

# **Электрохимическое наноструктурирование**

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<http://www.elch.chem.msu.ru/rus/prgfnm.htm>

# Характерные размеры элементов электрохимических систем

Elements	Size intervals /m	Components
Electrodes for practical applications	0.1 – 10	metals, semiconductors, composition materials
for research	$10^{-3} - 10^{-2}$	
microelectrodes	$10^{-5} - 10^{-4}$	
ultramicroelectrodes	$10^{-8} - 10^{-6}$	
thin-film electrodes	$< 10^{-8}$	
Electrolyte layers		solutions, melts, solid electrolytes
electrolysers	0.1 – 10	
research cells	$10^{-3} - 0.1$	
thin-layer cells	$10^{-6} - 10^{-5}$	
microcells	$10^{-7} - 10^{-6}$	
Membranes	$10^{-7} - 10^{-2}$	polymers, porous inorganic materials
Diffusion layers	$10^{-6} - 10^{-4}$	all electrolyte components
Chemisorption layers	$10^{-10} - 10^{-9}$	the same
'Electronic tails' and near-surface layers in semiconductors	$< 10^{-11}$	electrons and other charge carriers

# Наноструктурирование

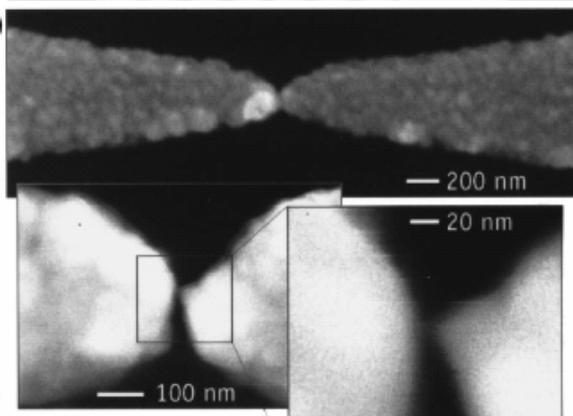
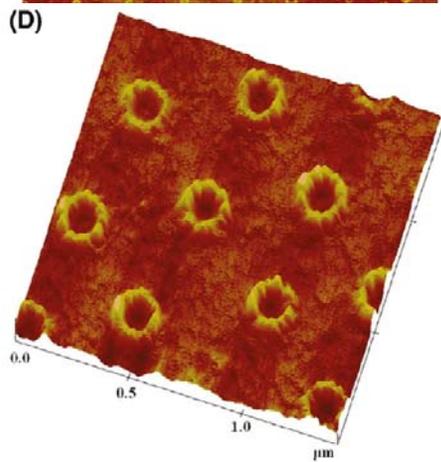
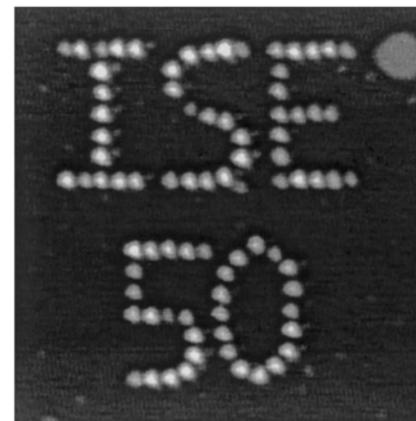
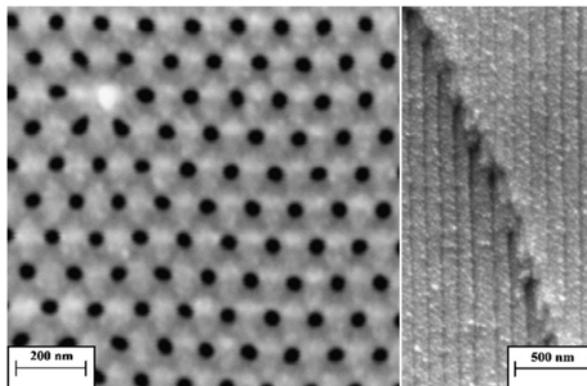
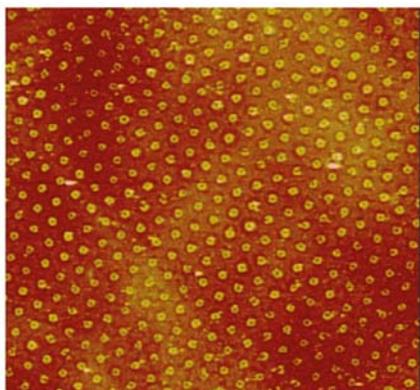
Создание ансамблей  
наноструктур

Создание индивидуальных  
наноструктур

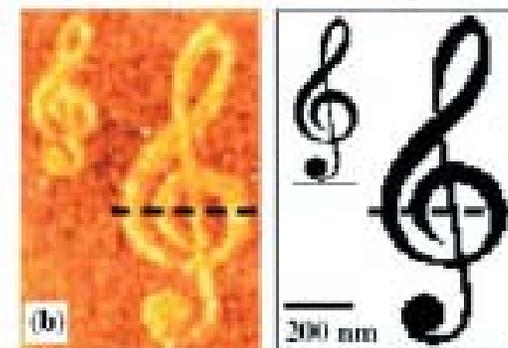
Электроосаждение

Травление  
(растворение)

Зондовые методы

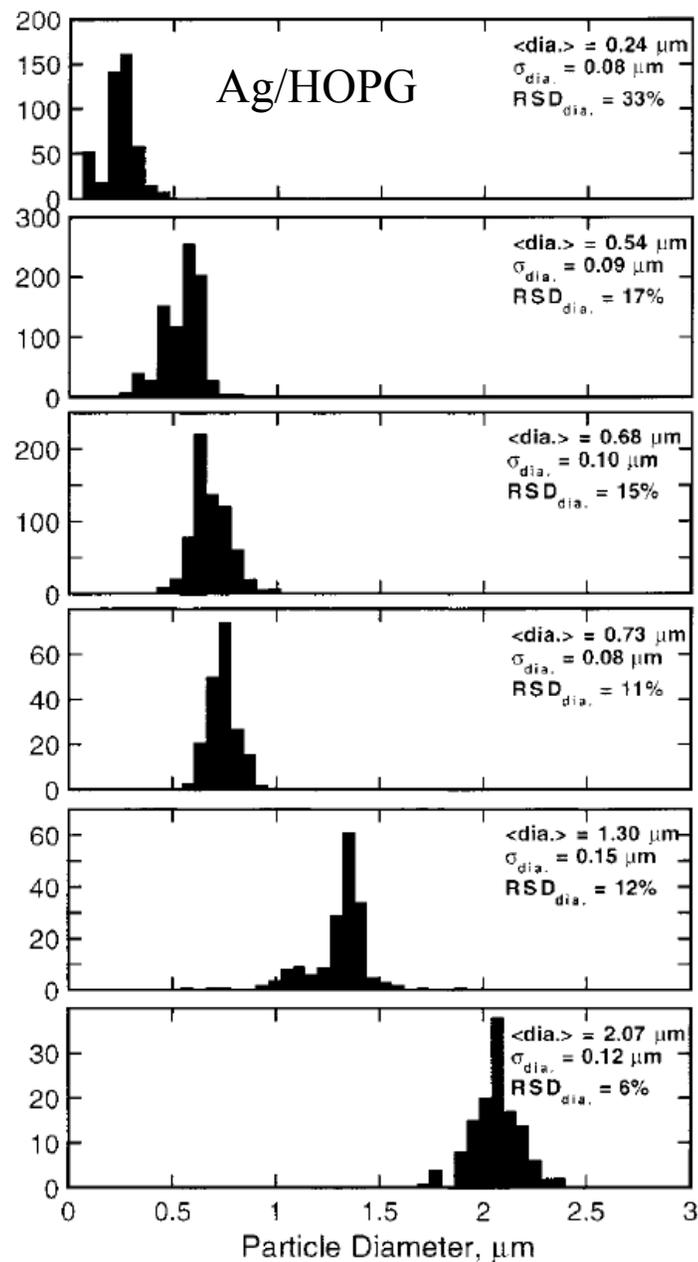
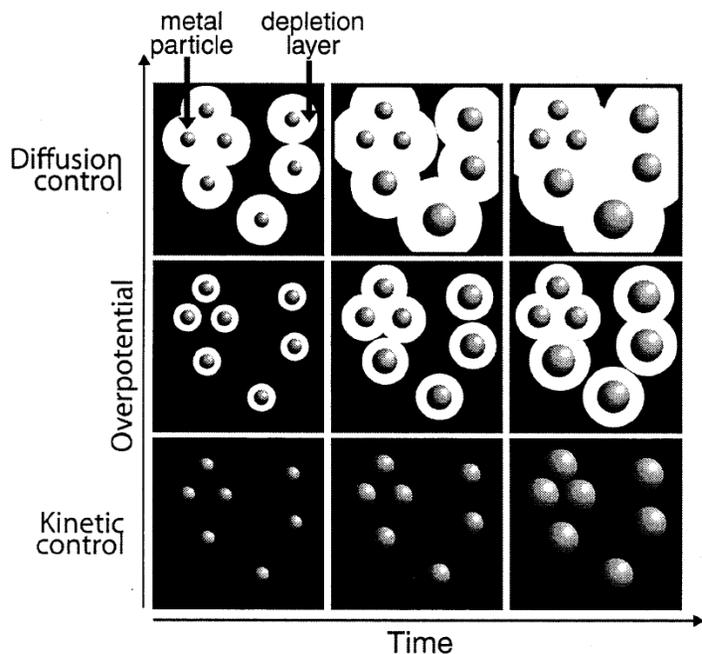
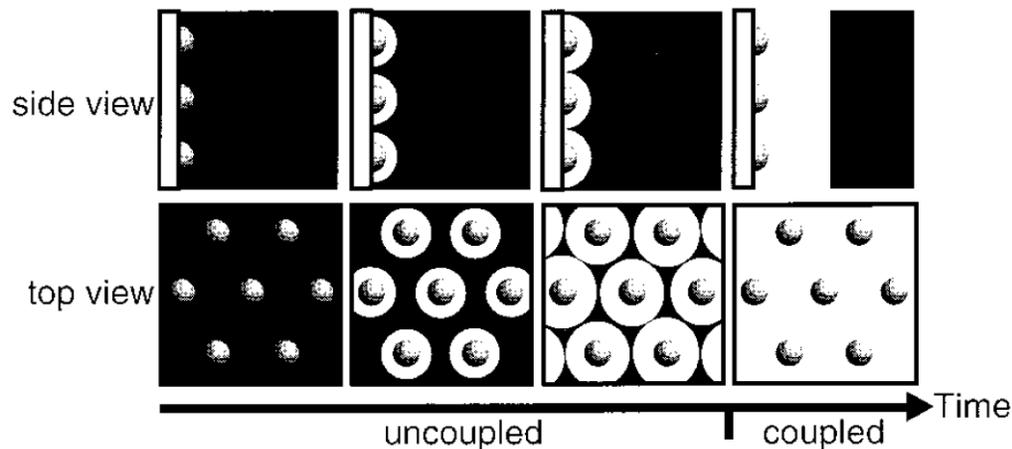


100 x 100 nm<sup>2</sup>



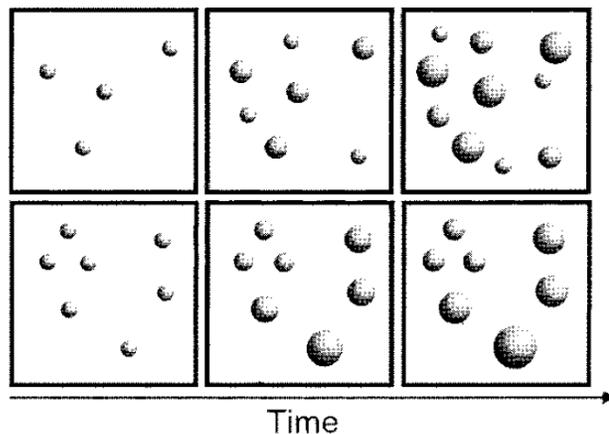
# Электросождение

Кинетика нуклеации и роста новой фазы

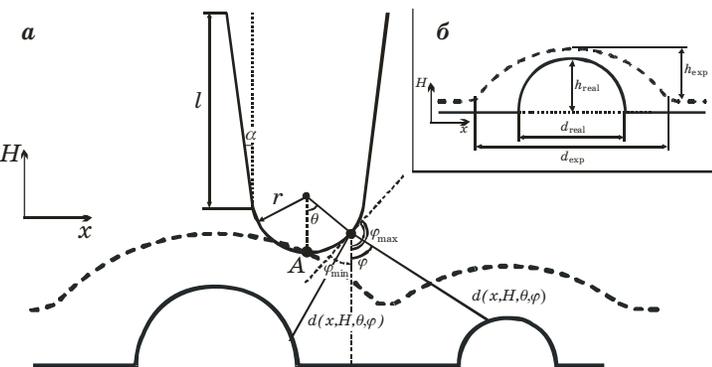
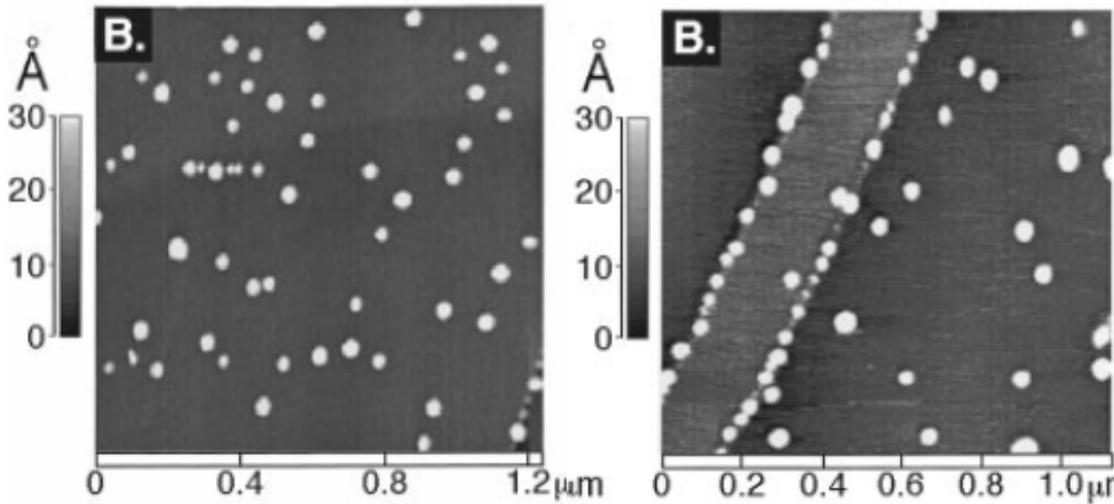
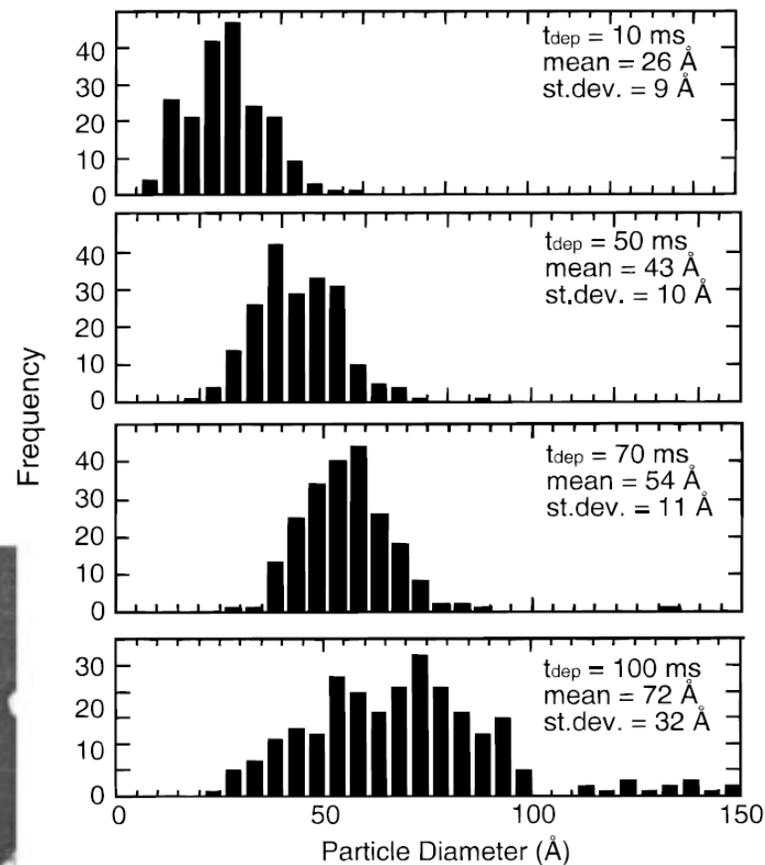


# Электросождение

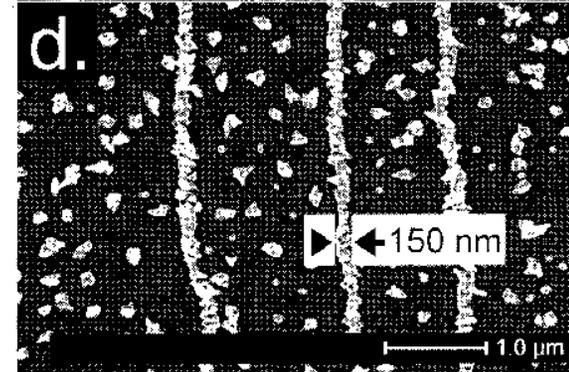
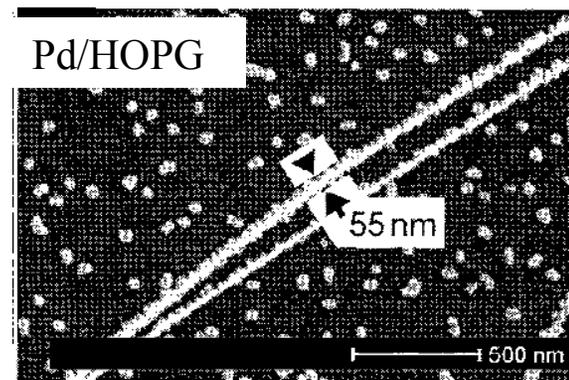
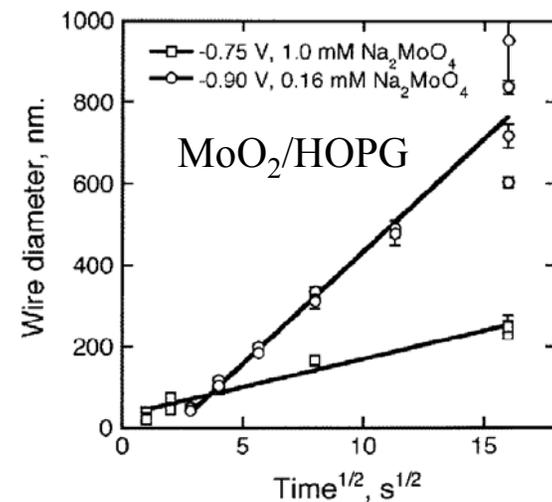
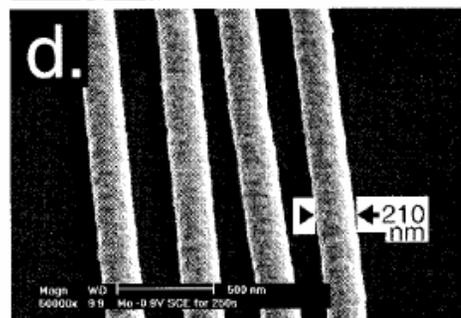
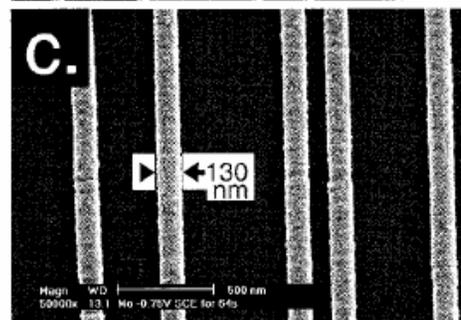
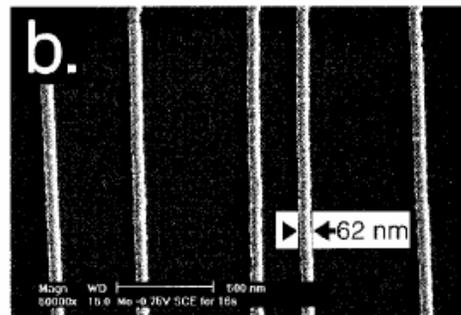
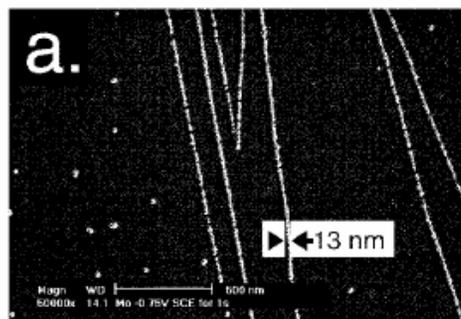
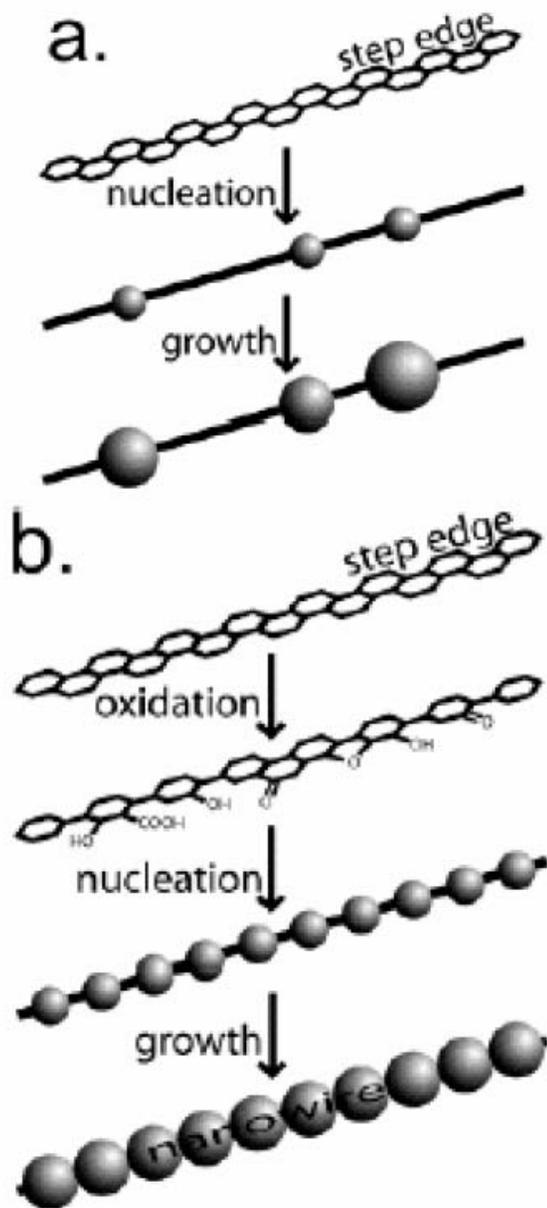
Кинетика нуклеации и роста новой фазы



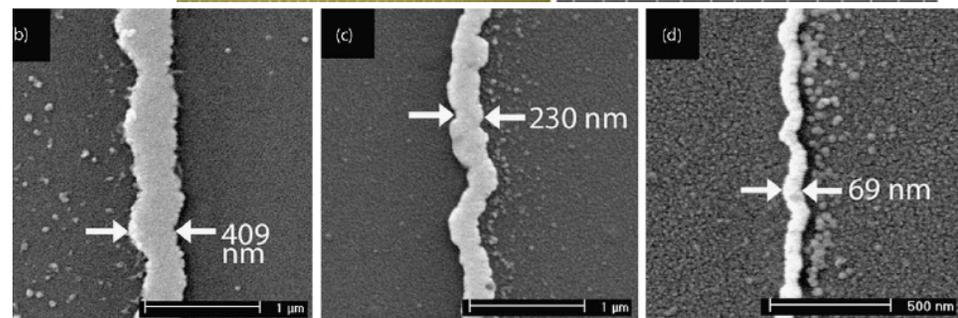
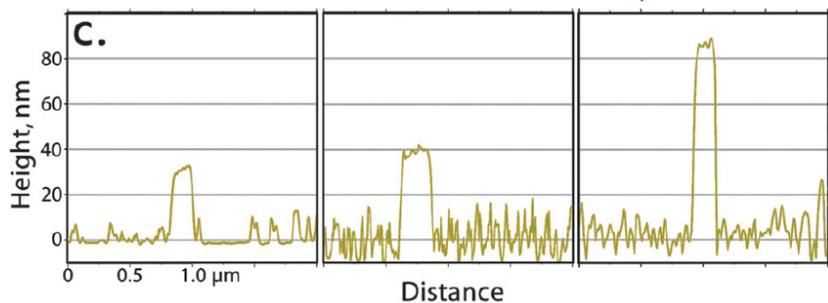
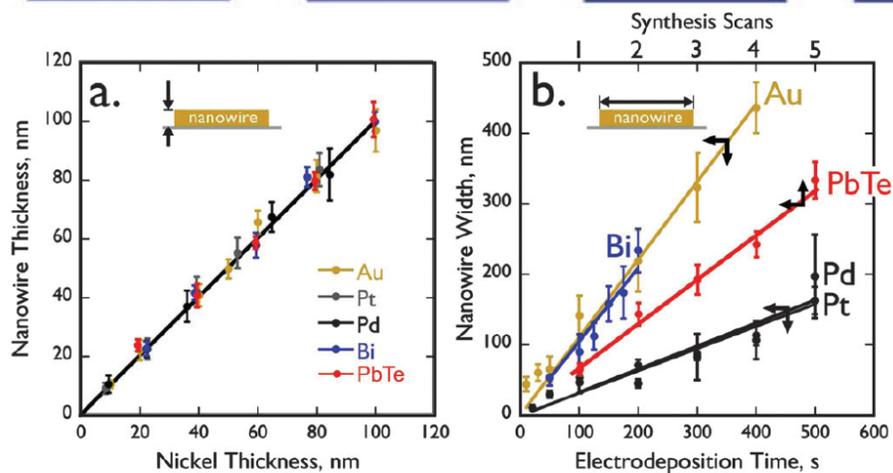
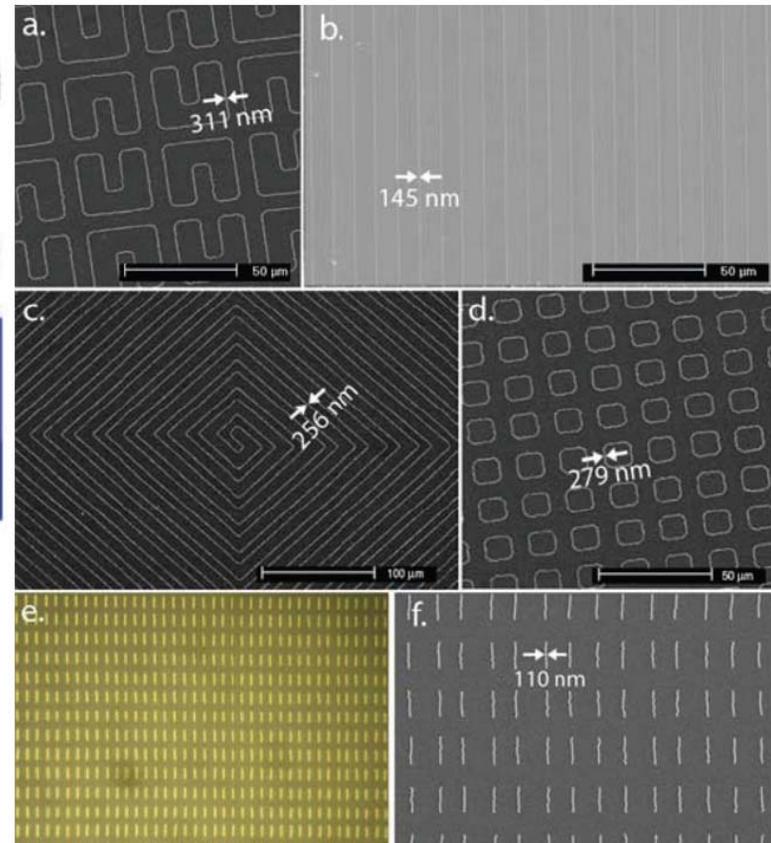
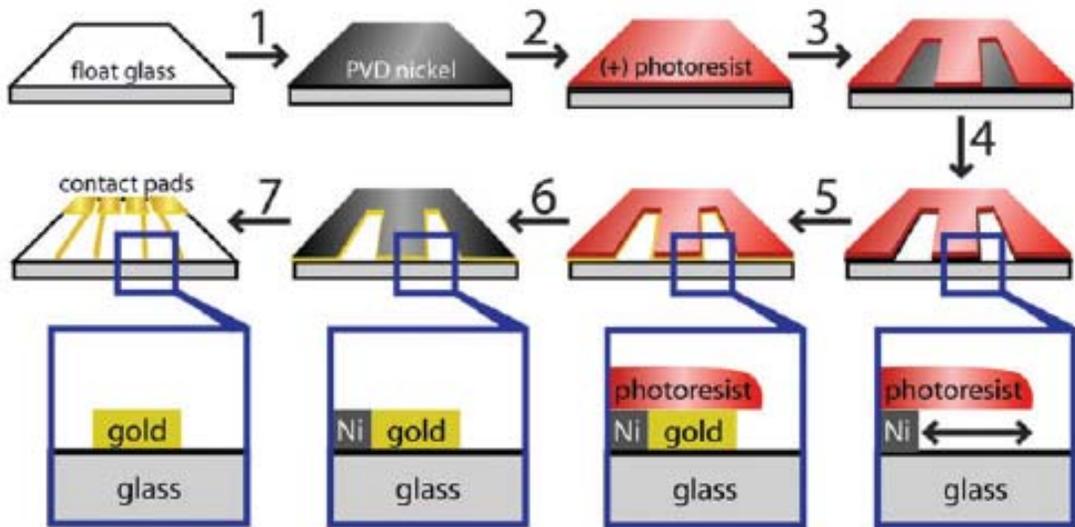
Pt/HOPG



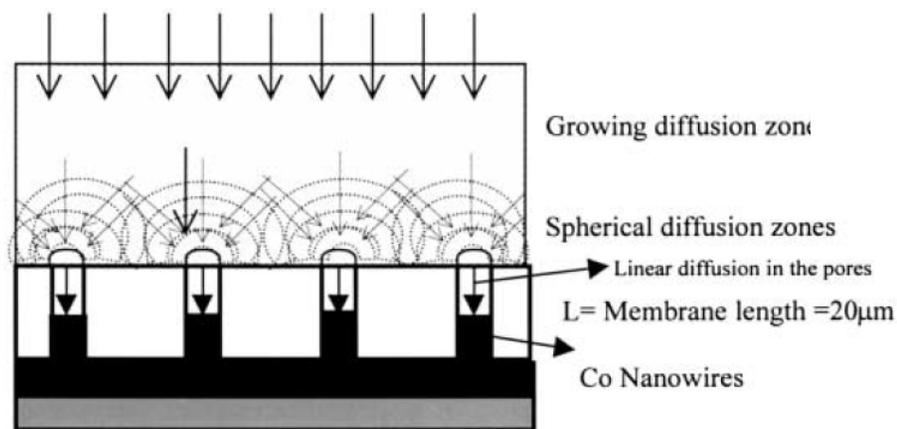
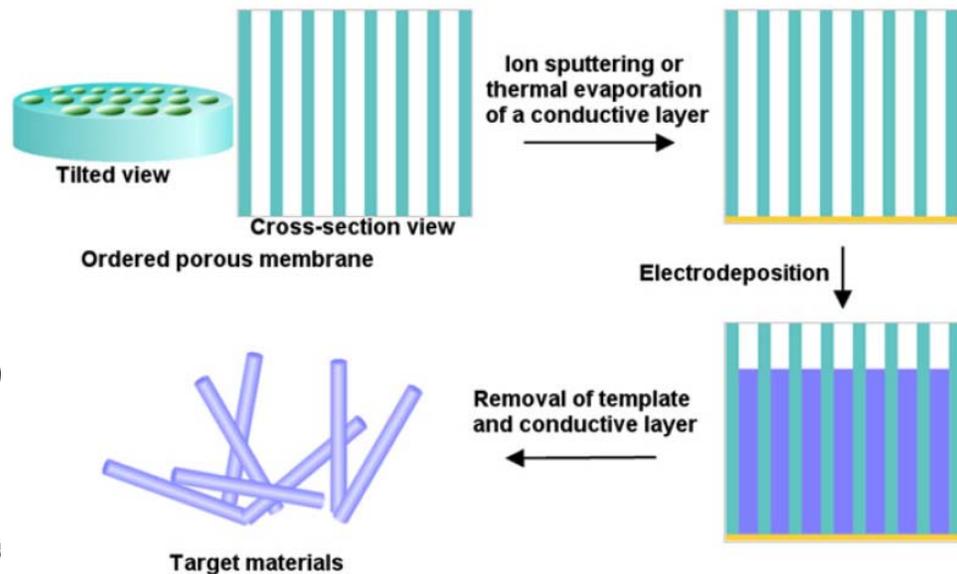
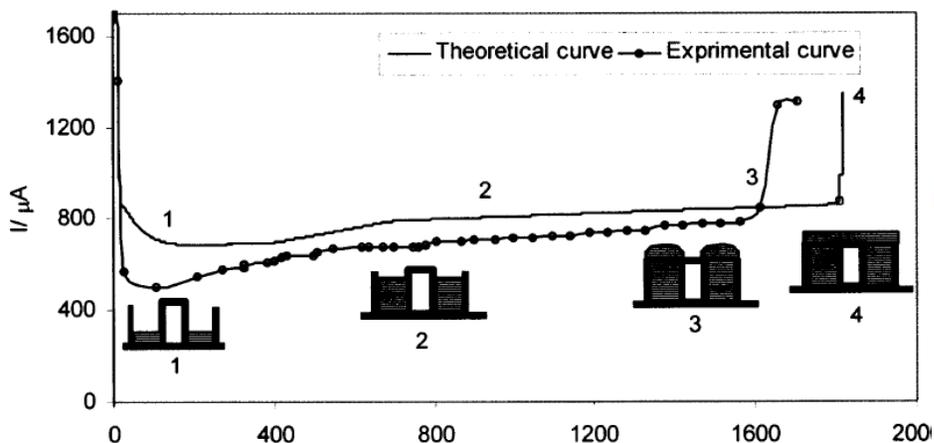
# Электросаждение: центры нуклеации



# Электросаждение: нановолокна

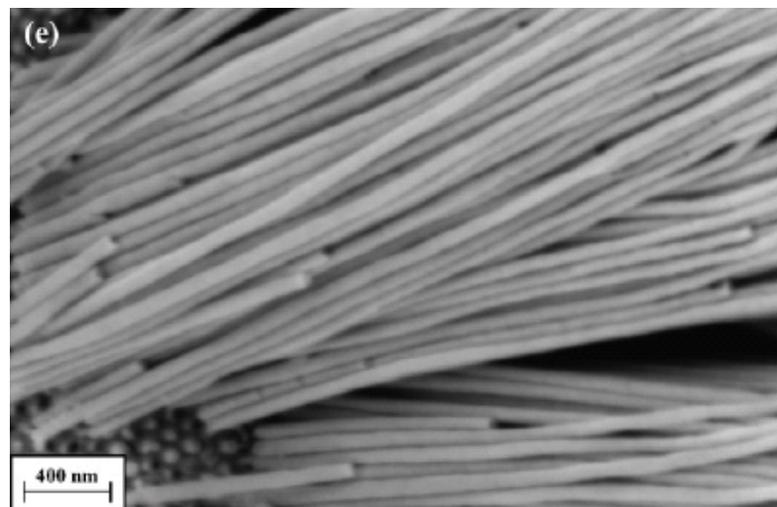


# Электроосаждение: матрицы

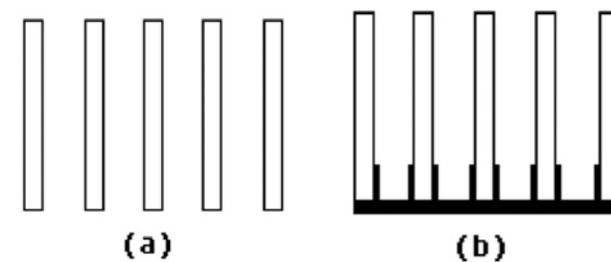
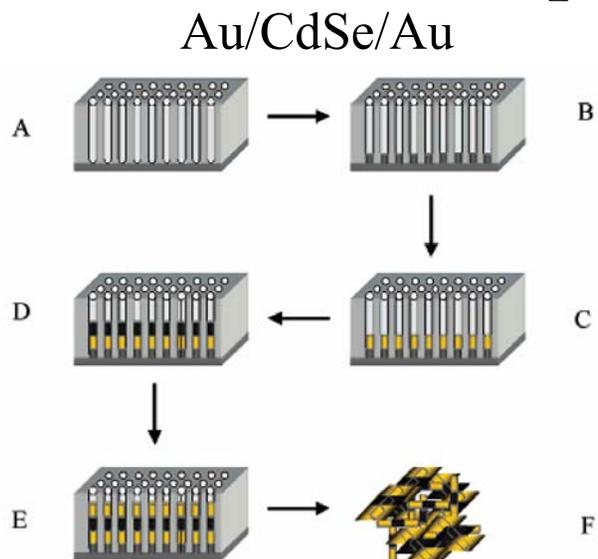


## Матрицы:

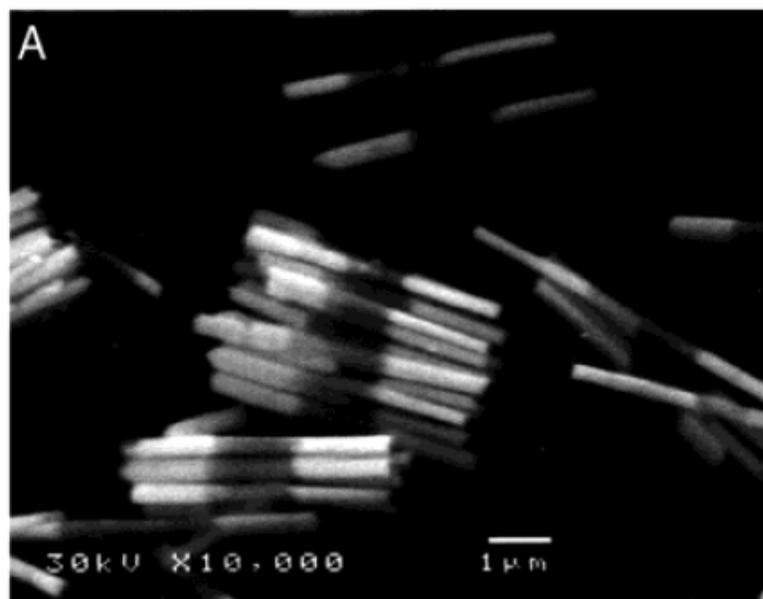
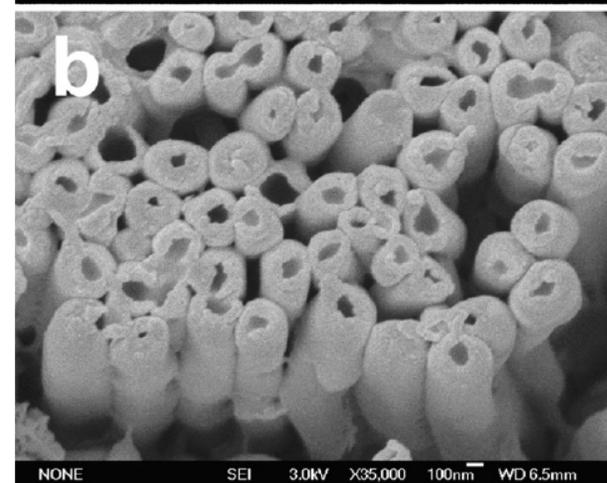
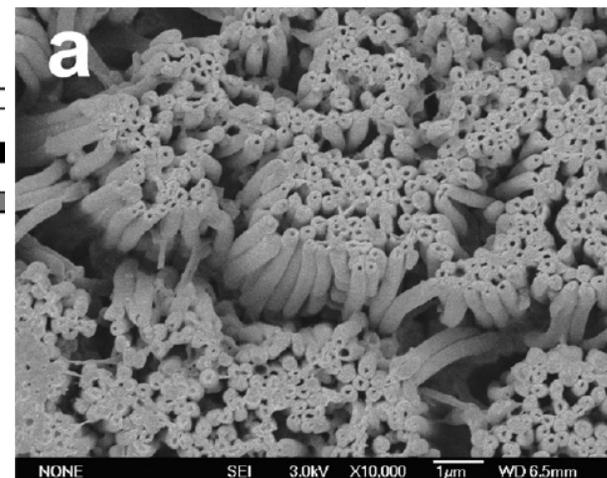
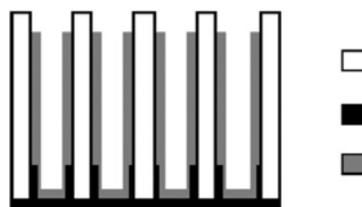
- твердые неорганические
- полимерные
- жидкие кристаллы



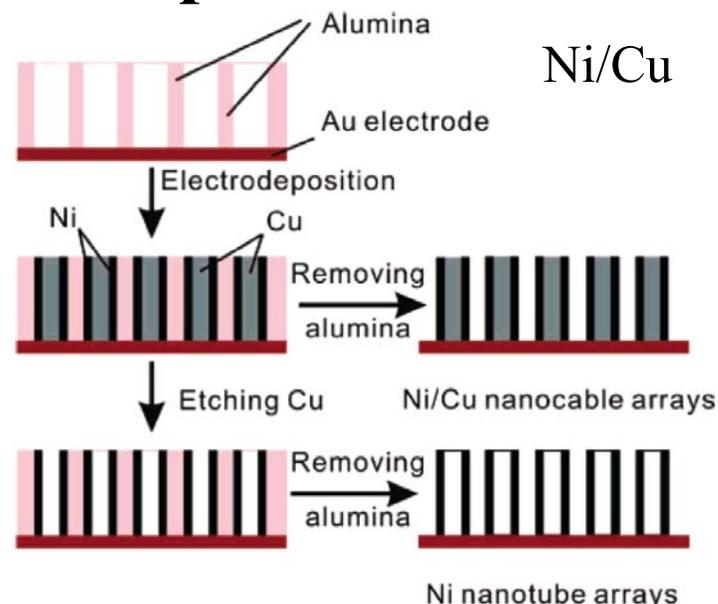
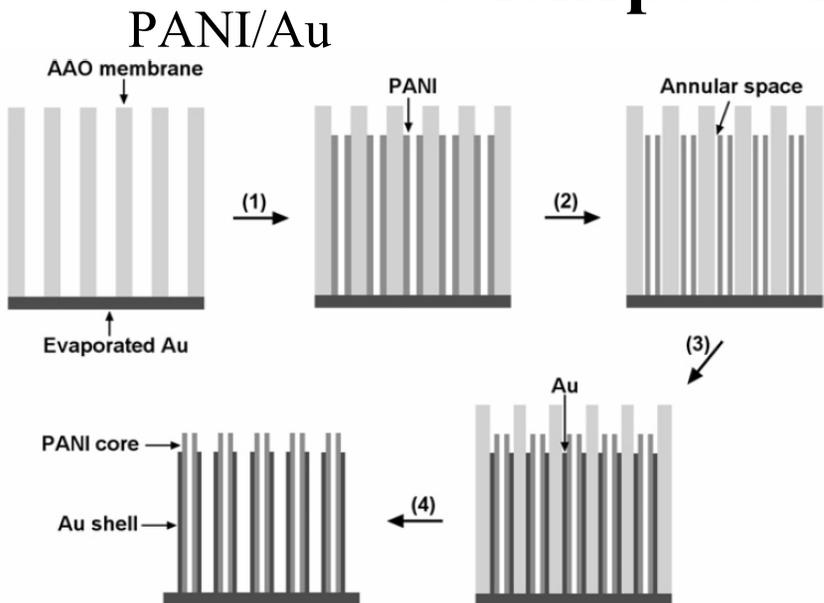
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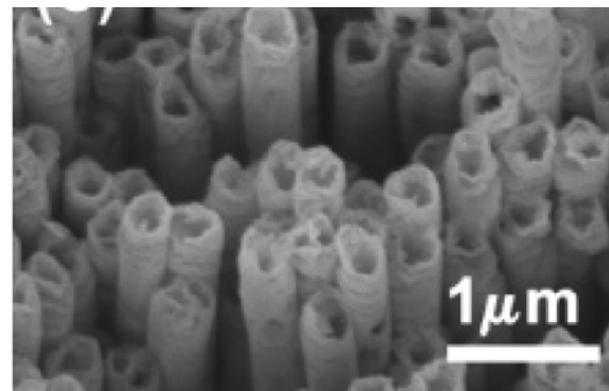
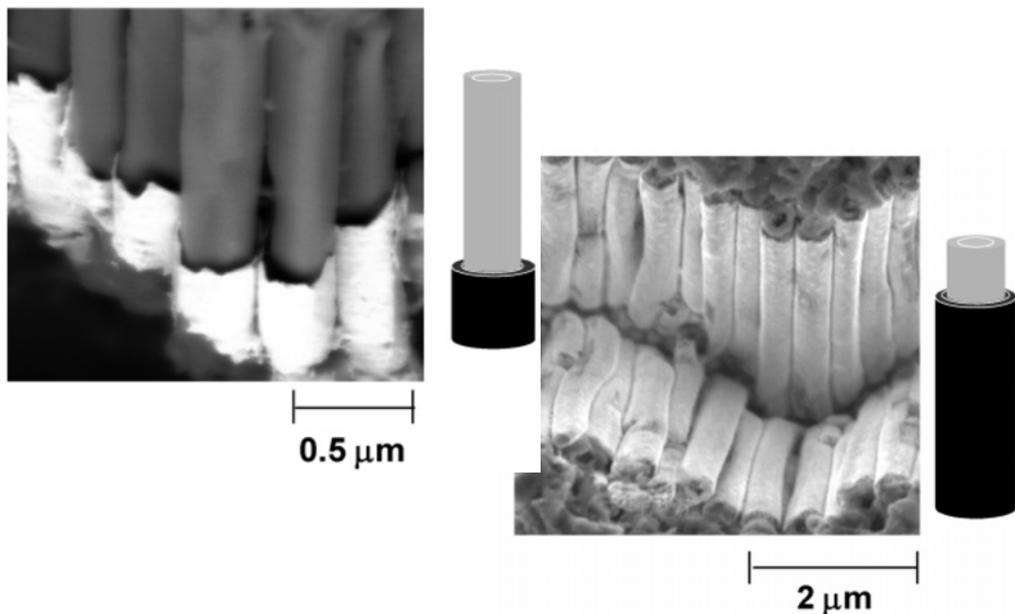
трубки



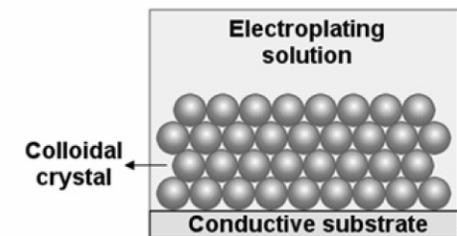
# Электроосаждение: матрицы



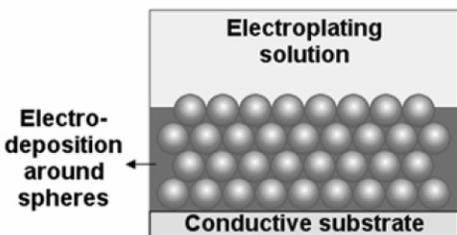
**B**



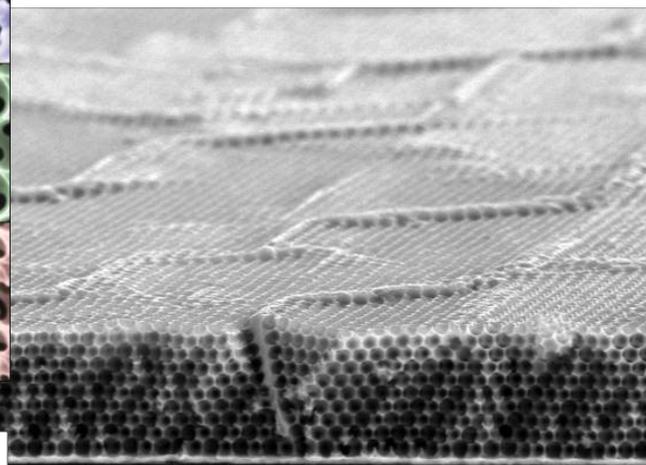
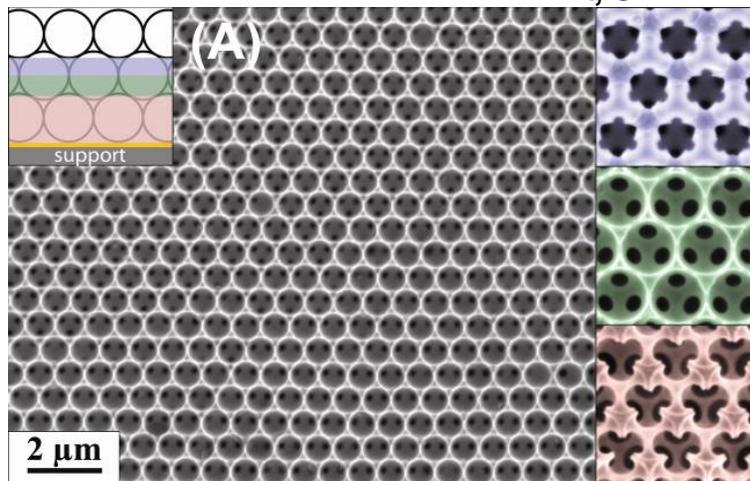
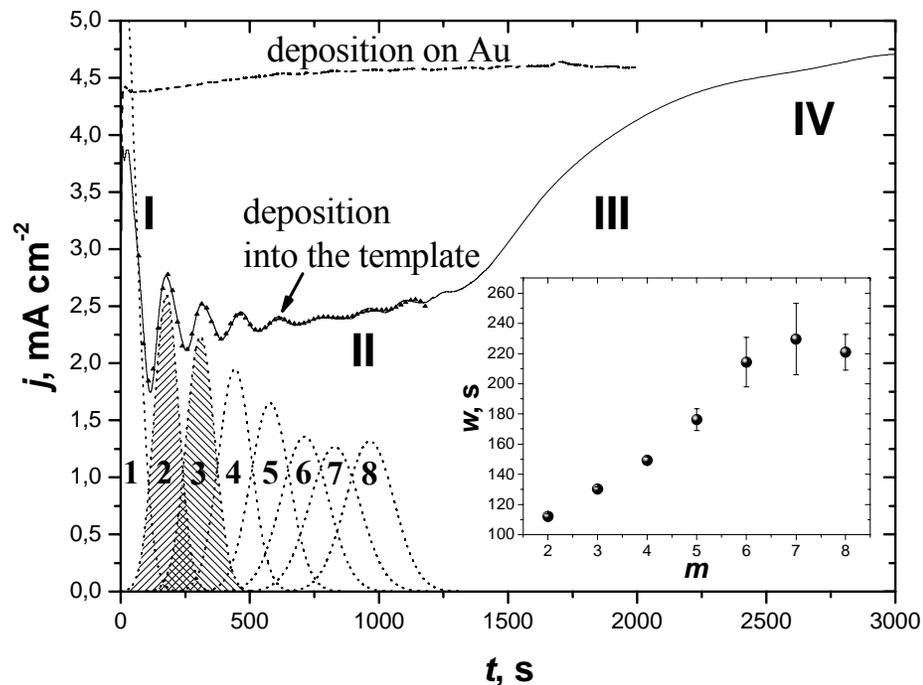
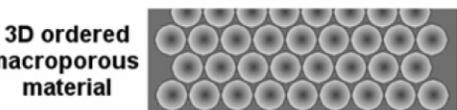
# Электроосаждение: инвертированные опалы



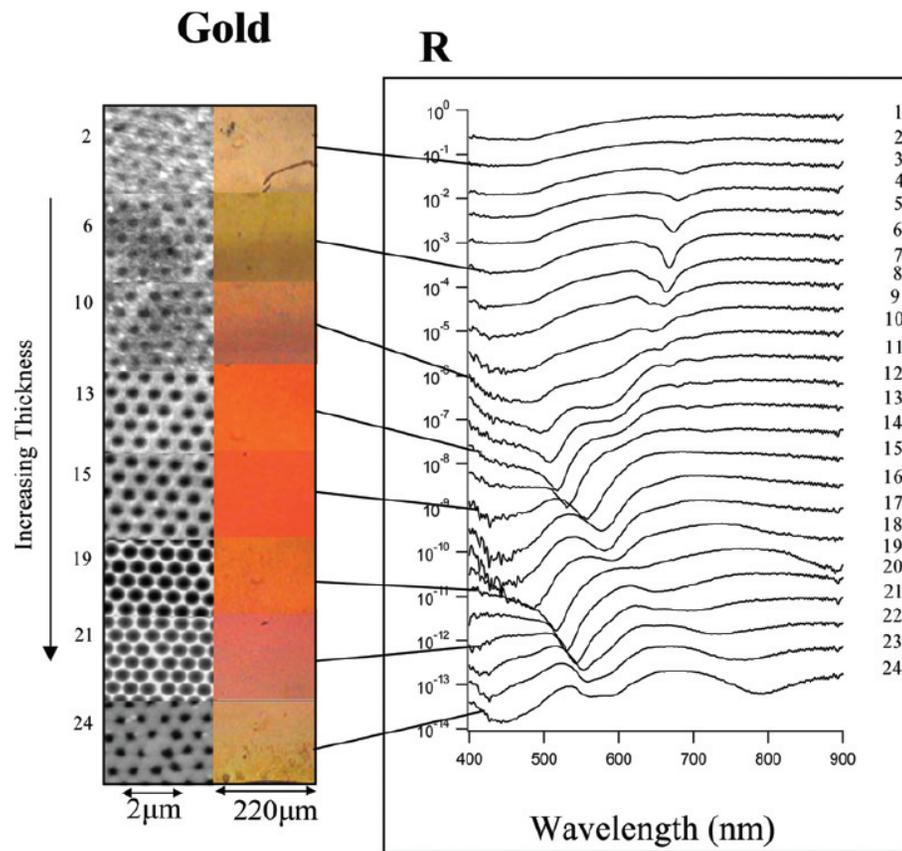
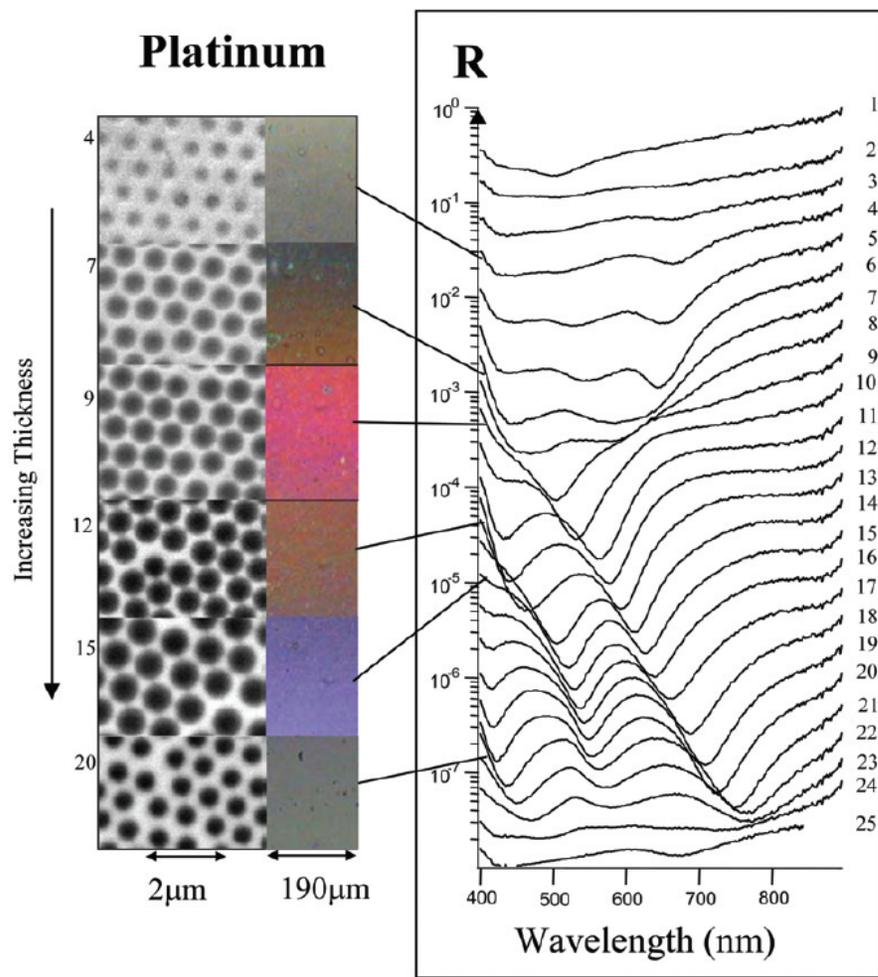
↓ Electro-synthesis



↓ Removal of template

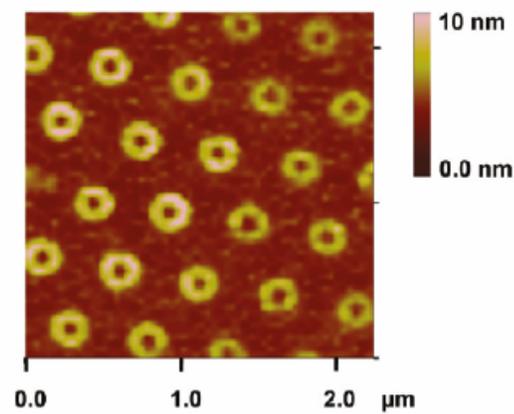
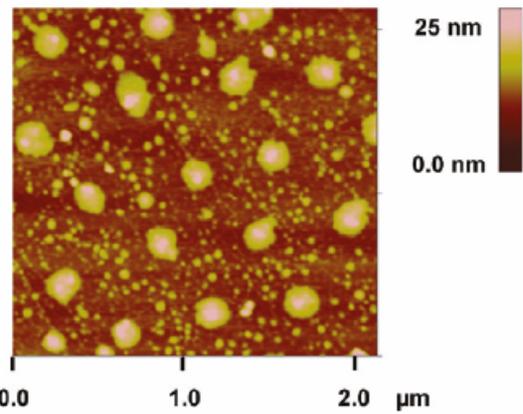
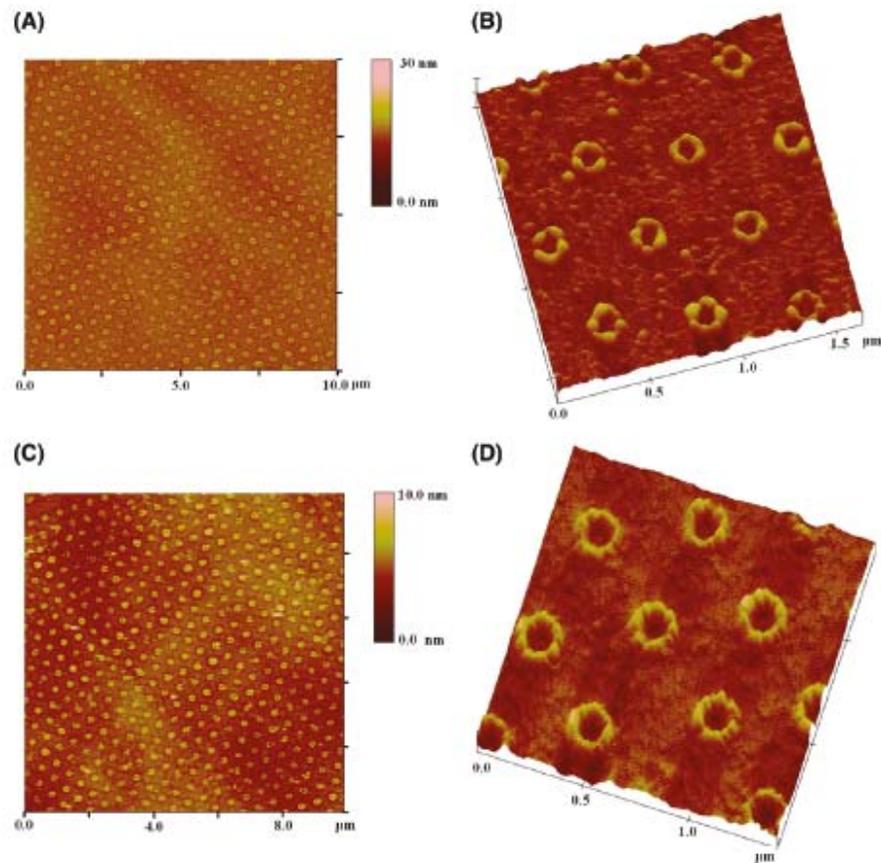
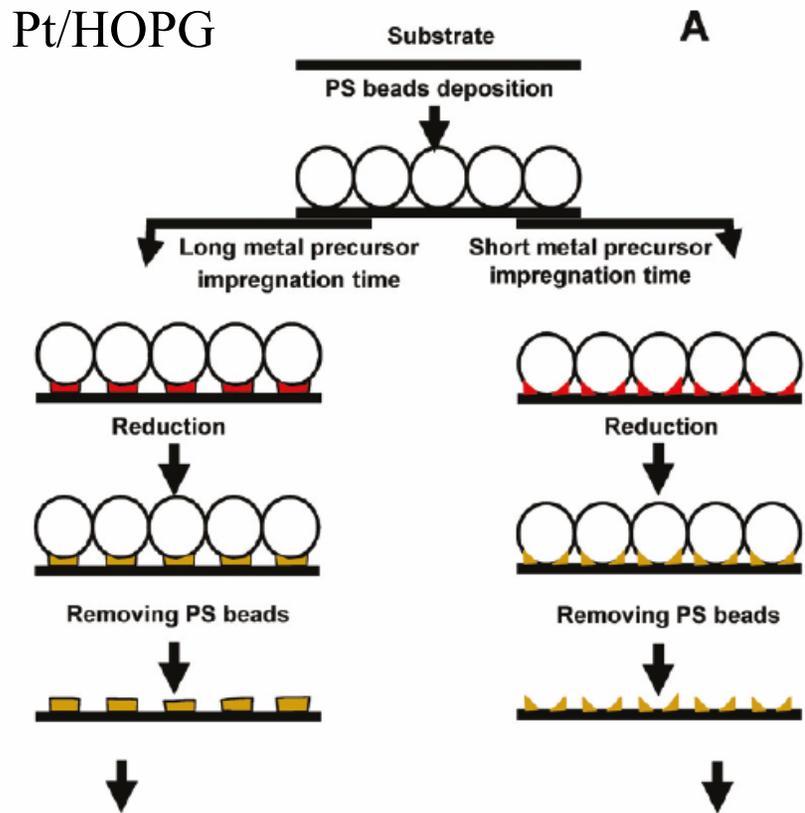


# Электроосаждение: инвертированные опалы

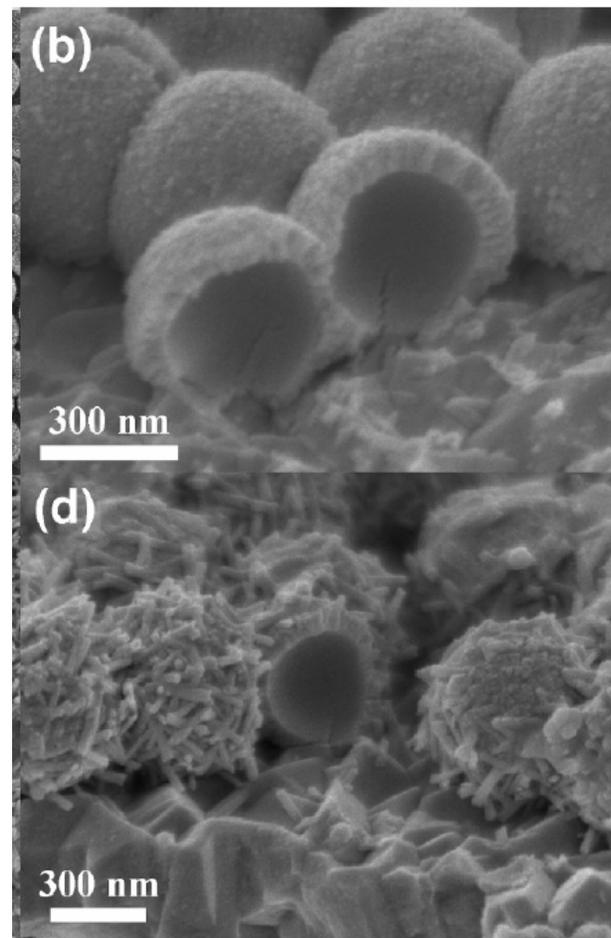
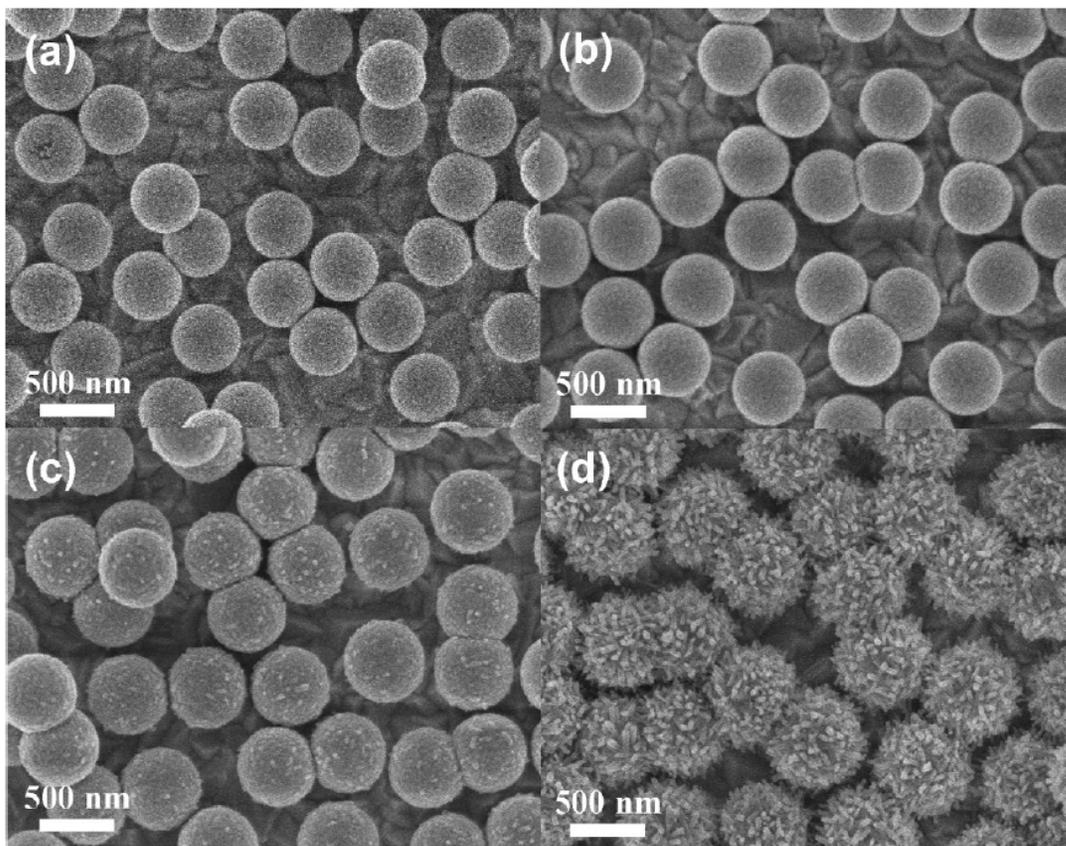
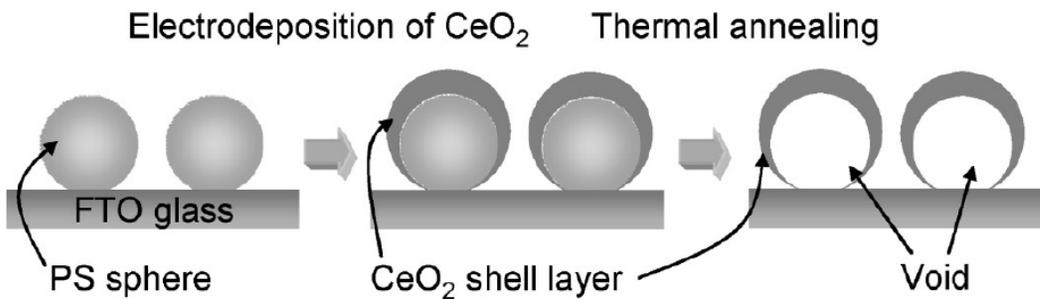


# Электроосаждение: инвертированные опалы

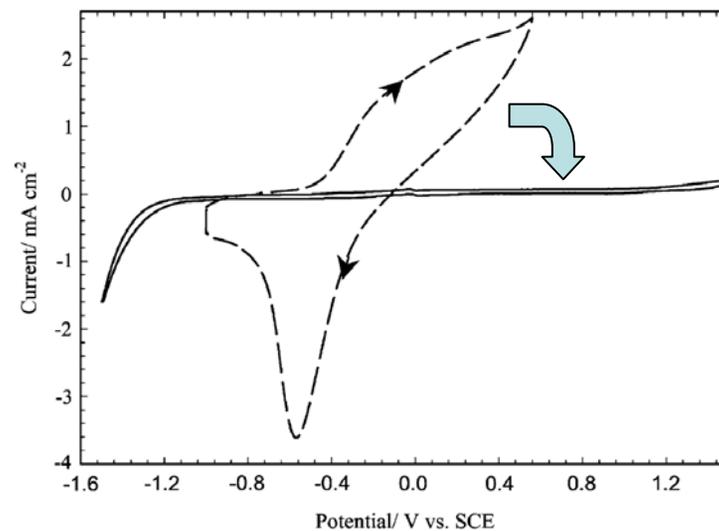
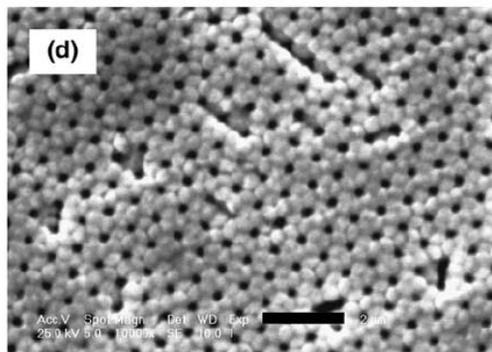
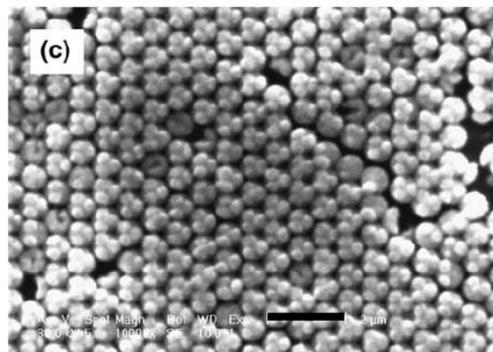
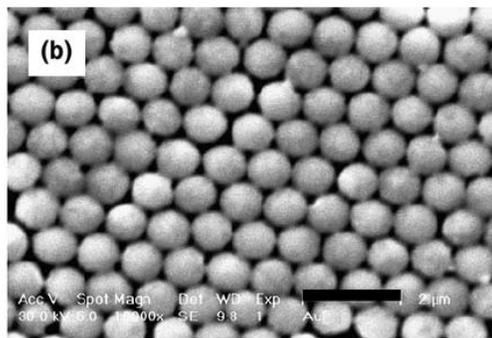
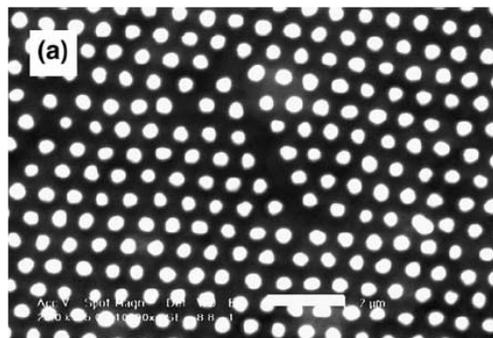
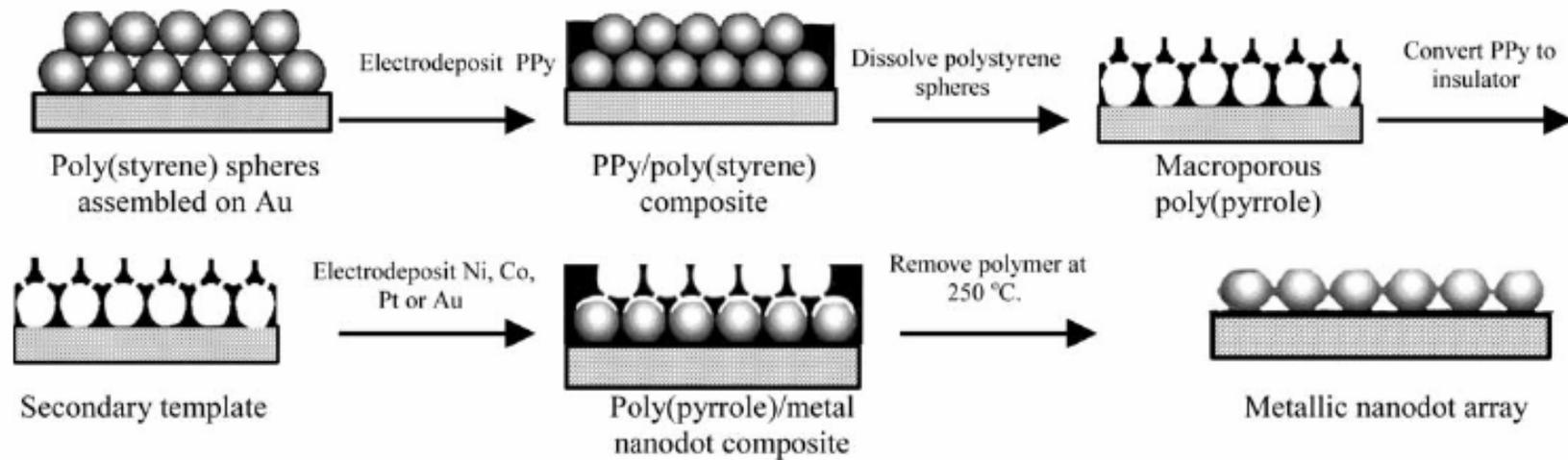
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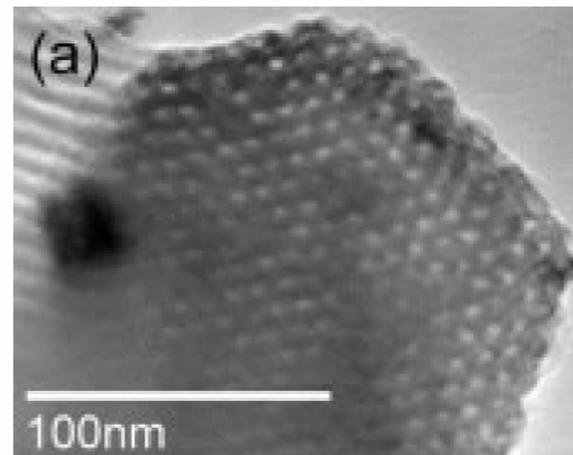
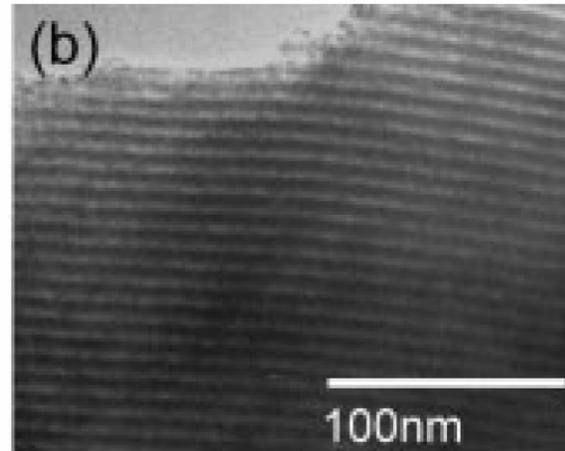
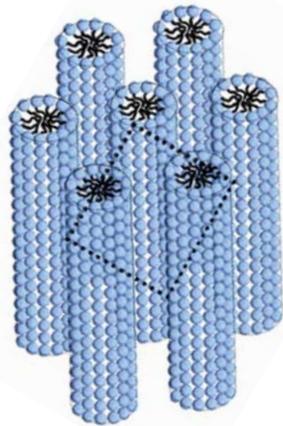
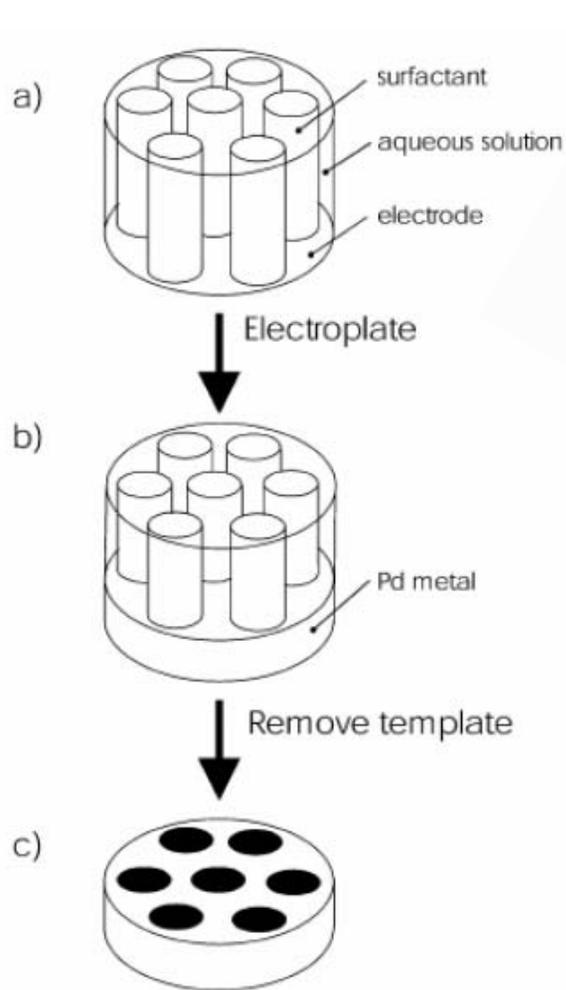
# Электроосаждение: инвертированные опалы



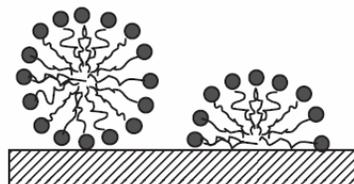
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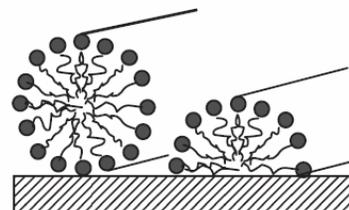
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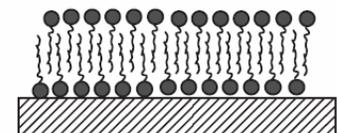
Spheres/hemispheres



Cylinders/hemicylinders

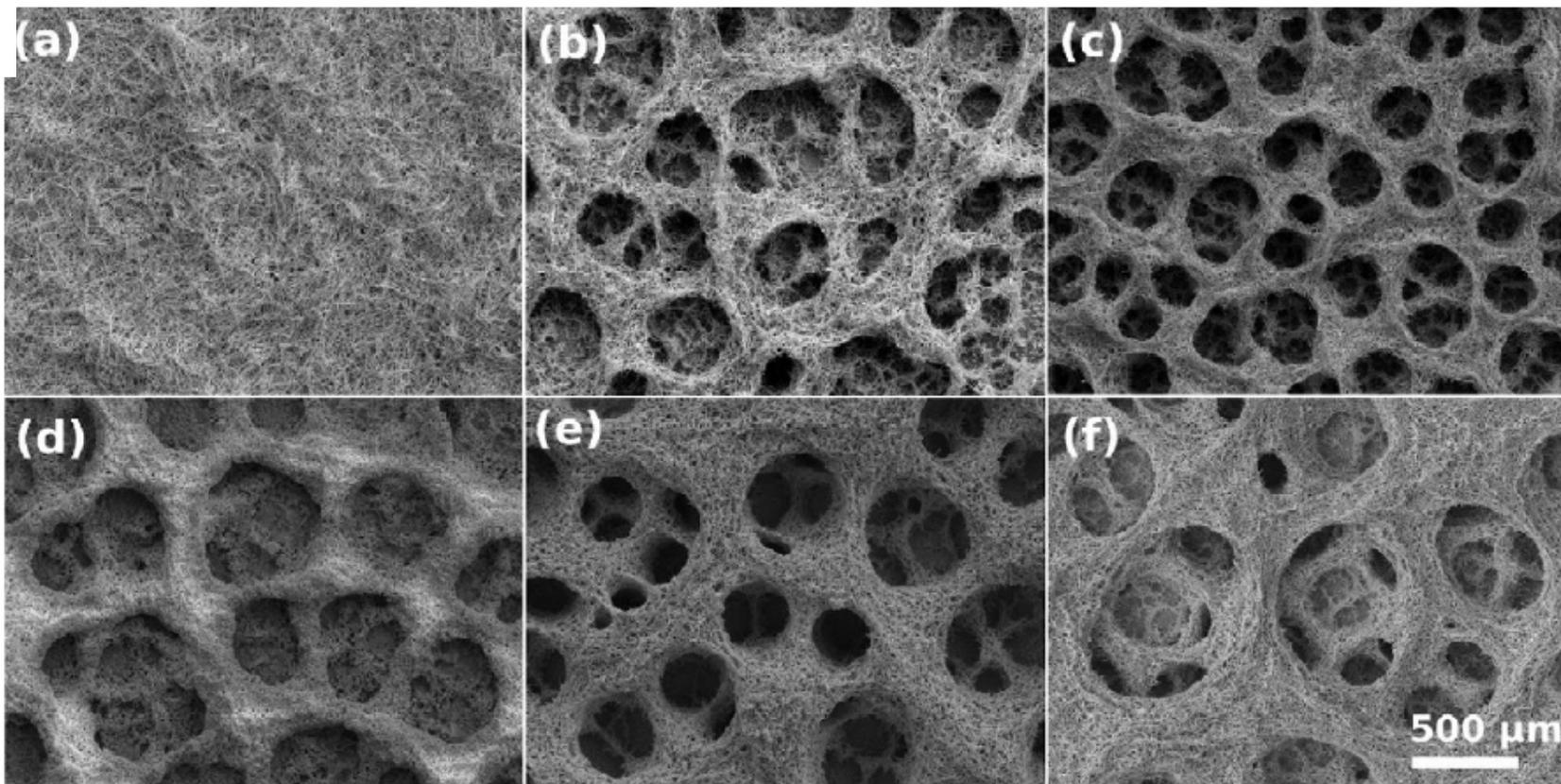


Bilayers

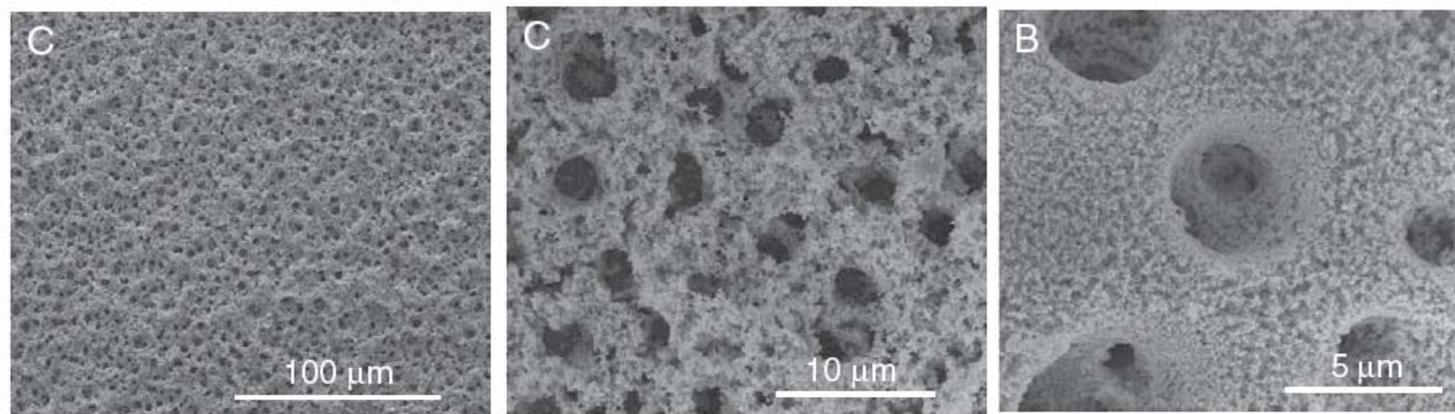


# Электроосаждение: пузырьки

Pb

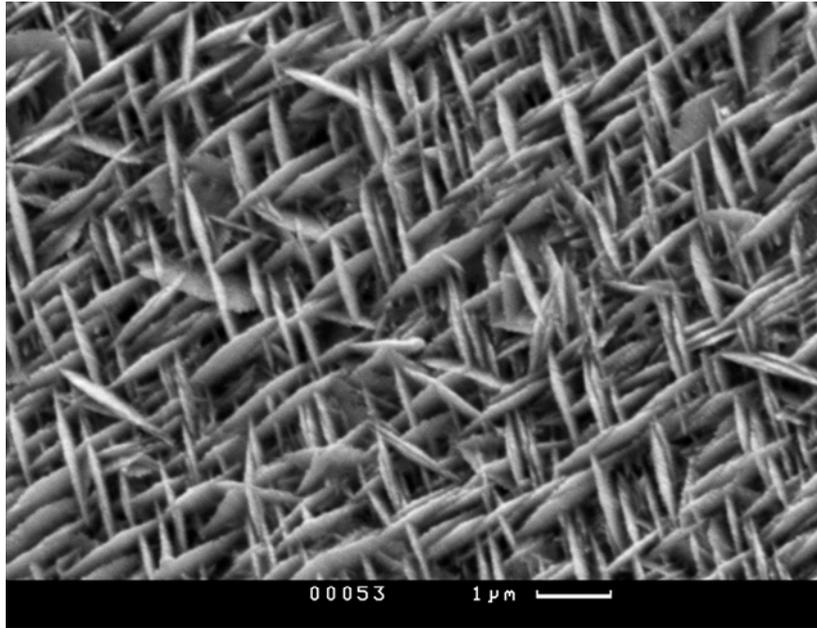


Pt

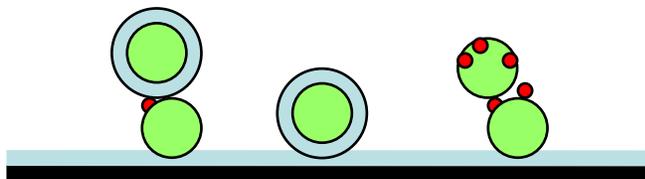


# Электросаждение: квазитемплатирование

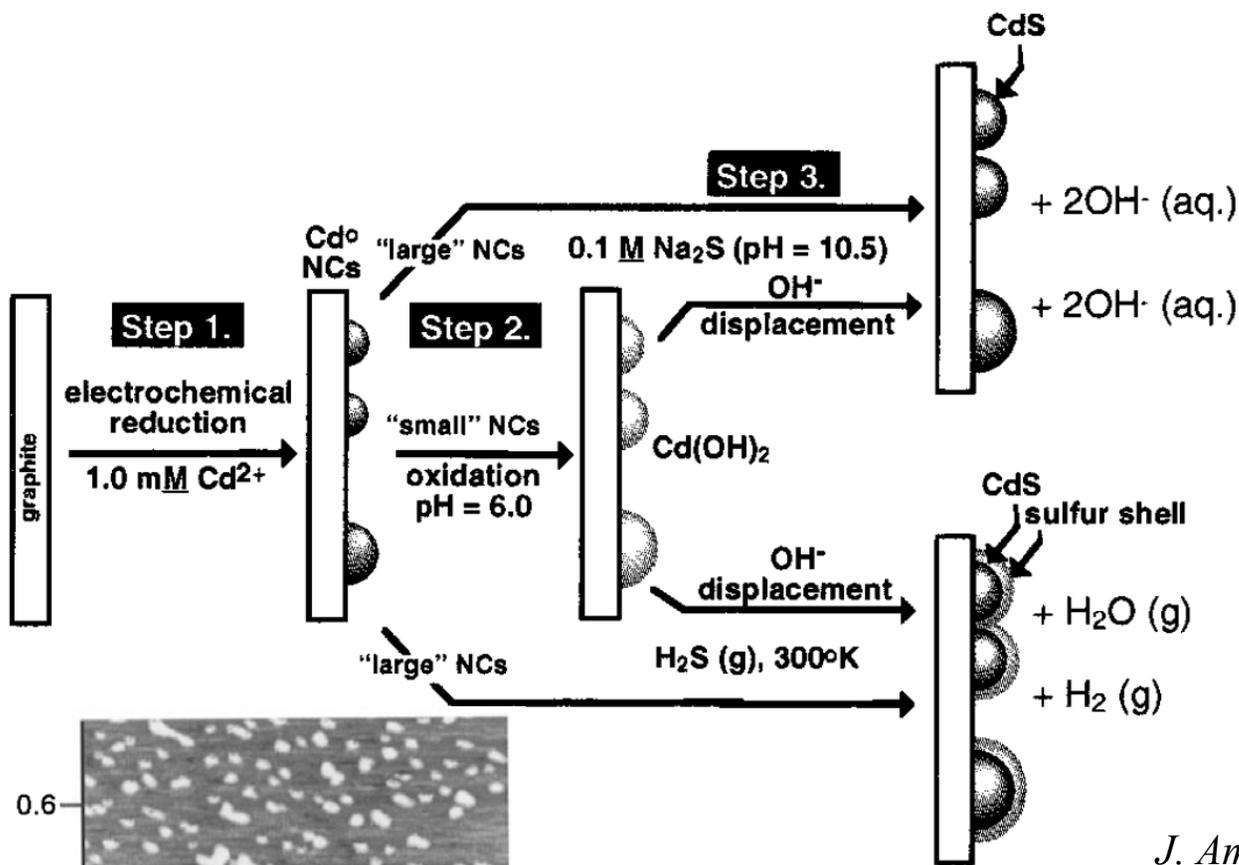
Pd-PEG



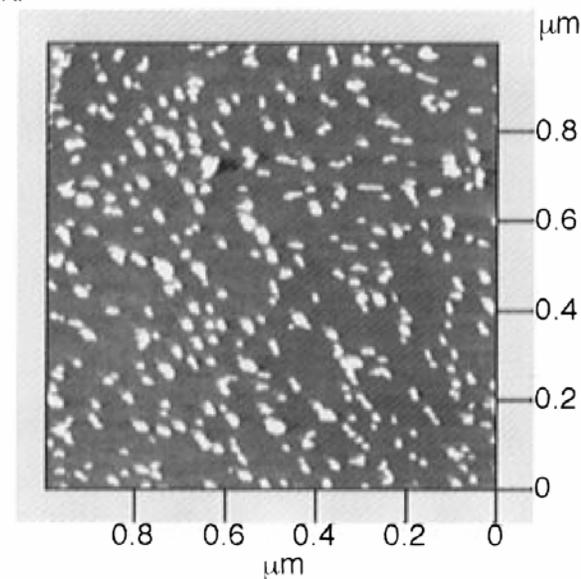
5 nm



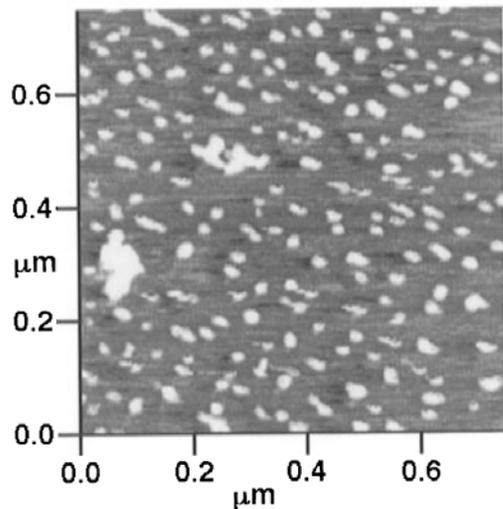
# Электроосаждение: гибридные методы



A.

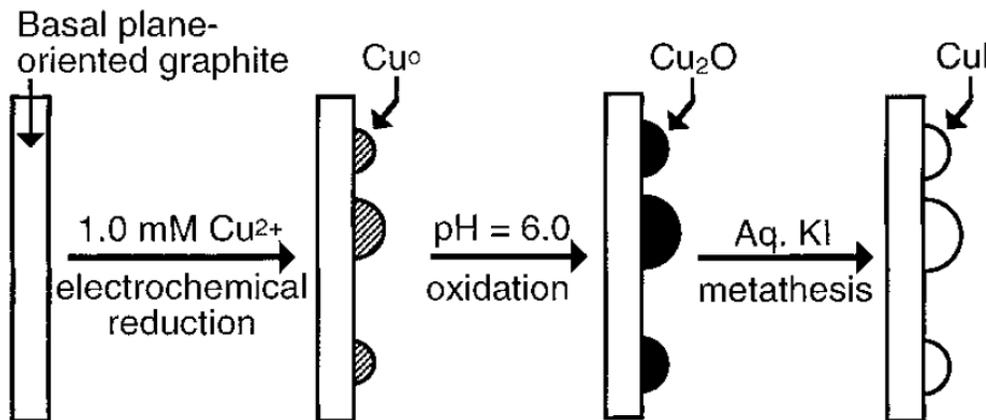


*J. Am. Chem. Soc.* **1997**, *119*, 1439-1448



*J. Am. Chem. Soc.* **1998**, *120*, 9584-9593

*J. Phys. Chem. B* **1997**, *101*, 5895-5899

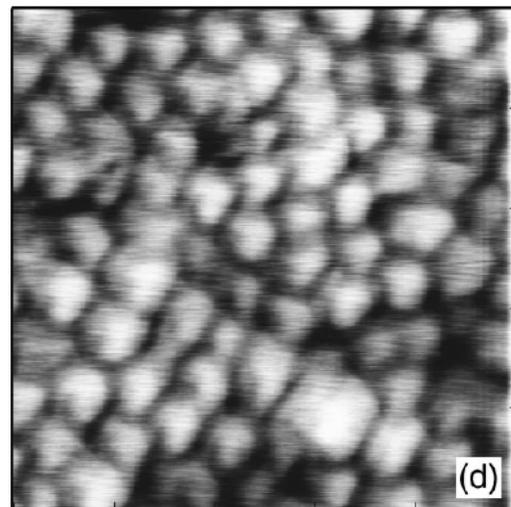
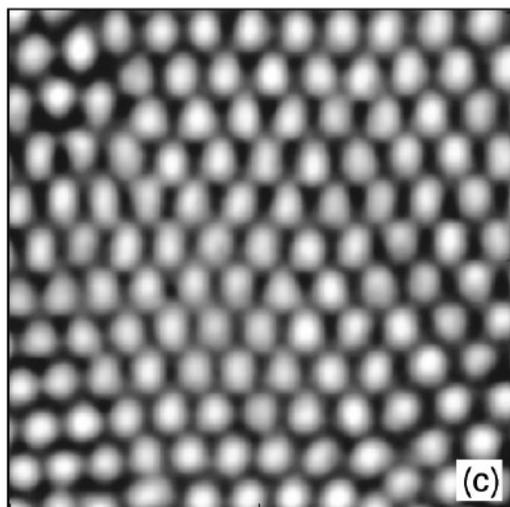
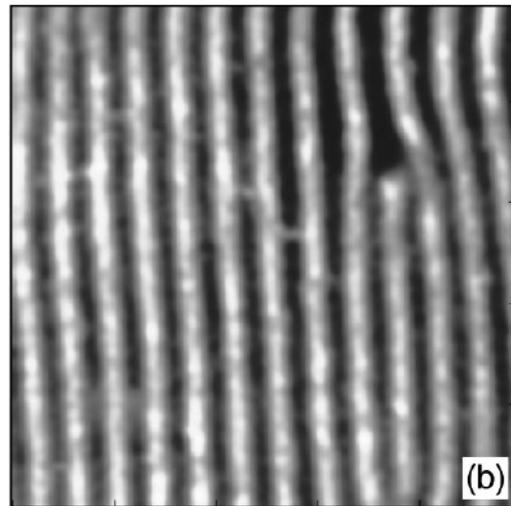
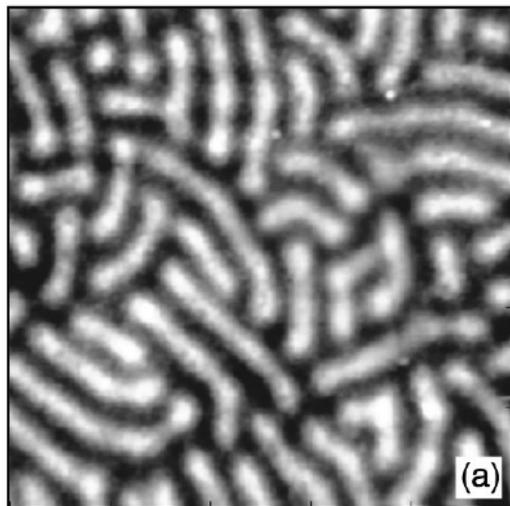


# Травление: алюминий

Этанол + вода +  $\text{HClO}_4$

40 В

50 В



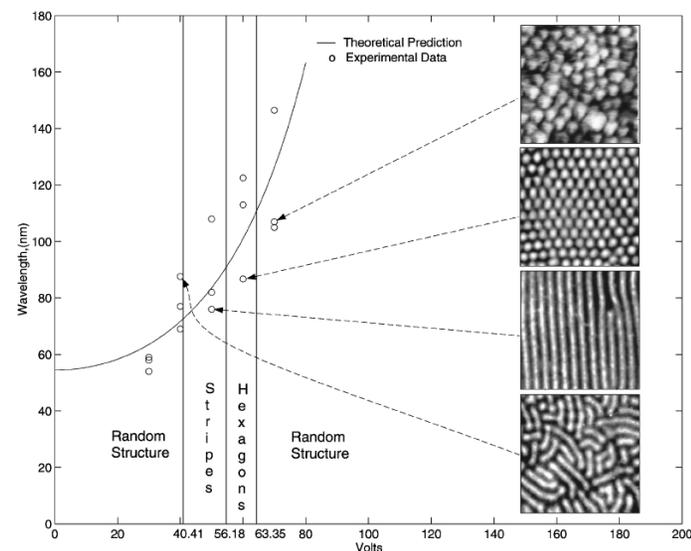
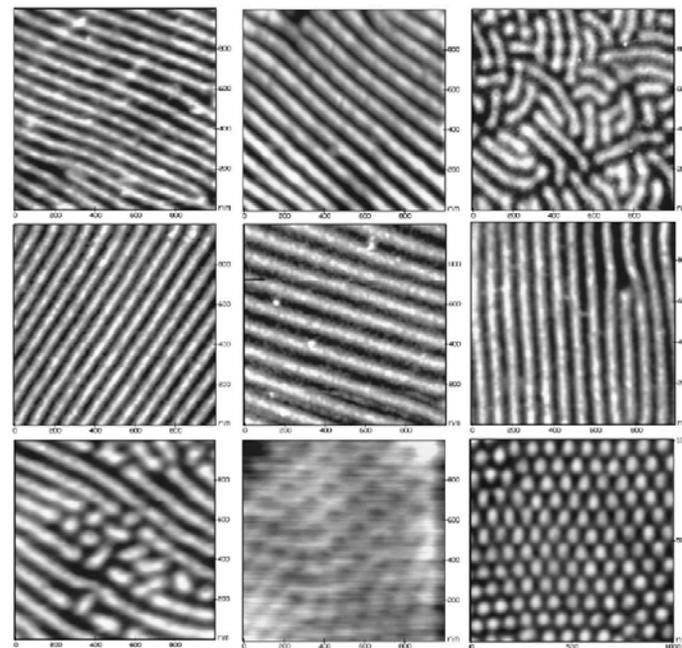
60 В

70 В

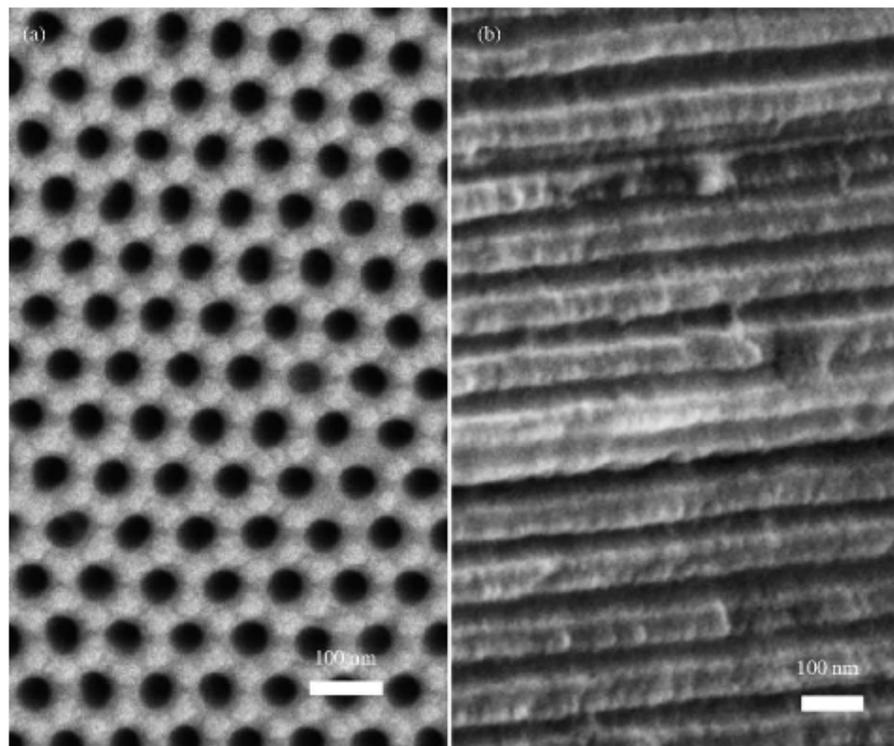
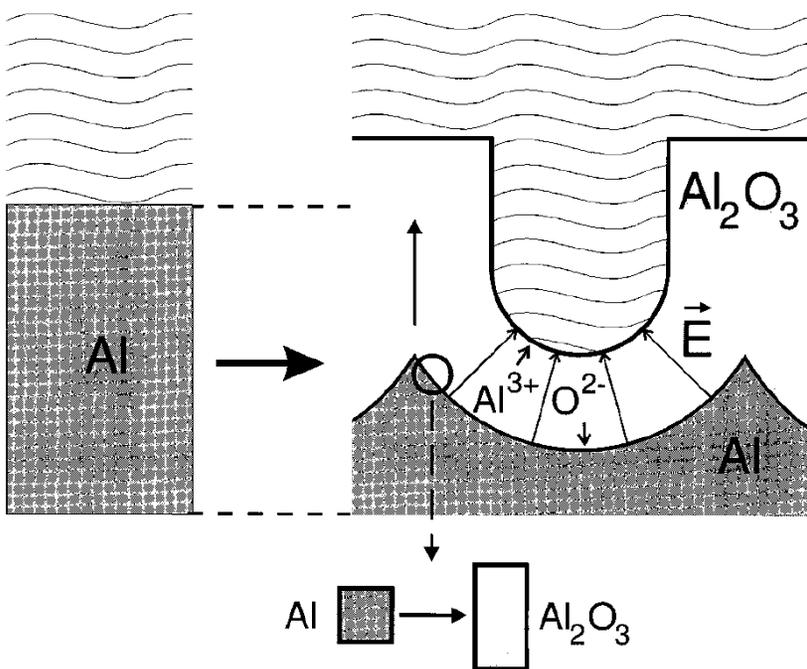
10 с

20 с

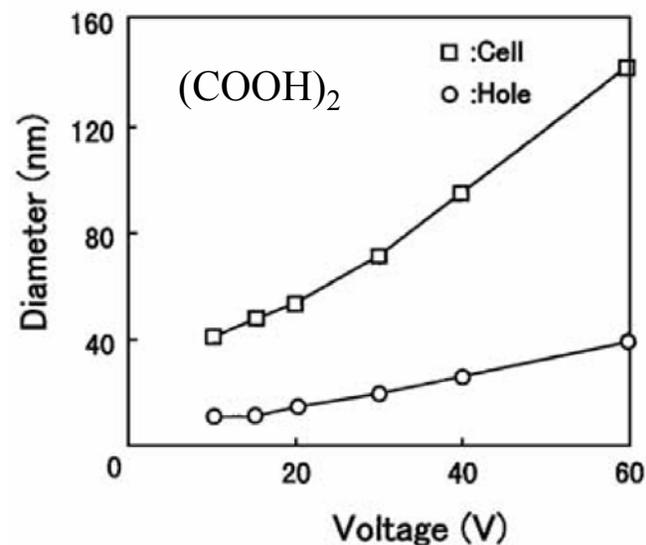
30 с



# Травление: алюминий



Acid/voltage	Hole diameter (nm)	Cell diameter (nm)
H <sub>2</sub> SO <sub>4</sub> /25–27 V	> 13	50–60
(COOH) <sub>2</sub> /40 V	> 25	90
H <sub>3</sub> PO <sub>4</sub> /195 V	> 200	500

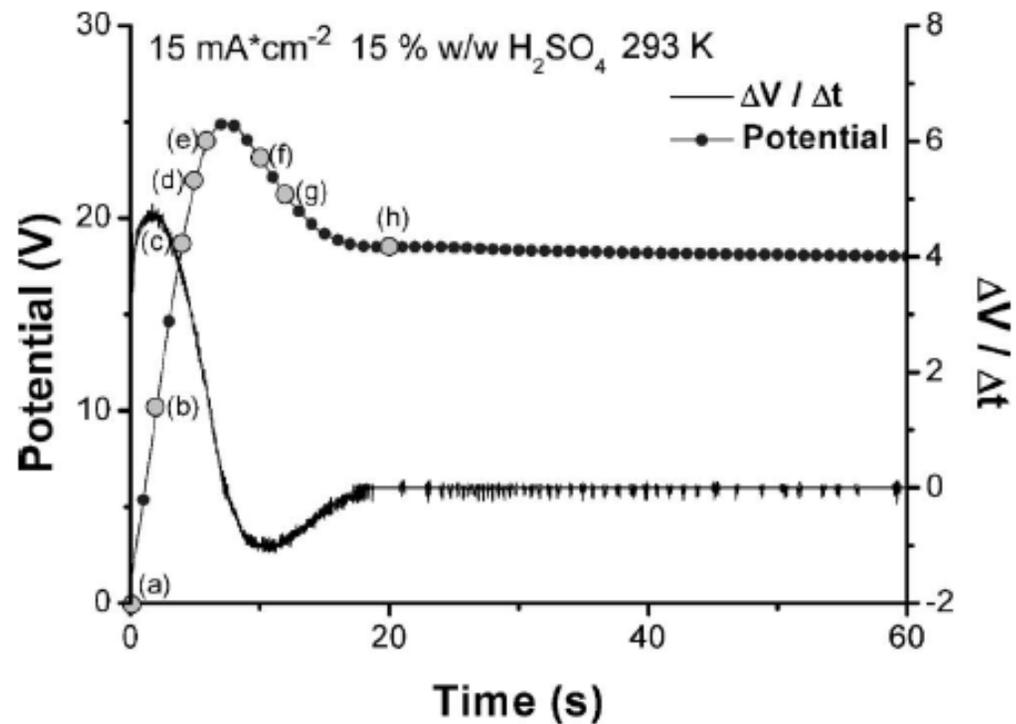
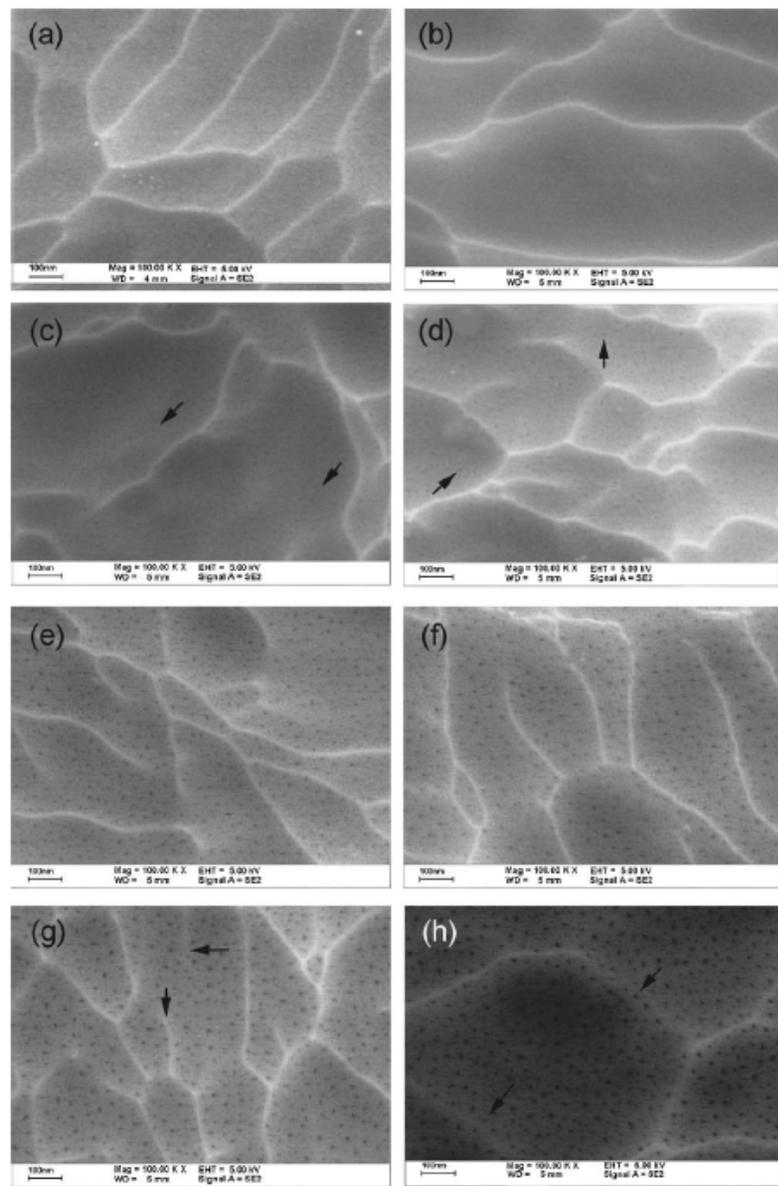


Appl. Phys. Lett., Vol. 72, No. 10, 9 March 1998, 1173

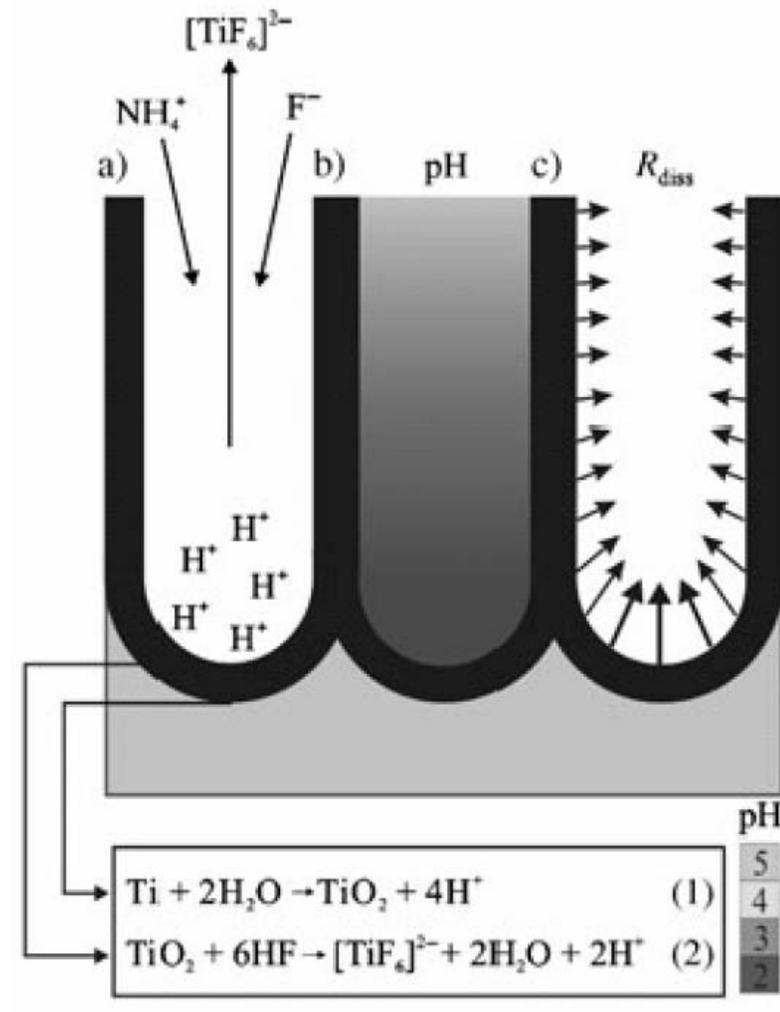
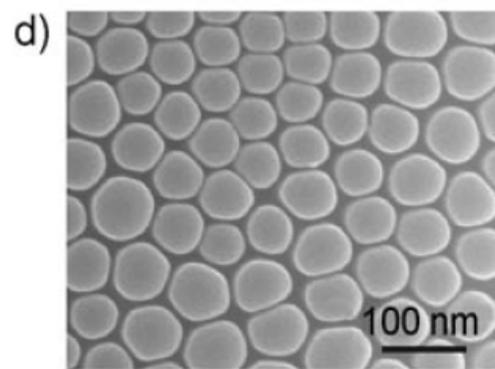
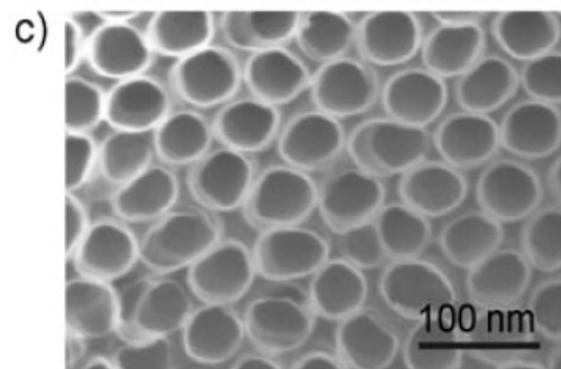
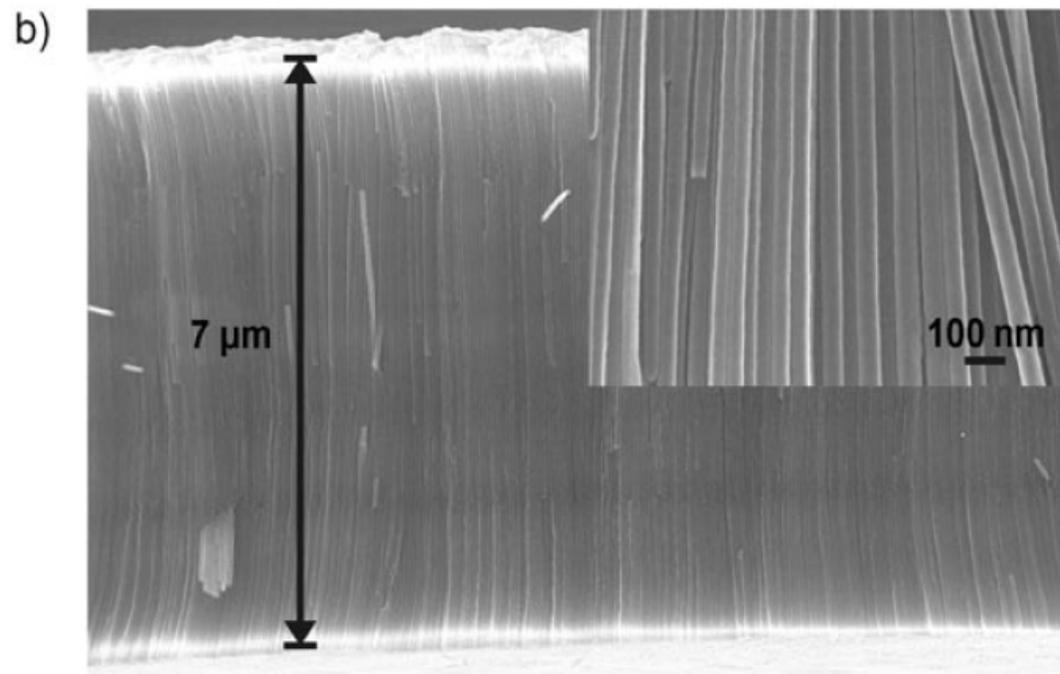
*Electrochimica Acta* 50 (2005) 2997–3013

*Journal of Nanoparticle Research* 5: 17–30, 2003.

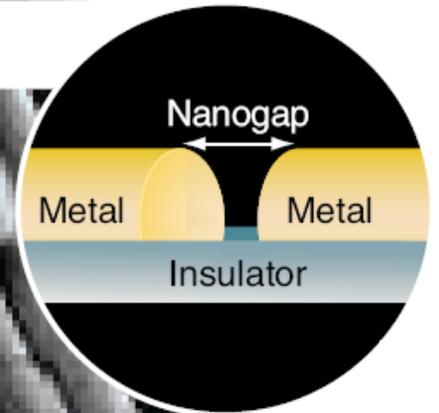
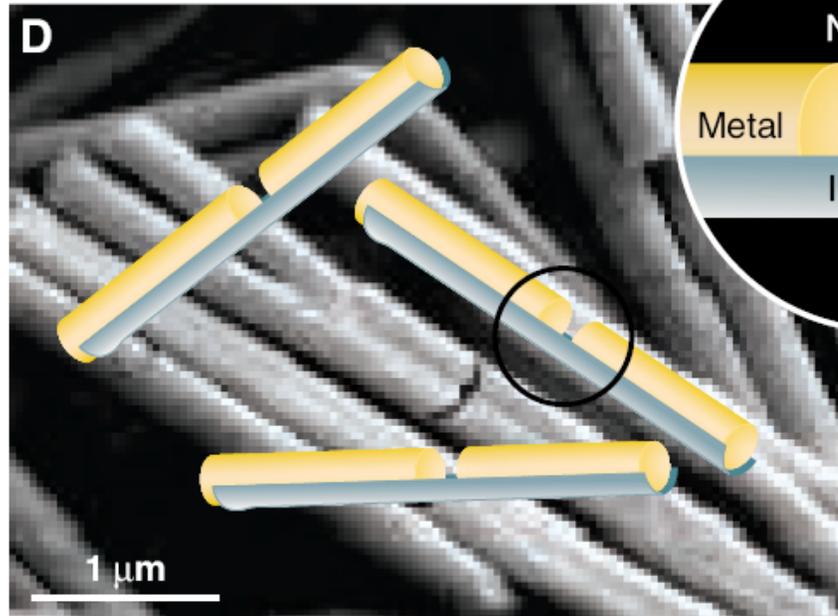
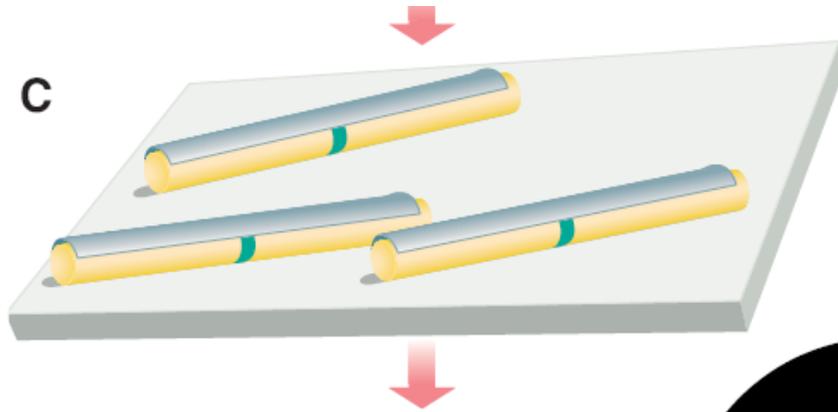
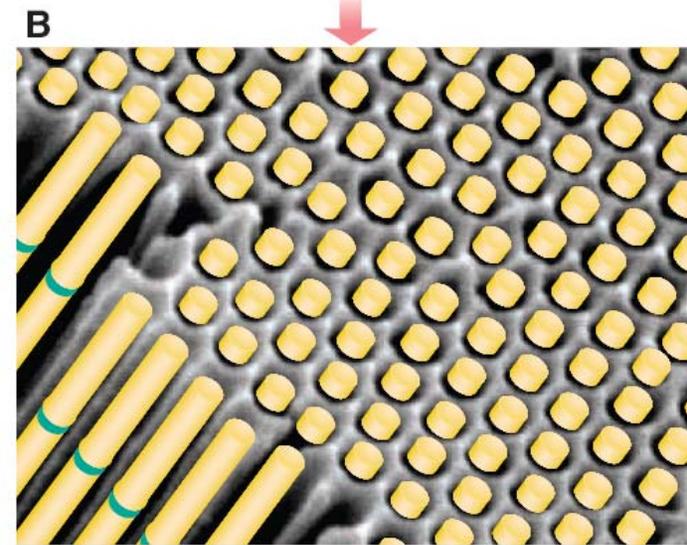
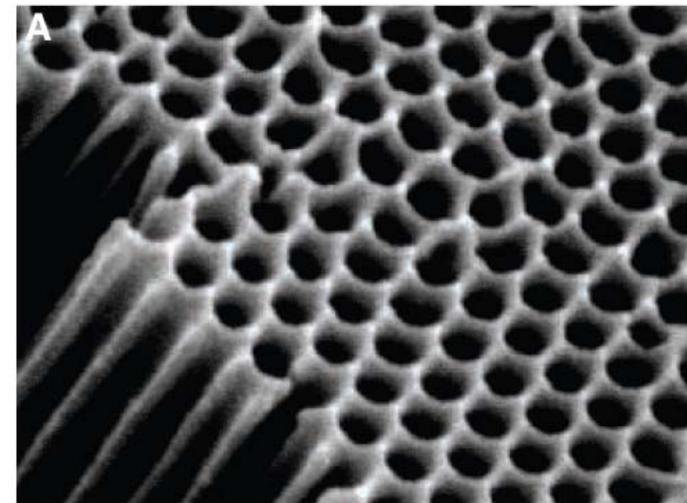
# Травление: алюминий



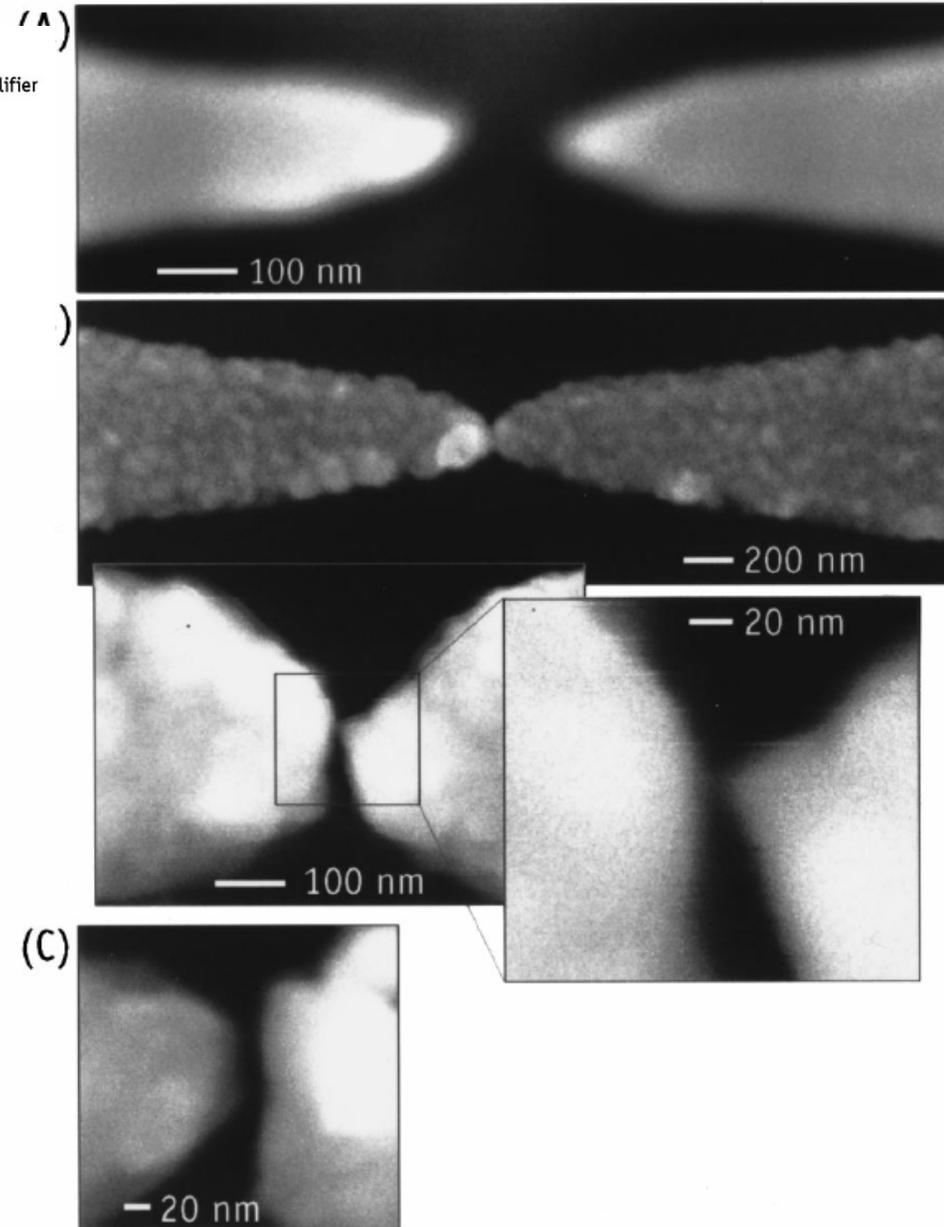
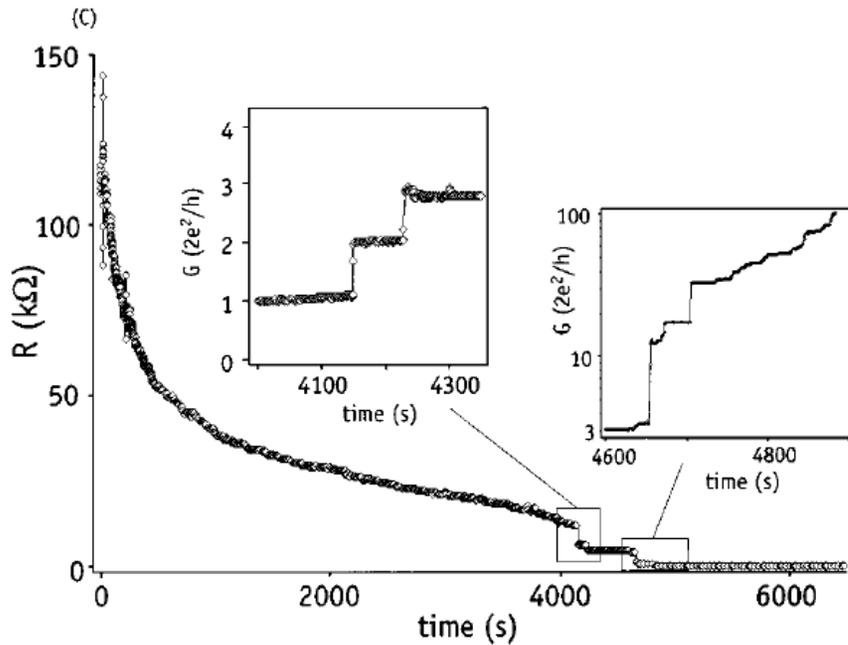
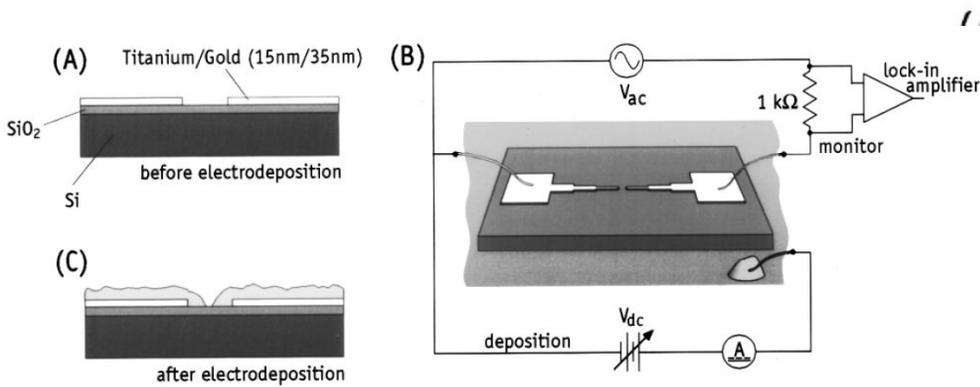
# Травление: титан



# Травление: зазоры

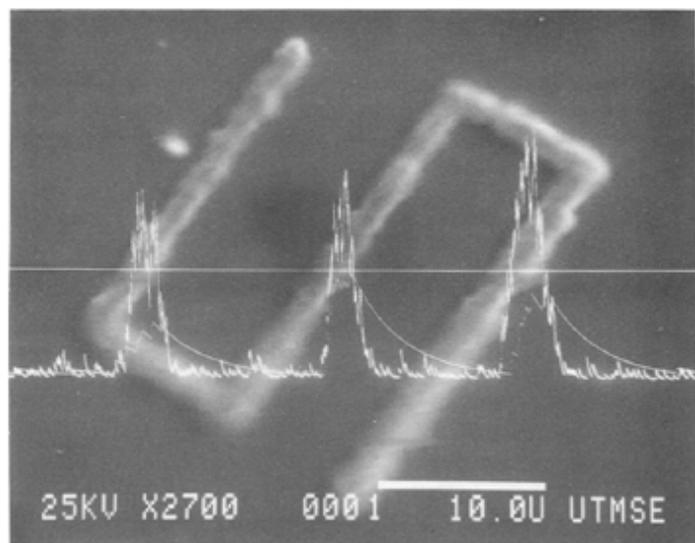
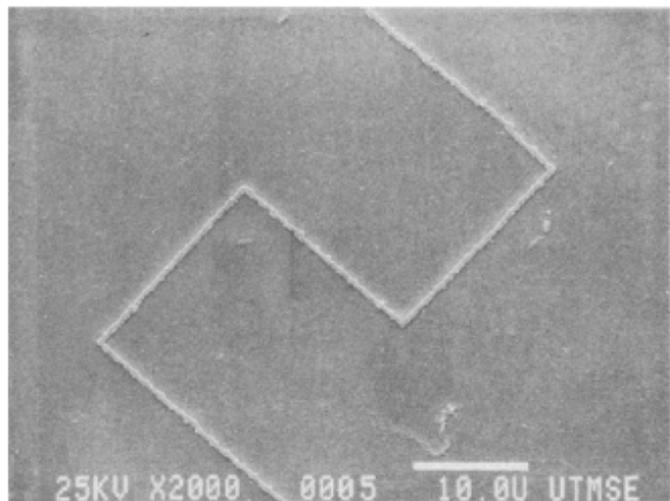


# Травление: контролируемый зазор

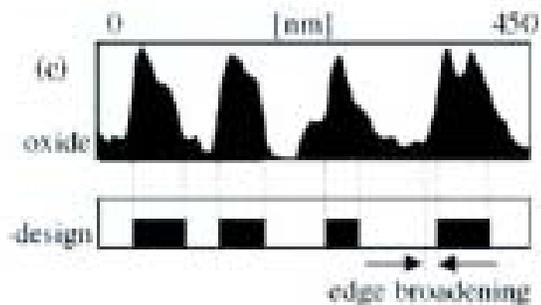
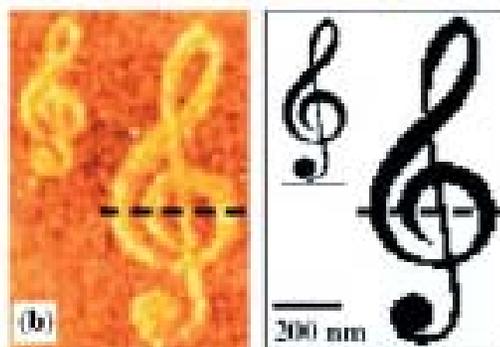
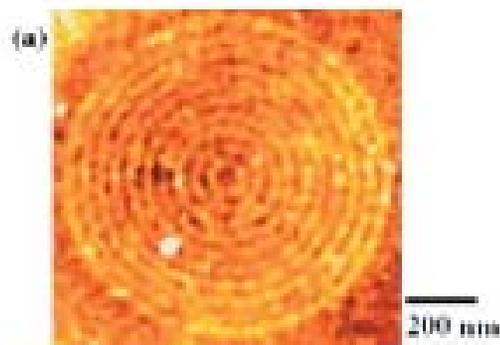


# Локальное химическое воздействие

SECM: Ag/Cu осажденный на Nafion

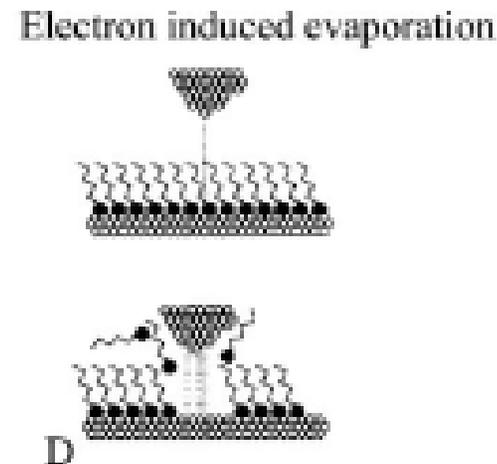
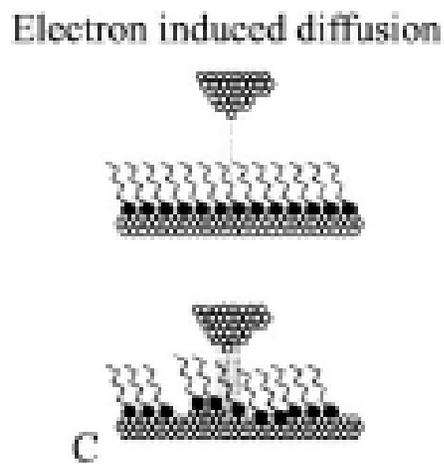
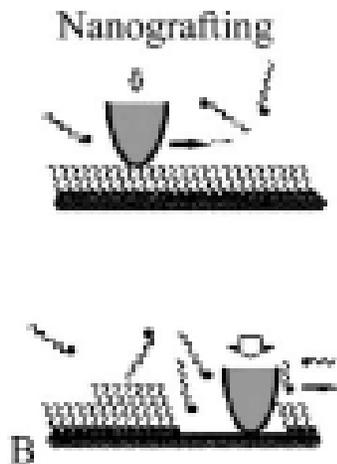
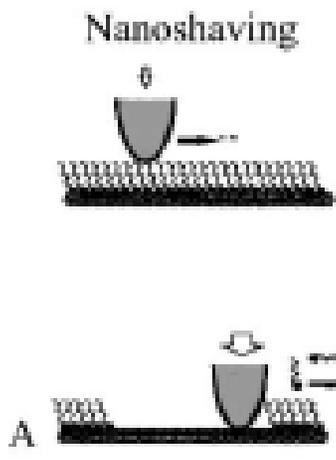
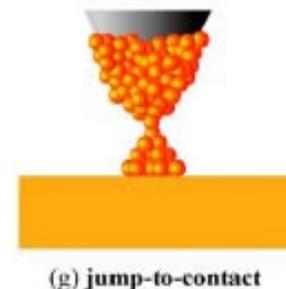
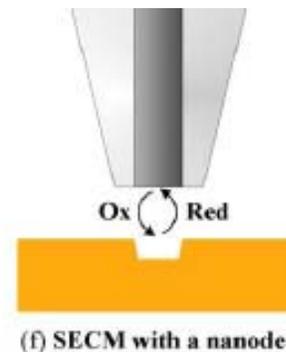
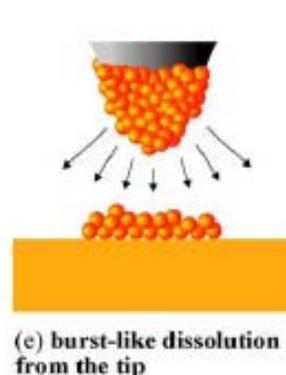
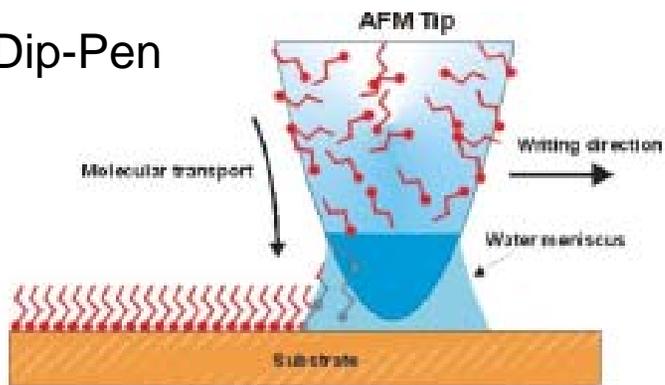


АСМ: локальное окисление Ti, Si

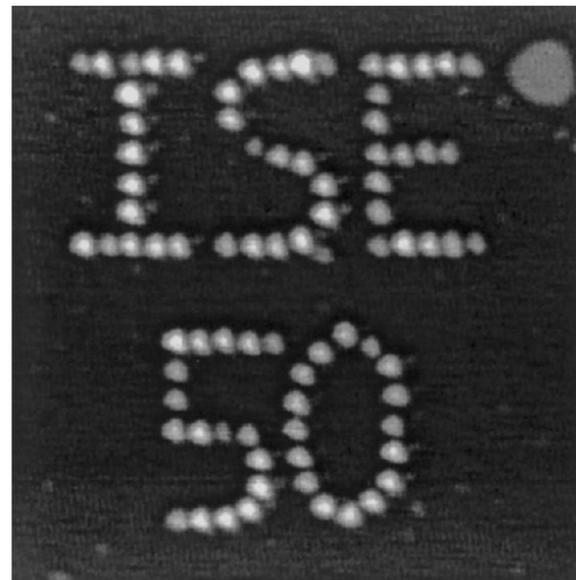
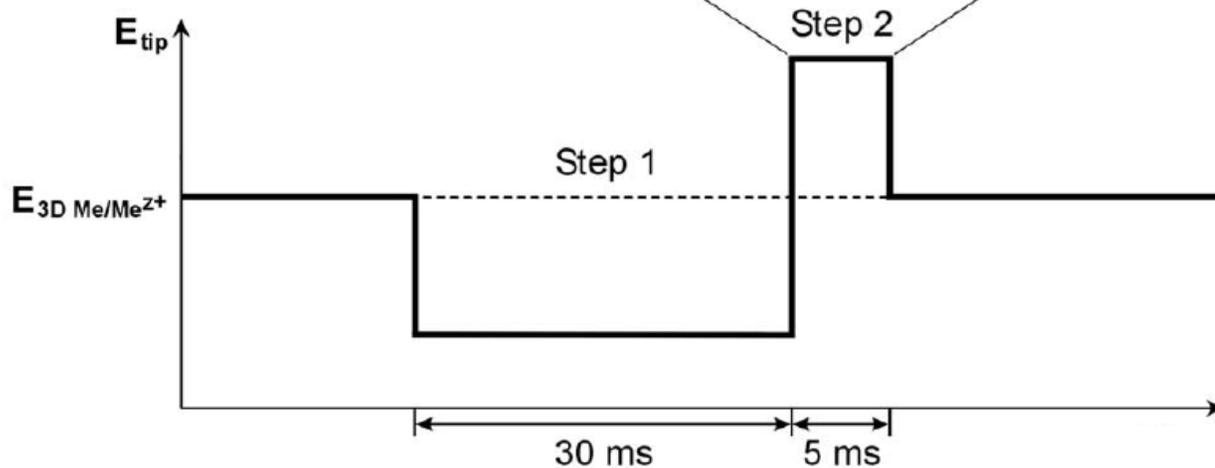
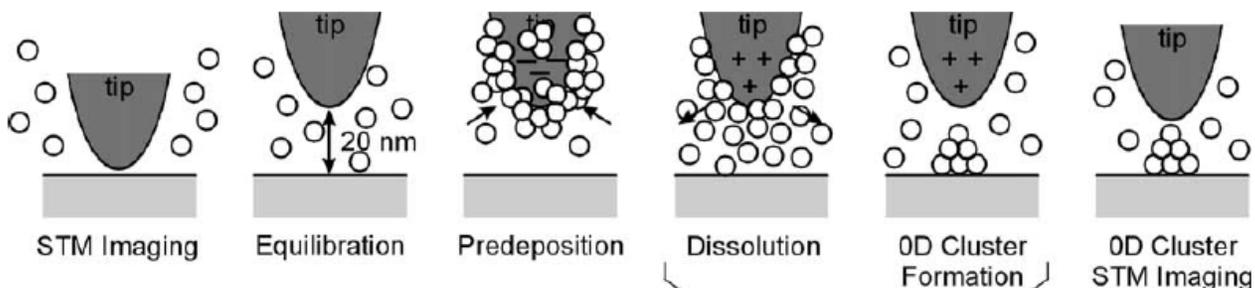


# Нанолитография

Dip-Pen



# Локализованное электроосаждение



100 x 100 nm<sup>2</sup>

