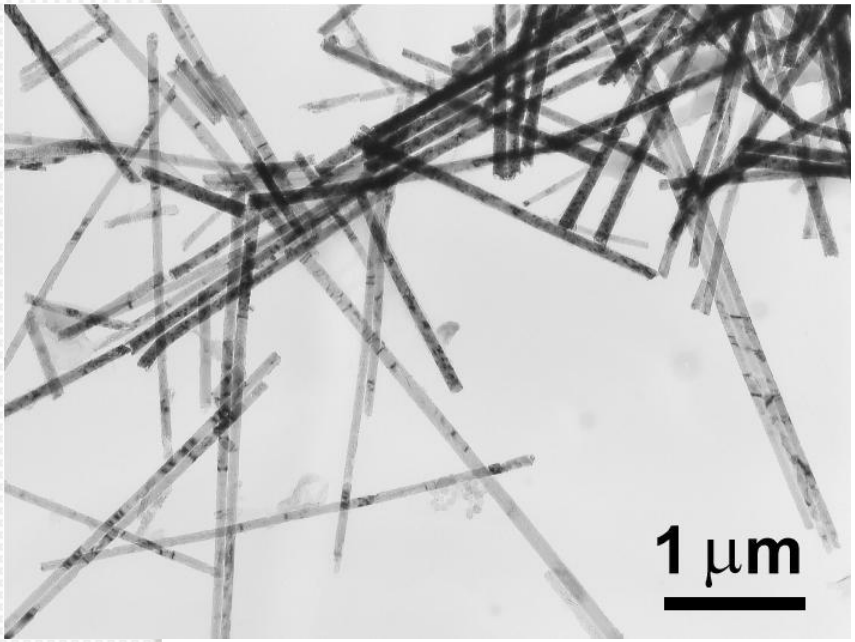
$Zn(NO_3)_2 + 2e^- \rightarrow ZnO\downarrow + NO_3^- + NO_2^-$ (3)

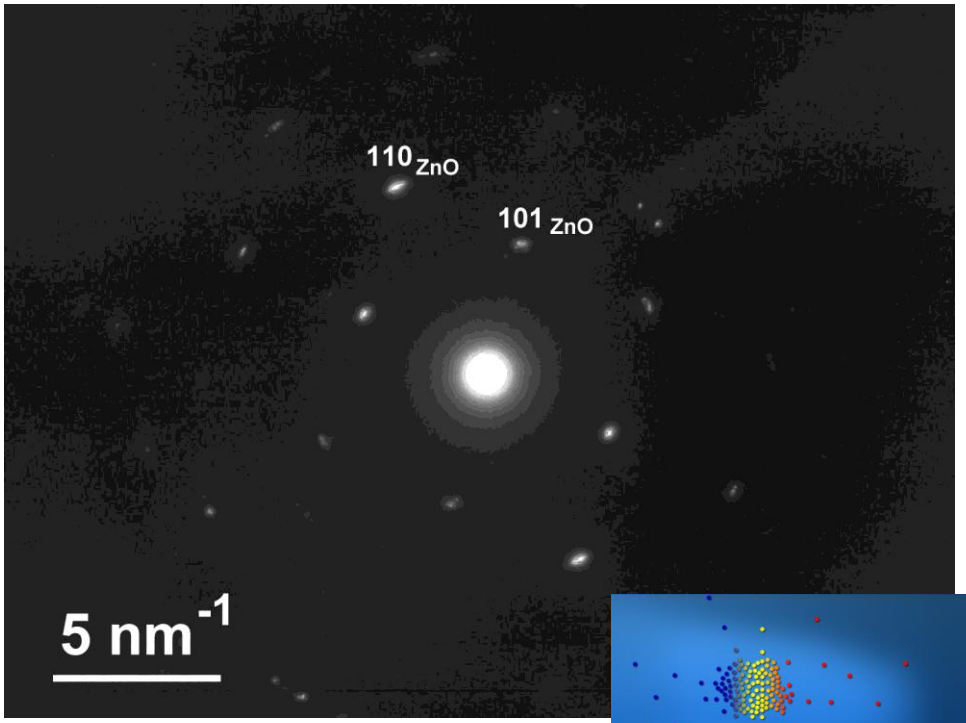
PVP was used as an additive in order to improve pore wetting




SE 03-Nov-05 WD32.0mm 15.0kV x4.0k 10um


200 nm
WD = 7.0 mm EHT = 15.00 kV Signal A = SE1
Mag = 51.23 K X @ 19 inch Monitor Chamber = 7.43e-004 Pa
ZEISS
EVO60
CZ NTS
MH

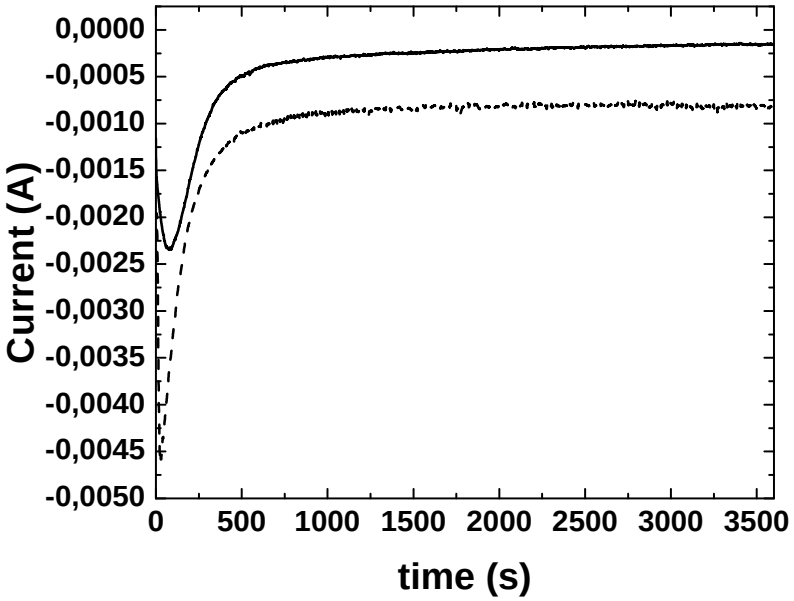

1 μm


110 ZnO
101 ZnO
5 nm-1

" Chemarea la Nationala a Cercetatorilor Romani din Diaspora! "

One can go further and dope the wires

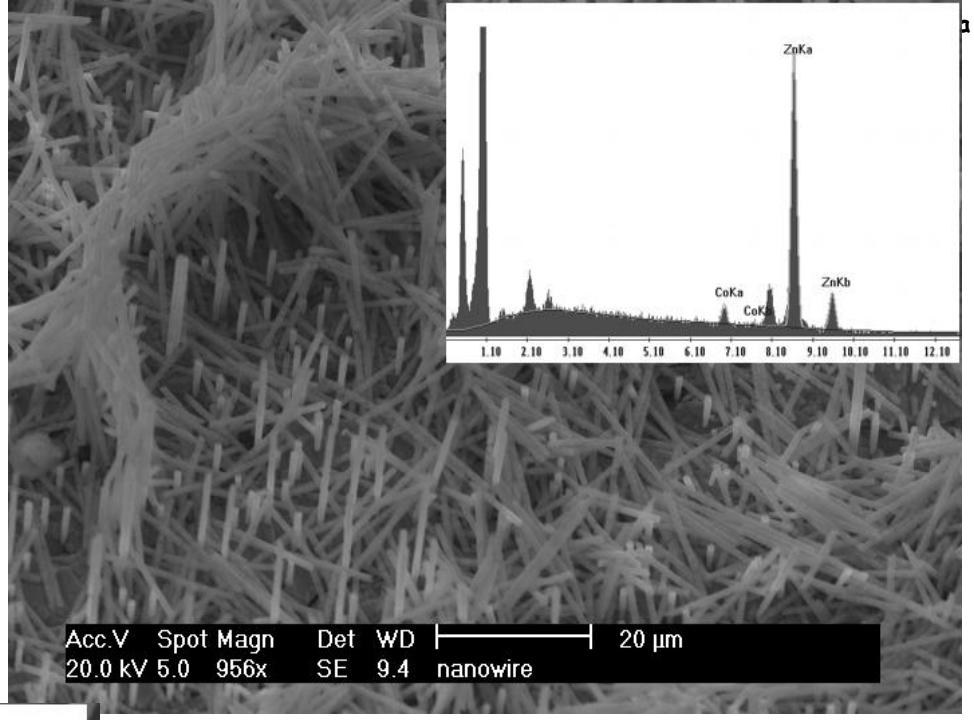
Electrochemical polarization curves for the two solutions containing only Zn ions (continuous line) and both Zn and Co (dashed line).

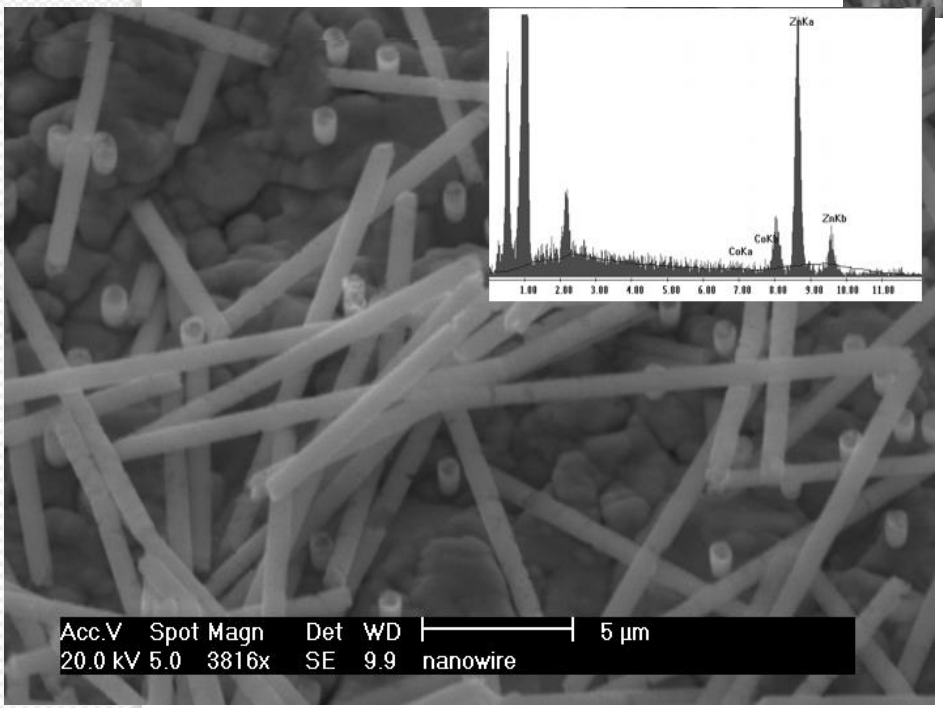


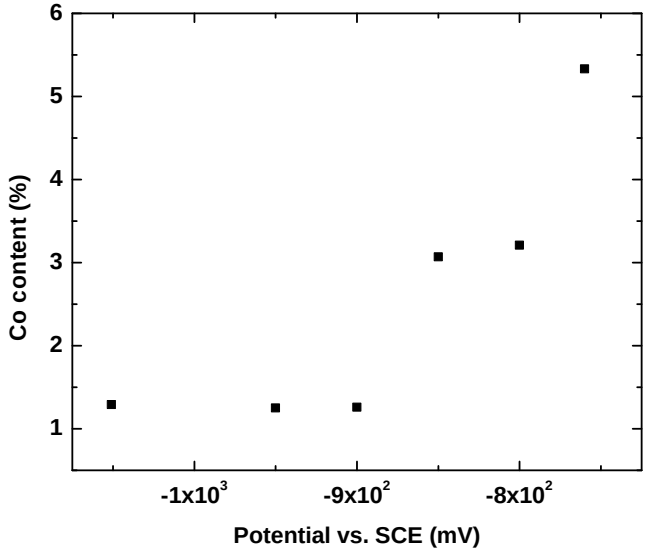
Two parameters control the composition of the wires:

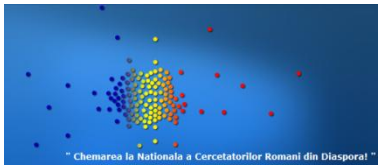
-bath composition;

-deposition potential









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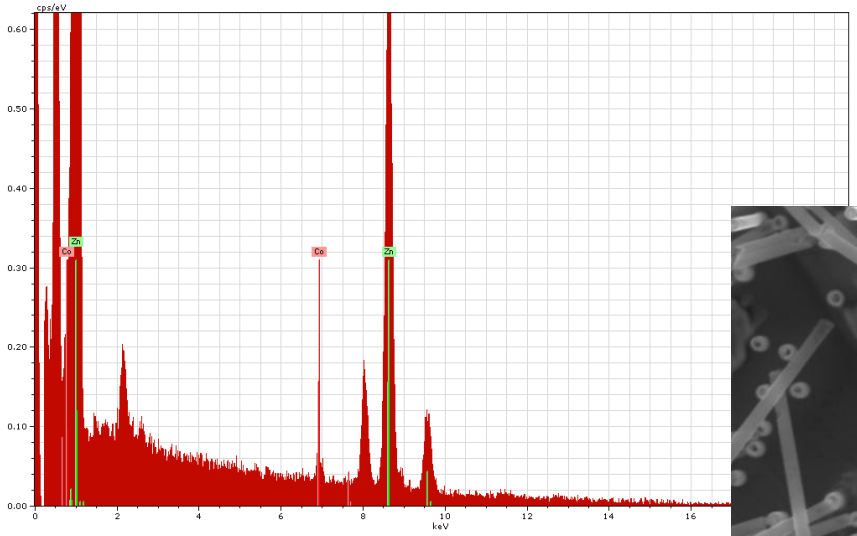
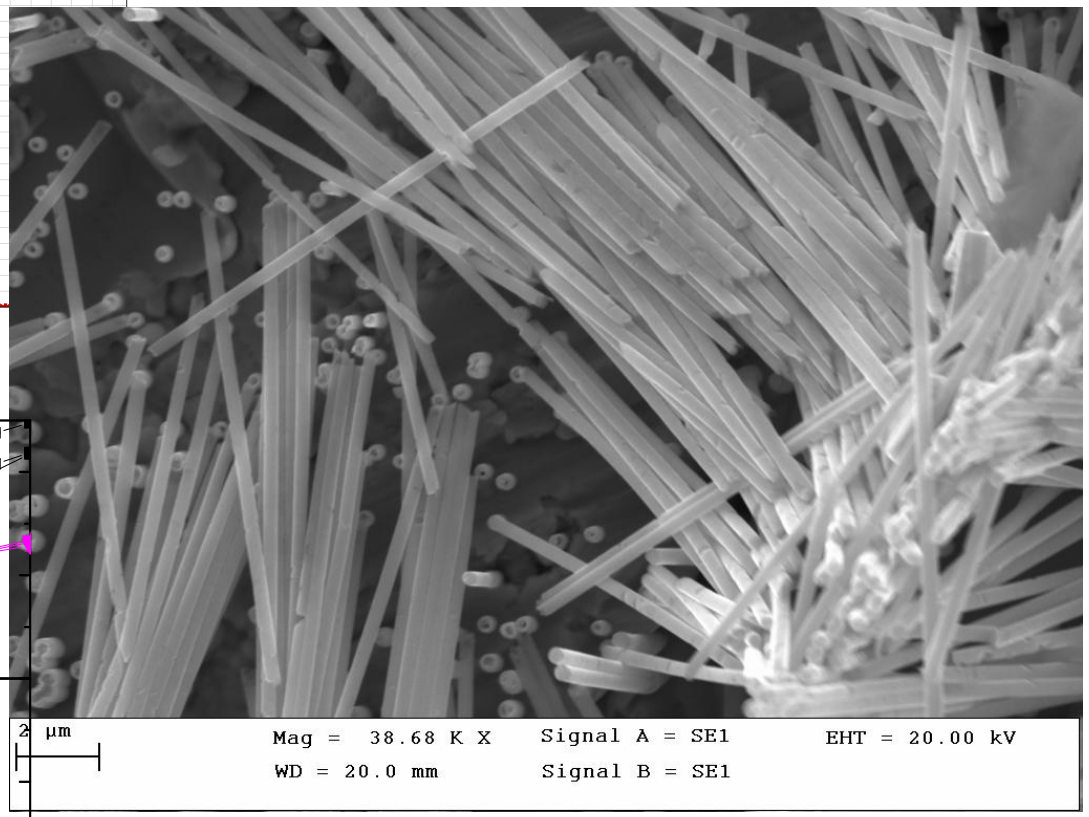
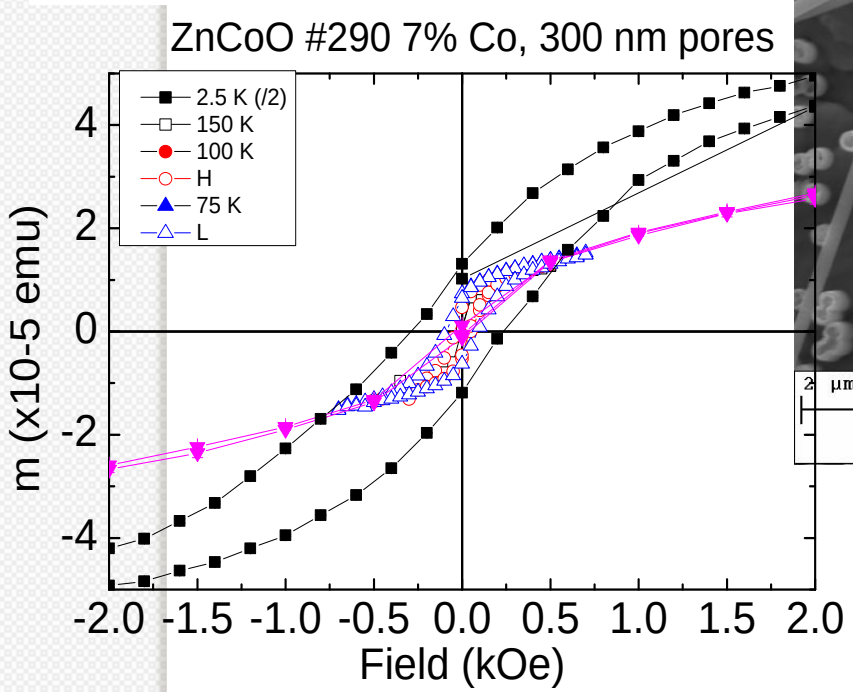
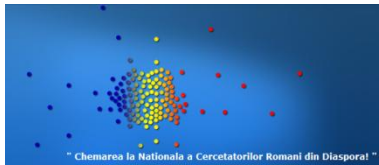


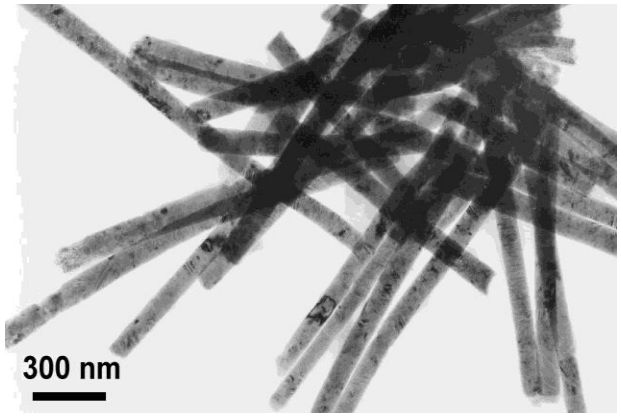


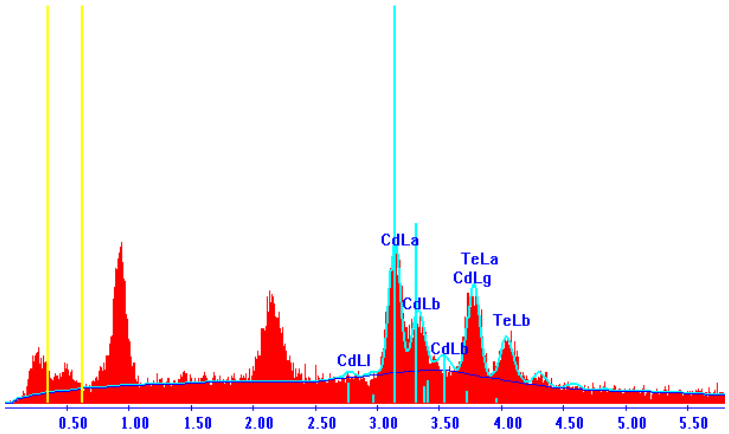


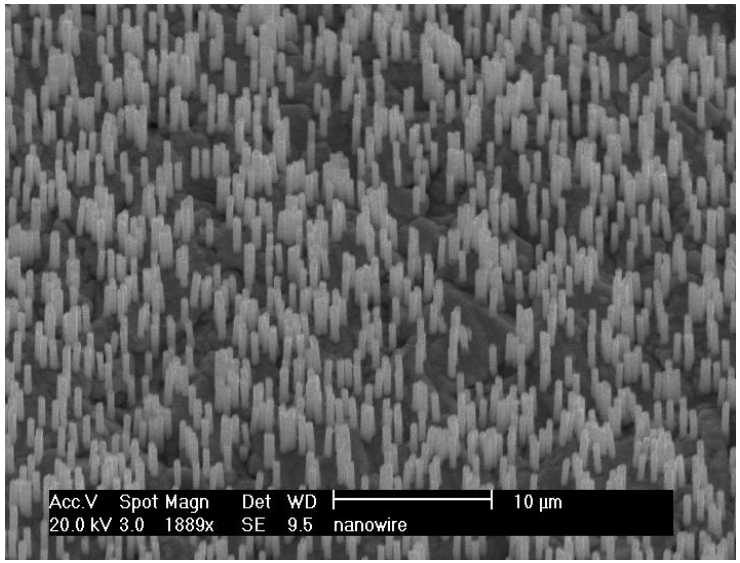


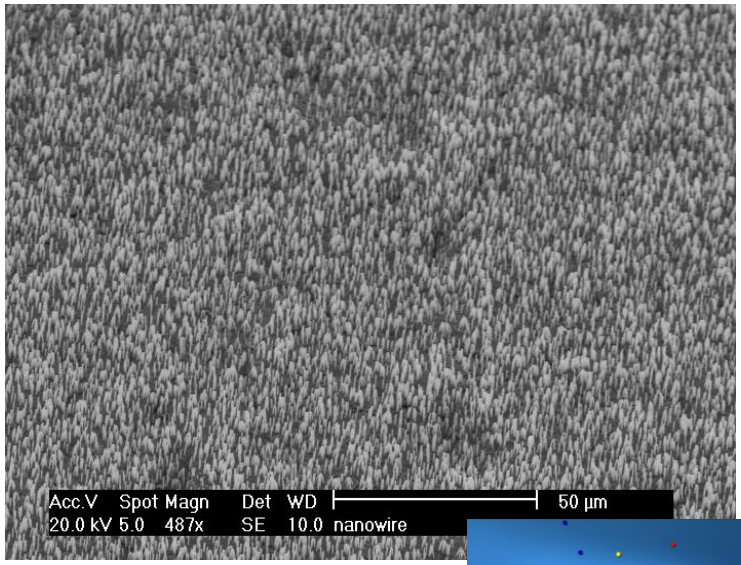
Uniform arrays of CdTe nanowires

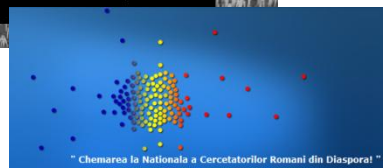
$$Cd^{2+} + HTeO_2^{+} + 3H^{+} + 6\bar{e} \rightarrow CdTe + 2H_2O.$$









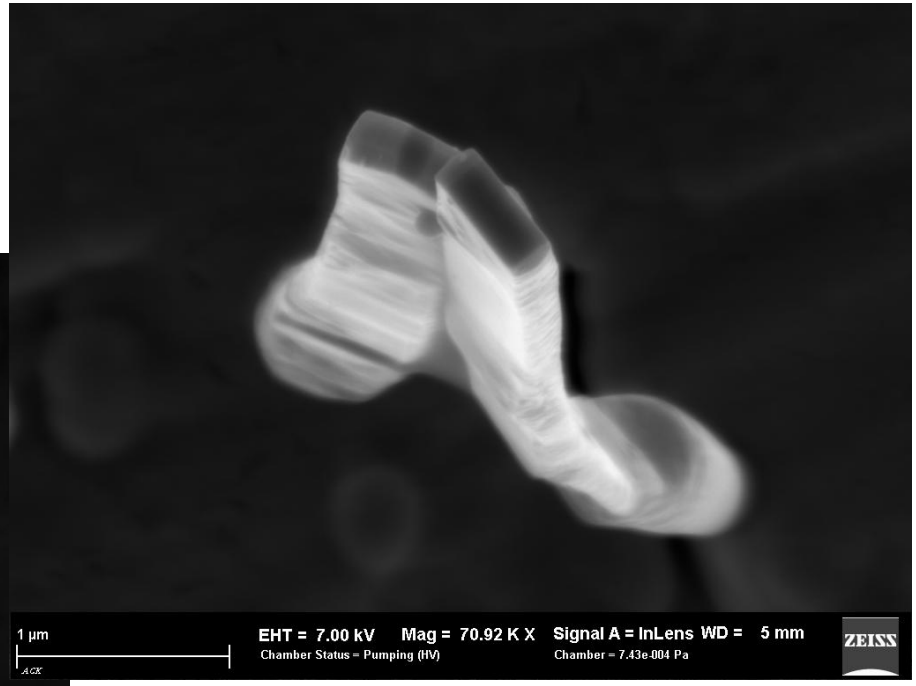


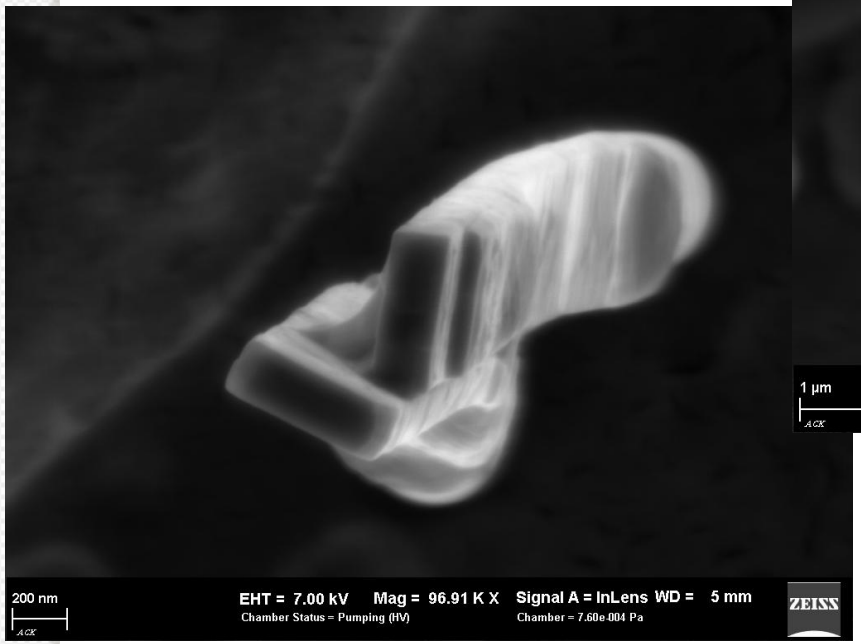
Multisegment nanowires

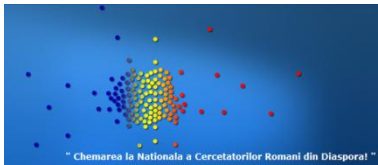
- One can successively deposit different materials:

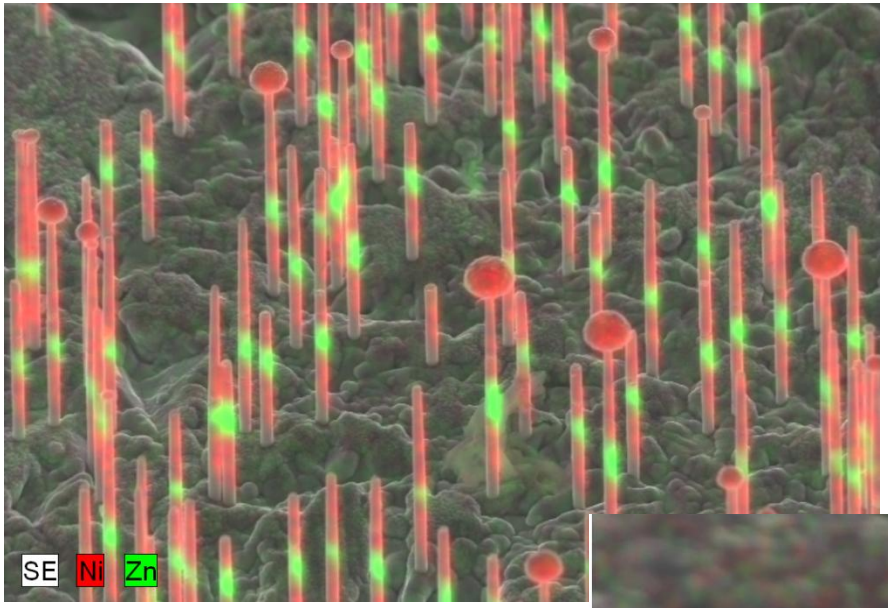
1.Metal
2.Semiconductor

Ni/CdS

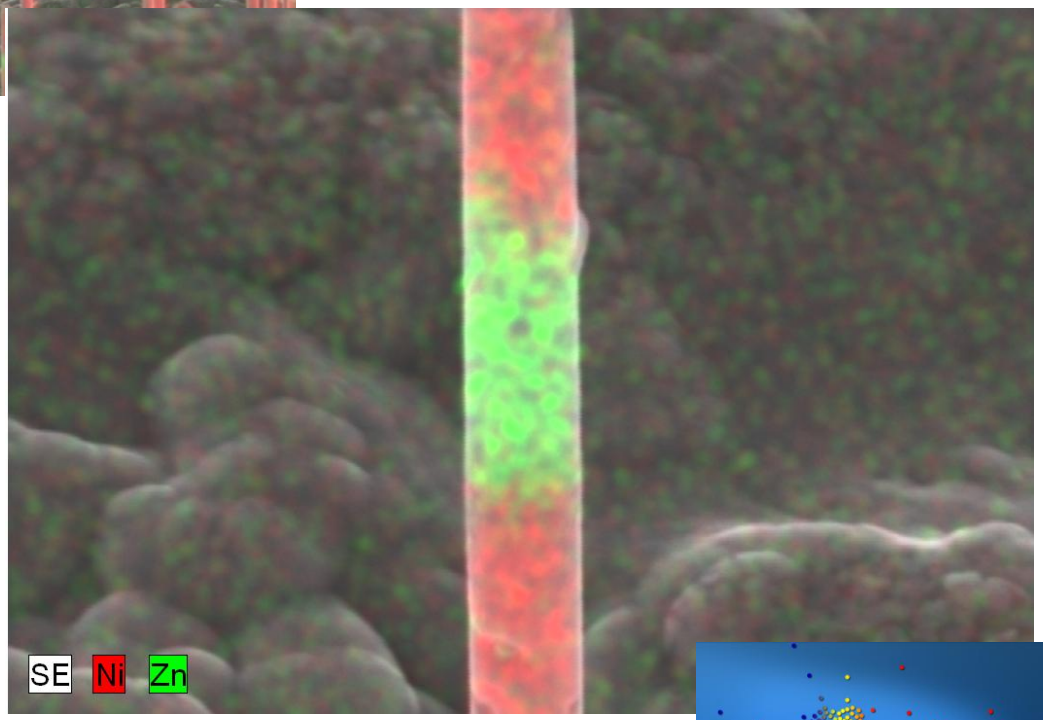


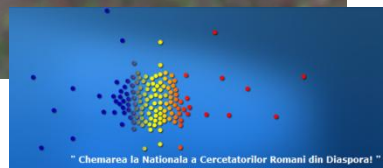




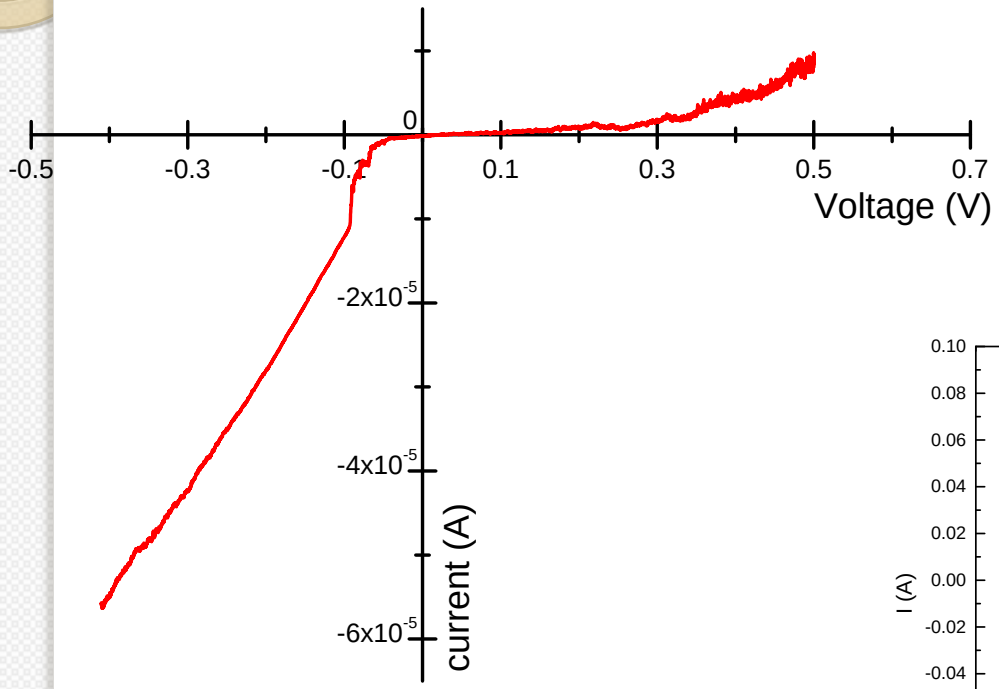


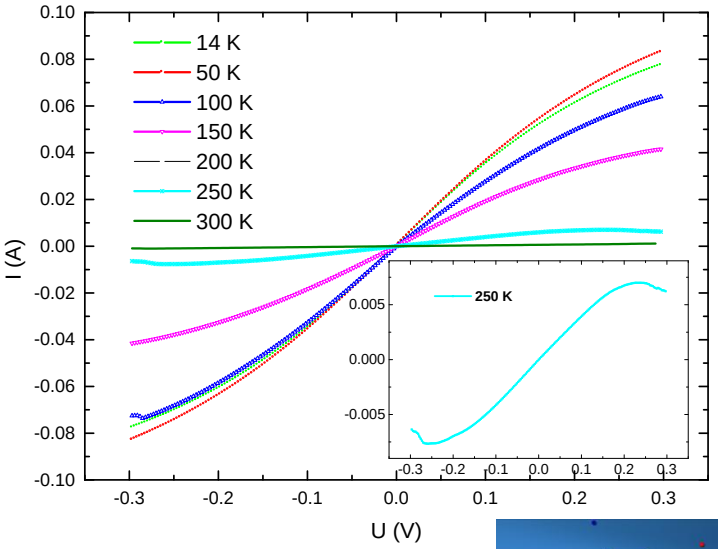
Ni – ZnO – Ni nanowires

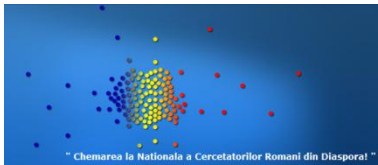


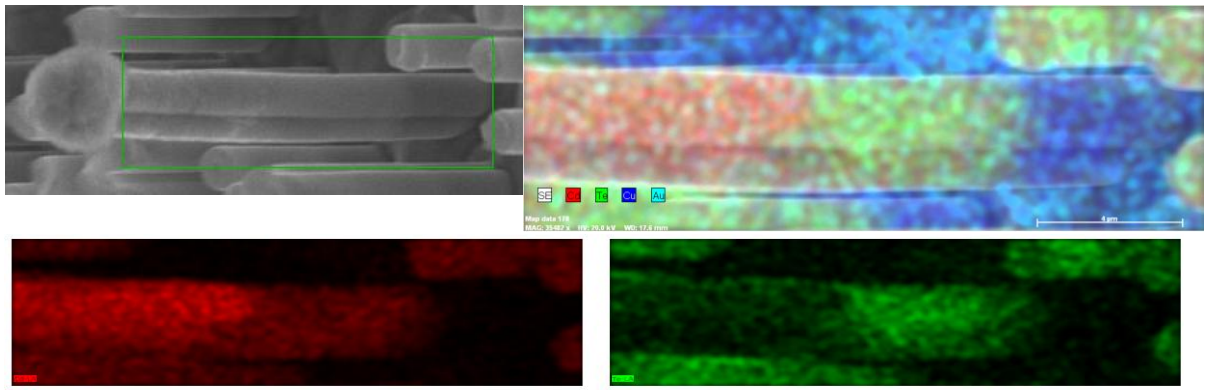


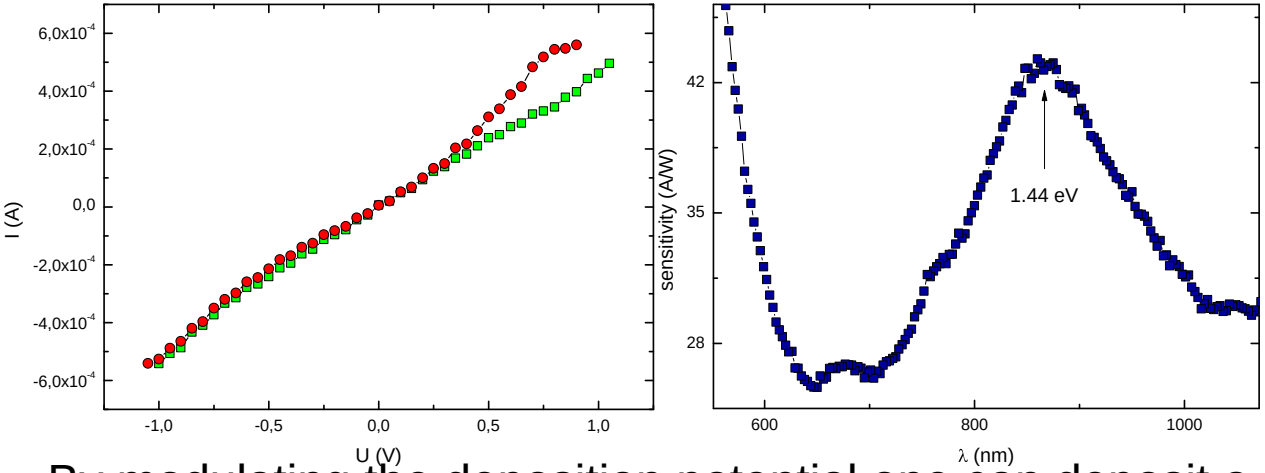
Transport measurements. I-V characteristics for symmetric and asymmetric multisegment nanowires (Ni–CdTe–Au) and Ni–CdTe–Ni. – NANOWIRE DIODES





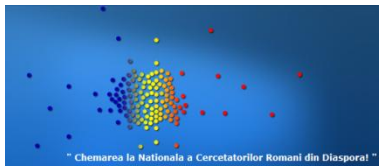


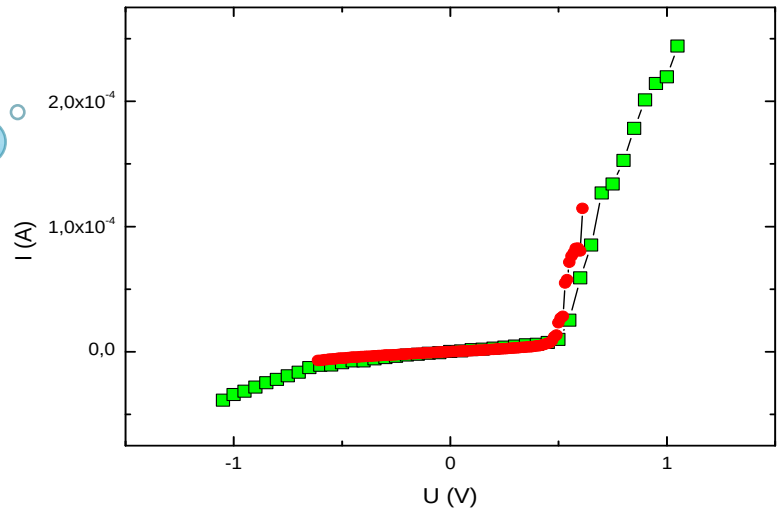




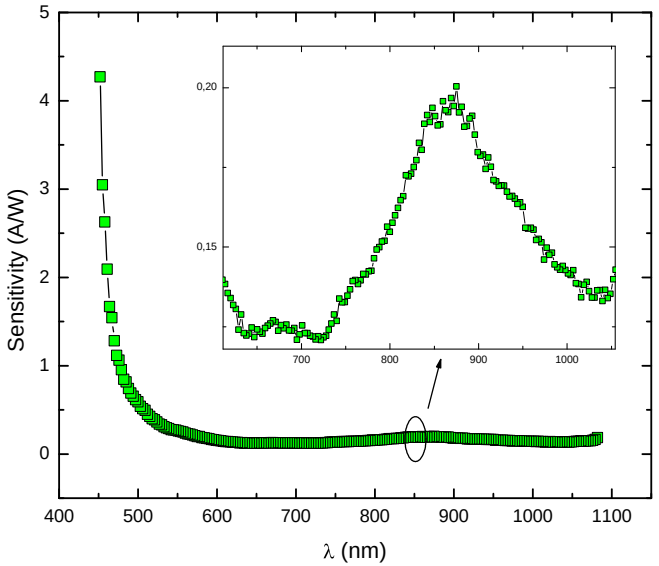
By modulating the deposition potential one can deposit a junction in a single step.

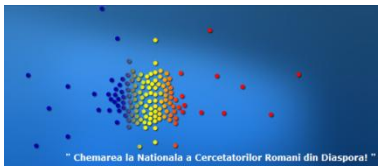
Example 1 an ohmic junction with photoconductive behavior



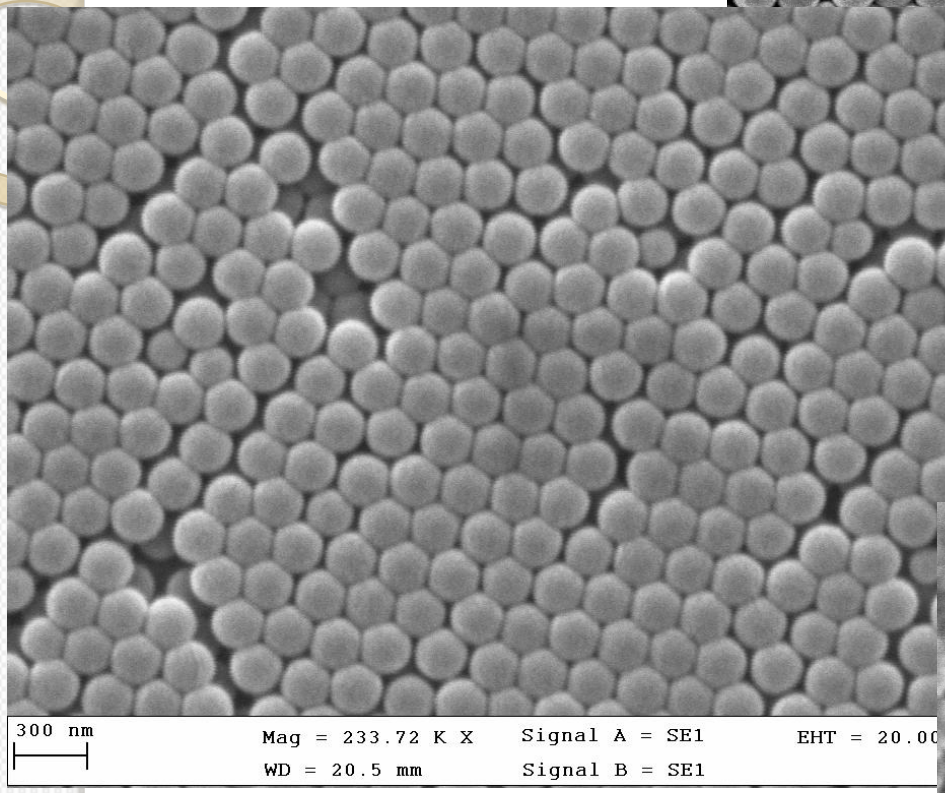


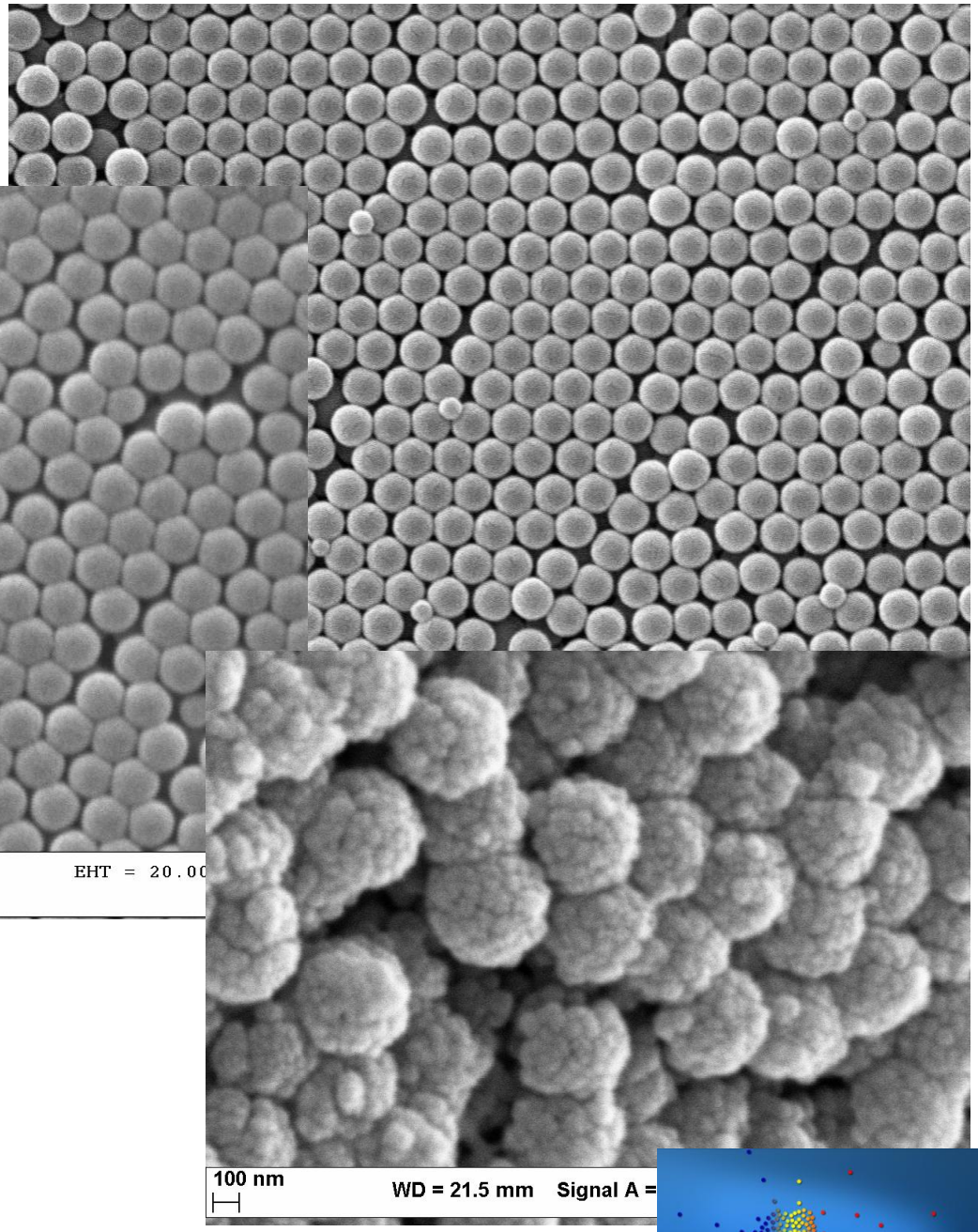
Rectifying junction nanowire deposited by potential step.- A nanowire photodiode

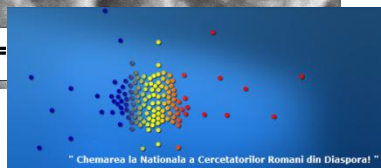




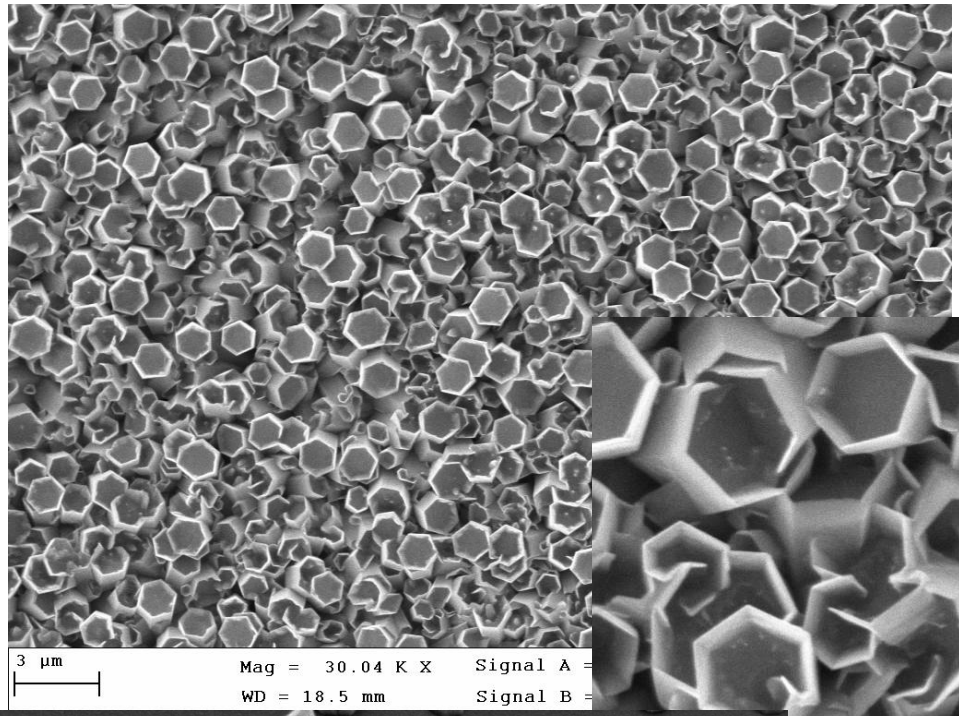
Other templates?
Other means of deposition…

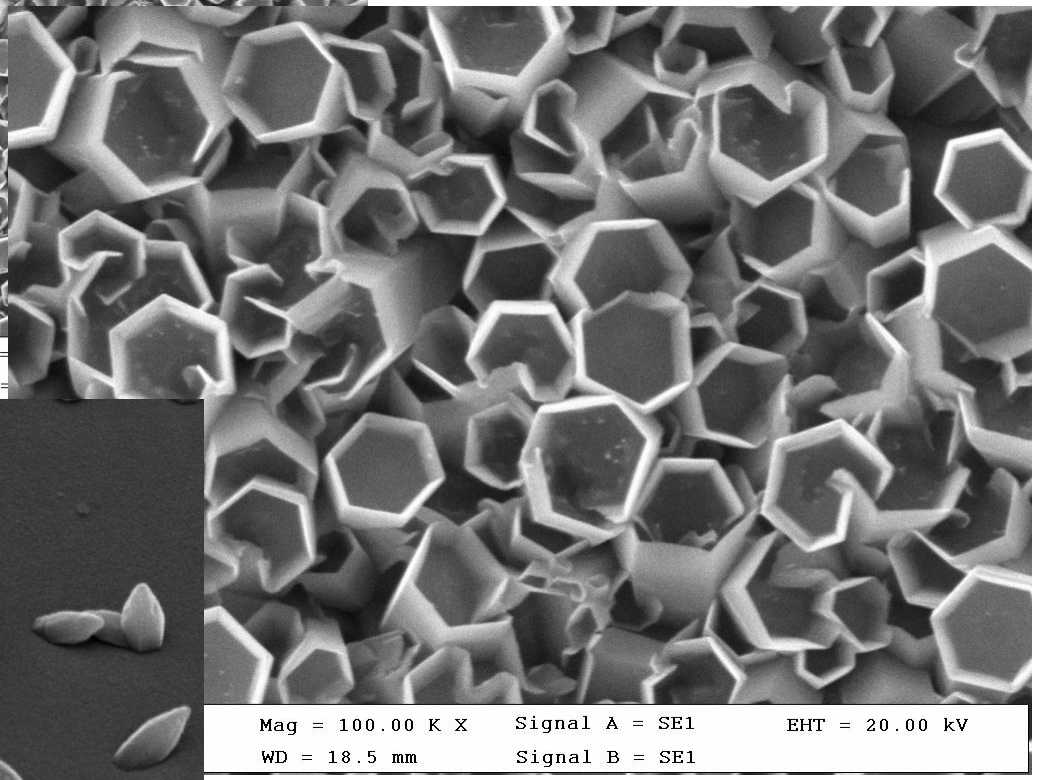


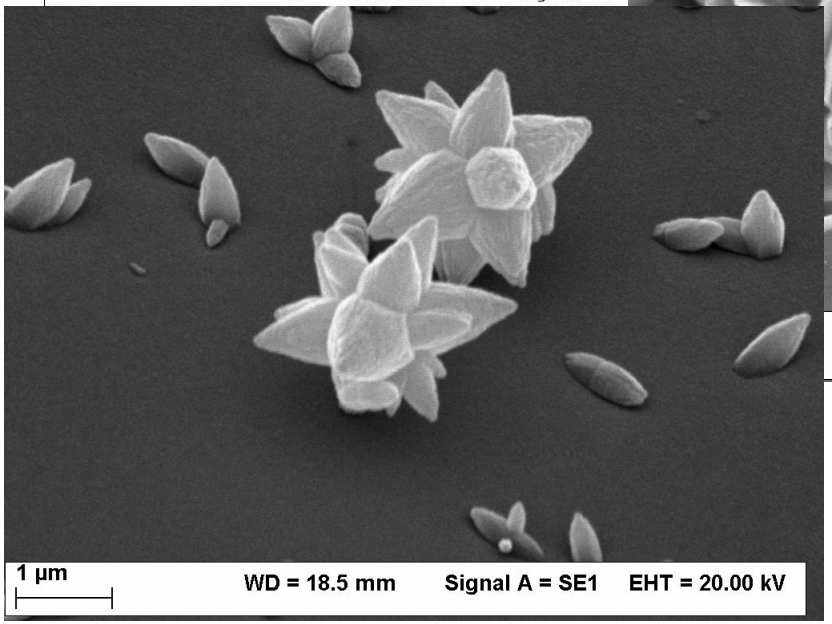


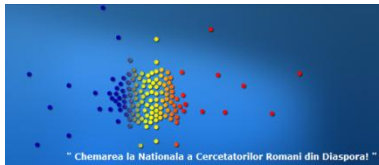


ZnO


3 µm
Mag = 30.04 K X
WD = 18.5 mm
Signal A =
Signal B =


Mag = 100.00 K X
WD = 18.5 mm
Signal A = SE1
Signal B = SE1
EHT = 20.00 kV


1 µm
WD = 18.5 mm
Signal A = SE1
EHT = 20.00 kV


" Chemarea la Nationala a Cercetatorilor Romani din Diaspora! "

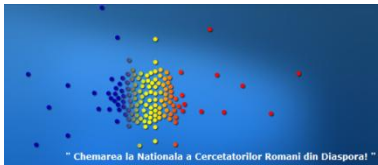
Other potential templates:

-anodic alumina – easy to fabricate, ordered pores

-block copolymers

-glass balls

-biologic molecules and structures (ranging from DNA to insects antennae)



Conclusions:

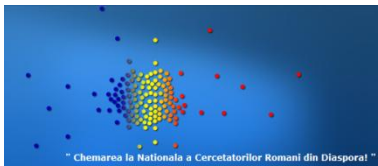
-ion track nanoporous membranes – excellent templates for producing nanowires

-besides shape one can control composition, structure and finally function

A large number of nanoobjects can be used as templates: from nanospheres to nanowires

Intersting alternatives are bio - templates

Thank you!!!



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