

# Nanotechnologies and Nanoelectronics

## 2021-2022

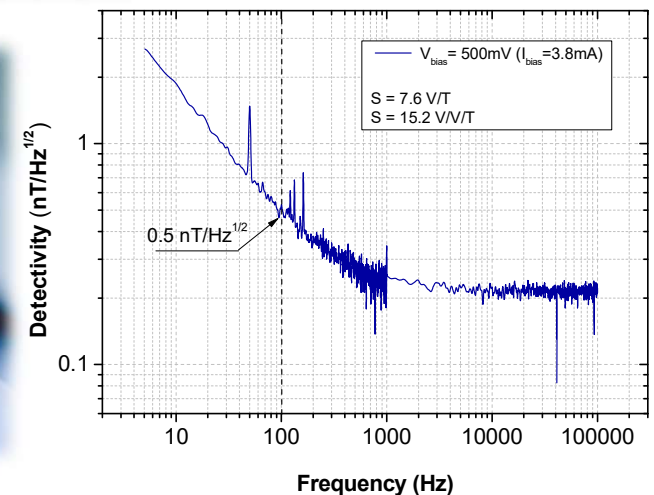
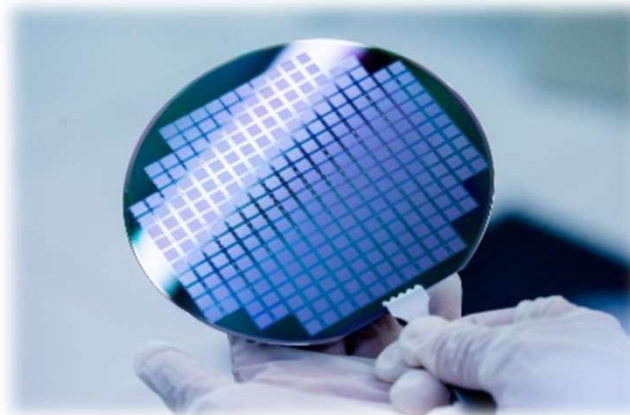
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[scardoso@inesc-mn.pt](mailto:scardoso@inesc-mn.pt)  
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Phone: 21 3100348



INESC



# On-line informations

## Disciplinas Leccionadas

Período Execução: 1º Semestre 2021/2022 ▼

Escolha a disciplina a administrar:

Semestre	Disciplina e Página Pública	Licenciatura(s)
1º Semestre 2021/2022	<b>Física e Tecnologia dos Materiais Magnéticos (FTMM)</b> <a href="https://fenix.tecnico.ulisboa.pt/disciplinas/FTMM/2021-2022/1-semester">https://fenix.tecnico.ulisboa.pt/disciplinas/FTMM/2021-2022/1-semester</a>	MEFT21
	<b>Nanotecnologias e Nanoelectrónica (NN)</b> <a href="https://fenix.tecnico.ulisboa.pt/disciplinas/NN/2021-2022/1-semester">https://fenix.tecnico.ulisboa.pt/disciplinas/NN/2021-2022/1-semester</a>	LEFT21 MBioNano MEFT21
1º Semestre 2021/2022	<b>Tecnologias a Plasma para o Processamento de Materiais (TPPM)</b> <a href="https://fenix.tecnico.ulisboa.pt/disciplinas/TPPM/2021-2022/1-semester">https://fenix.tecnico.ulisboa.pt/disciplinas/TPPM/2021-2022/1-semester</a>	MEFT21
1º Semestre 2021/2022	<b>Tópicos Avançados em Magnetismo (TAMag)</b> <a href="https://fenix.tecnico.ulisboa.pt/disciplinas/TAMag/2021-2022/1-semester">https://fenix.tecnico.ulisboa.pt/disciplinas/TAMag/2021-2022/1-semester</a>	DF
1º Semestre 2021/2022	<b>Tópicos Avançados em Magnetismo (TAMag-2)</b> <a href="https://fenix.tecnico.ulisboa.pt/disciplinas/TAMag-2/2021-2022/1-semester">https://fenix.tecnico.ulisboa.pt/disciplinas/TAMag-2/2021-2022/1-semester</a>	DEFT

## Alunos

- ☒ Todas
- ☒ Normal
- ☒ Não Inscrito
- ☒ Melhoria
- ☒ Época Especial
- ☒ Época Extraordinária

## Cursos

- ☒ Todas
- ☒ MEFT 2021
- ☒ MEMat 2021
- ☒ MBioNano2006
- ☒ LEFT 2021

Enviar Email Aos Alunos

Gerar Folha De Cálculo

66 Aluno(s) de 66

Filtrar

# Timetable

1) Theoretical class: Friday (11:00 - 13:00), FA3.

2) Practical class: each student should register in one shift:

NNTP02 ( Ter. 10:30 - 12:30 - V1.07 )

or

NNTP03 ( Qua. 09:00 - 11:00 - VA3 )

Week 2-

Group 2 - Wednesday class >>>> 9th December, 17:30 (room V1.14).

Group 1 – Tuesday class will be on the 7 Dec as planned

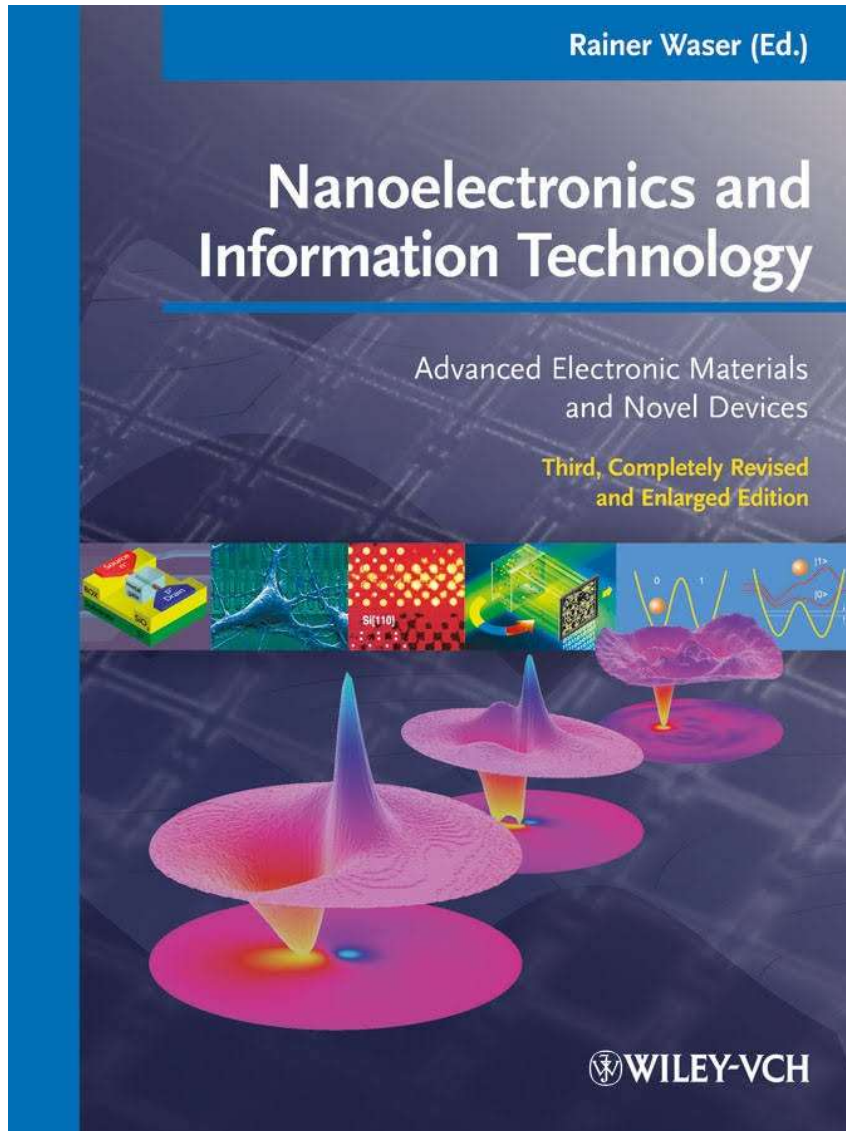
	Seg 12/13	Ter 12/14	Qua 12/15	Qui 12/16	Sex 12/17
07:00					
08:00					
09:00			09:00 - 11:00 TP VA3		
10:00		10:30 - 12:30 TP V1.07			
11:00					11:00 - 13:00 T FA3
12:00					
13:00					
14:00					
15:00					
16:00					
17:00				17:30 - 19:30 TP	
18:00				17:30 - 19:30 TP V1.14	
19:00					
20:00					

	<i>individual</i>		<i>individual</i>		<i>Groups of 2 students</i>	
	Quiz 15 min		Homework		Seminar 30 min	
Sem 1	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sem 2	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sem 3	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sem 4	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sem 5	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sem 6	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sem 7	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sem 8 (pausa)	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sem 9 (exame)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>

# 6 Topics

- Nanofabrication/Nanocharacterization
- Information storage
- Graphene/ 2D materials
- Semiconductor devices
- Memristors for neural computing
- Organic electronics

# Bibliography



## Nanoelectronics and Information Technology

Rainer Waser (Ed)

Wiley-VCH

2003

### Additionally:

Specific bibliography will  
be provided for each  
TOPIC



# Evaluation

**100% continuous evaluation.**

**No exams.**

20% of the grade (QUIZ)

**QUIZ tests (15 min) done in the classes**

Number of QUIZ expected = 5.

**Only the best 4 will count** for the average.

Individual work.

Minimum grade of the average of 4: 9.5 points (out of 20)

50% of the grade (HW)

**Homework (HW) to deliver every 2 weeks.**

Number of Homework expected = 4.

Individual work.

Minimum grade **of each** HW: 9.5 points (out of 20)

30% of the grade (S)

**Seminar on selected topics.**

Groups of 2 students.

Presentation (30 min, 2 presenters) at week 9.

Evaluation criteria: see sections Seminar

Minimum grade: 9.5 points (out of 20)

**The final grade is calculated with the formula:**

$$\text{FINAL} = 0.2 \cdot \text{QUIZ} + 0.5 \cdot \text{HW} + 0.3 \cdot \text{S}$$

# The Scale of Things – Nanometers and More



## Things Natural

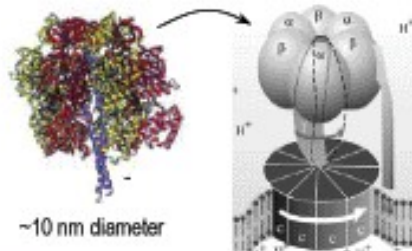


Dust mite  
200  $\mu\text{m}$



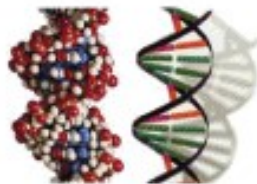
Human hair  
~ 60-120  $\mu\text{m}$  wide

Red blood cells  
(~7-8  $\mu\text{m}$ )



~10 nm diameter

ATP synthase



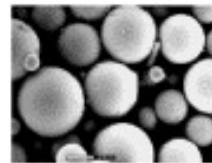
DNA  
~2-1/2 nm diameter



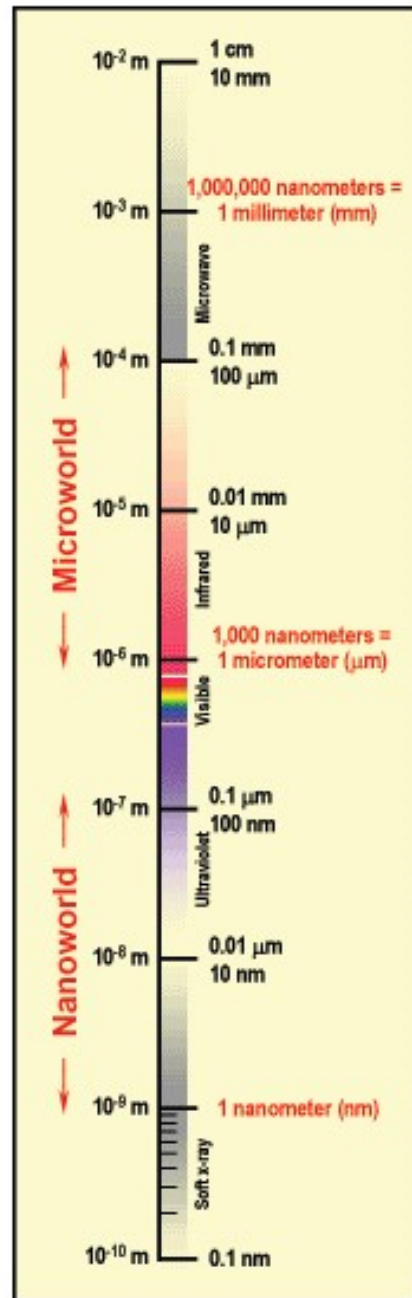
Atoms of silicon  
spacing 0.078 nm



Ant  
~ 5 mm



Fly ash  
~ 10-20  $\mu\text{m}$



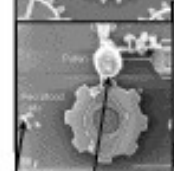
## Things Manmade



Head of a pin  
1-2 mm

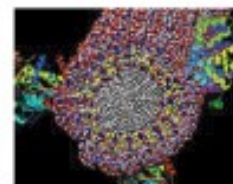


MicroElectroMechanical (MEMS) devices  
10 -100  $\mu\text{m}$  wide

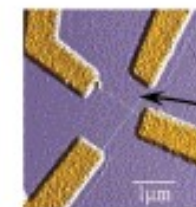


Pollen grain  
Red blood cells

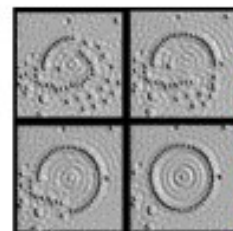
Zone plate x-ray "lens"  
Outer ring spacing ~35 nm



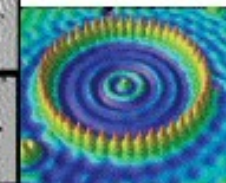
Self-assembled,  
Nature-inspired structure  
Many 10s of nm



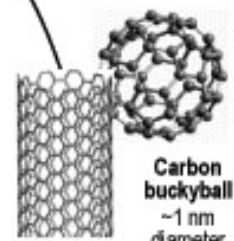
Nanotube electrode



Quantum corral of 48 iron atoms on copper surface  
positioned one at a time with an STM tip  
Corral diameter 14 nm

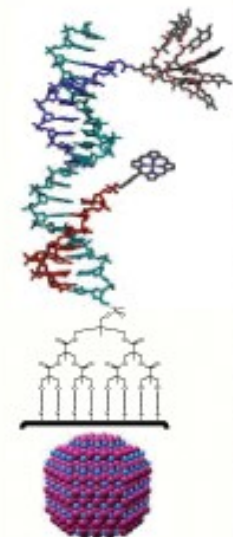


Carbon nanotube  
~1.3 nm diameter



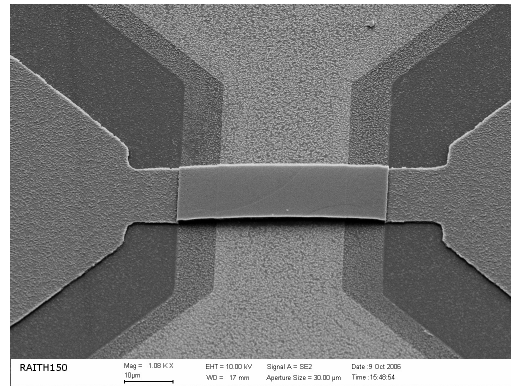
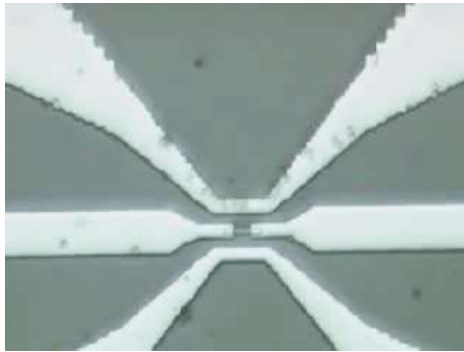
Carbon buckyball  
~1 nm diameter

### The Challenge

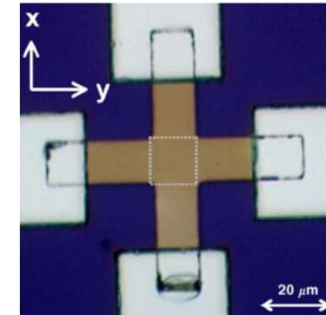
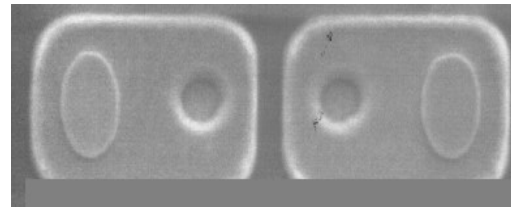
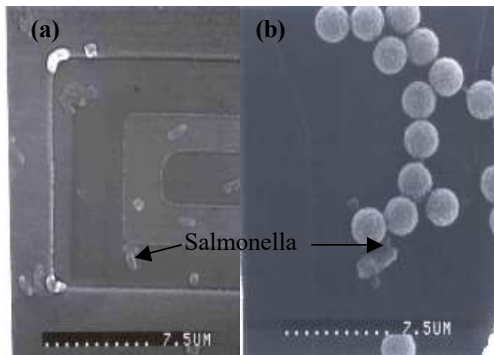
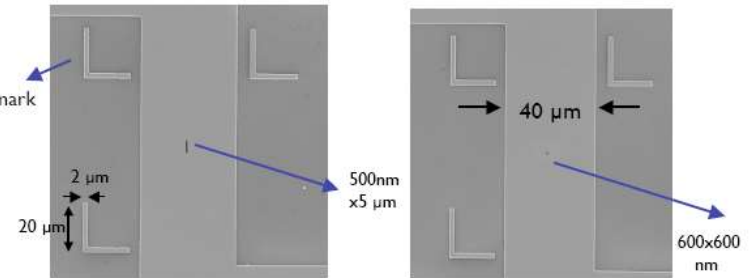


*Fabricate and combine nanoscale building blocks to make useful devices, e.g., a photosynthetic reaction center with integral semiconductor storage.*

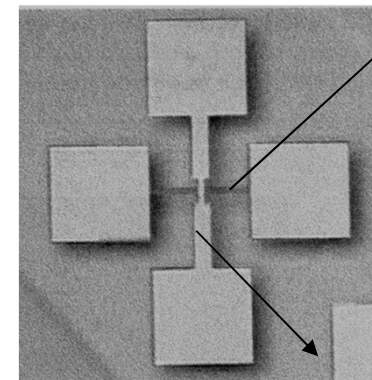
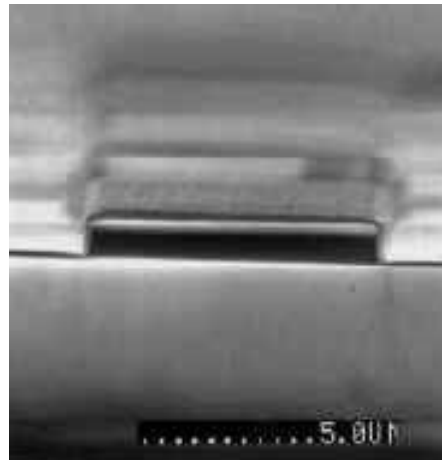
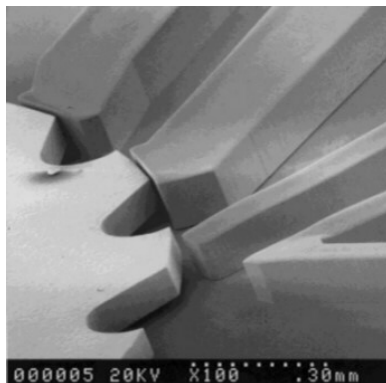
# Micro and Nano systems



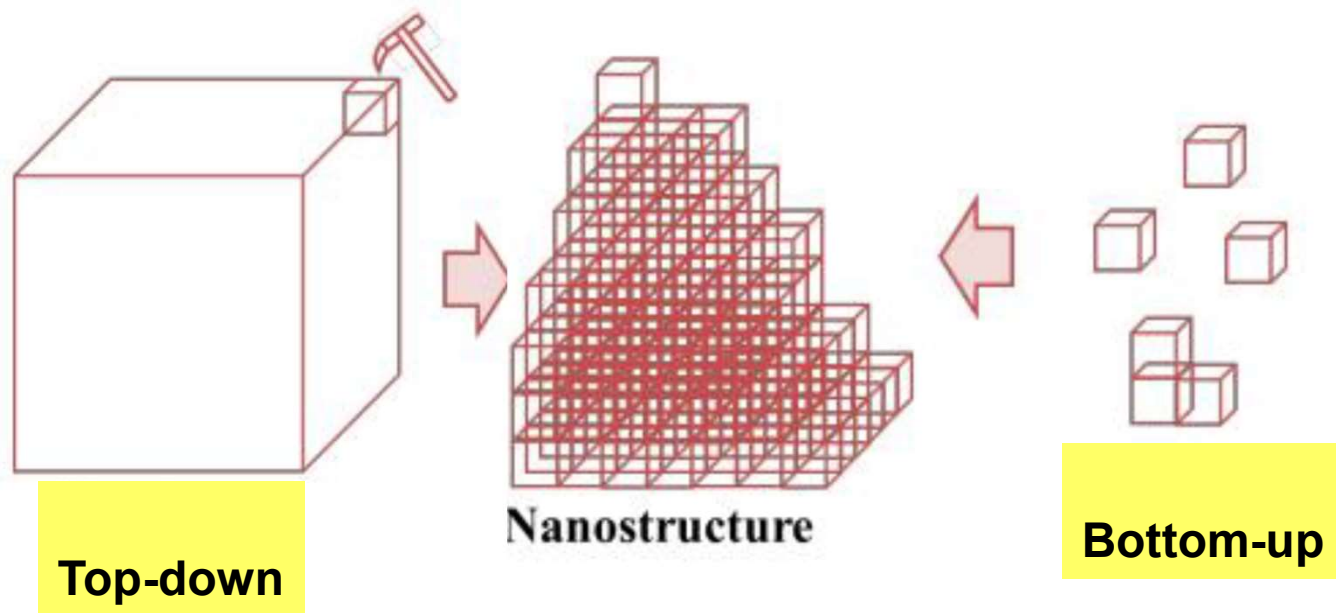
Alignment mark  
for e-beam



Bottom electrode  
(17 μm wide)

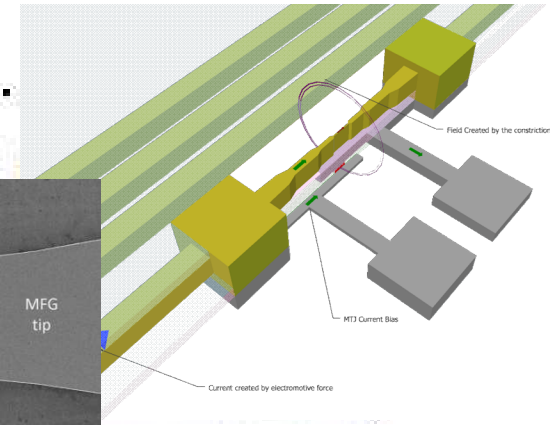
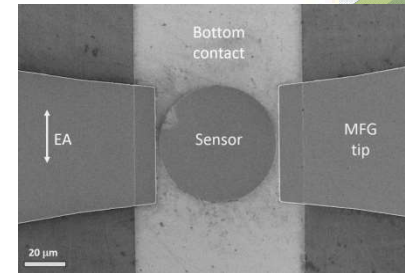


Top electrode



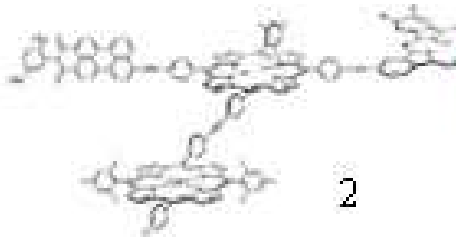


## Lithography.

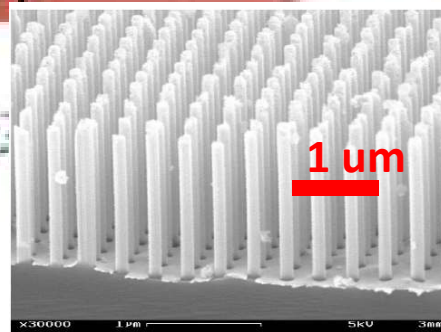


Bottom-Up

Top-Down

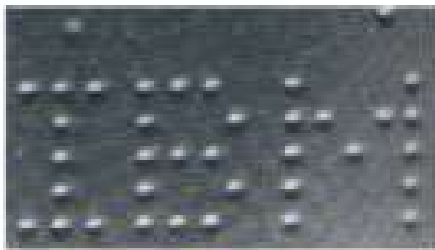


2



Lifeng Liu, A. Al-Obeidi, C.V. Thompson

**Synthetic Chemistry,  
Genetic Engineering, ...**



1

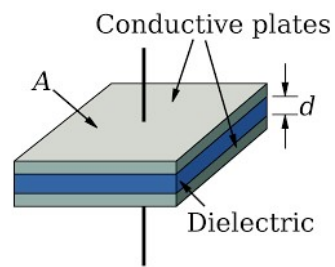
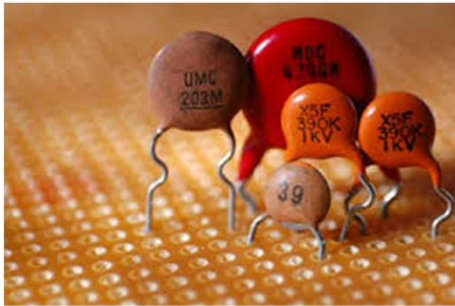
Image on-line (IBM research)

# Functional components

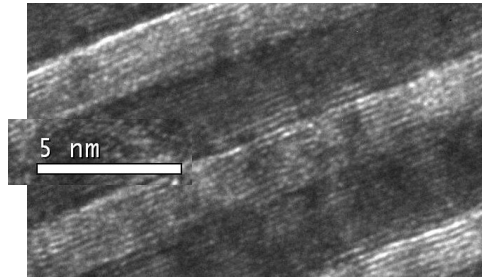


Capacitors	Resistances
Wires	Lamps
Inductive coils	...

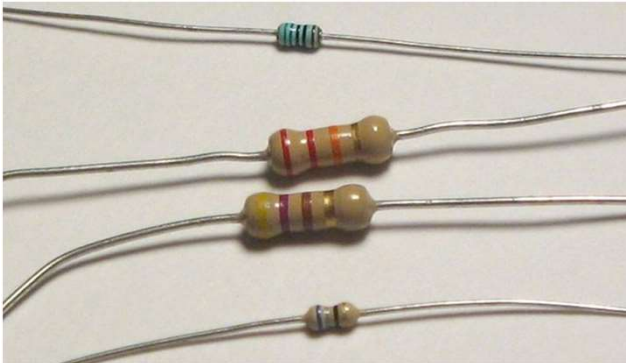
## Capacitor



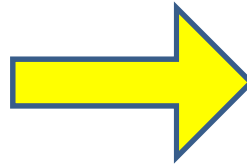
## Capacitor – thin film



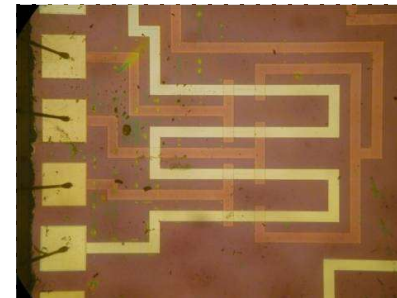
## Resistance



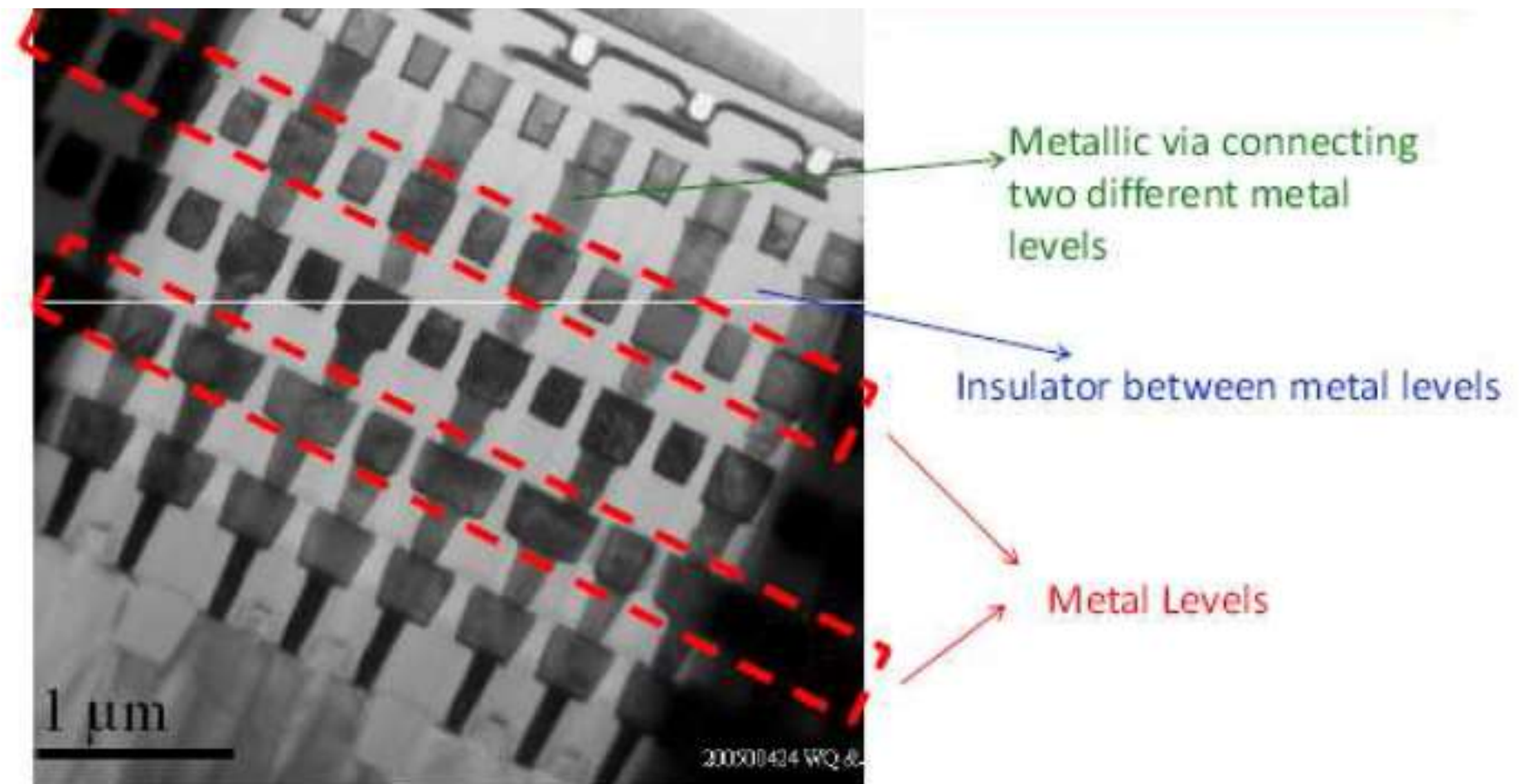
— 1 cm



## Resistance – thin film

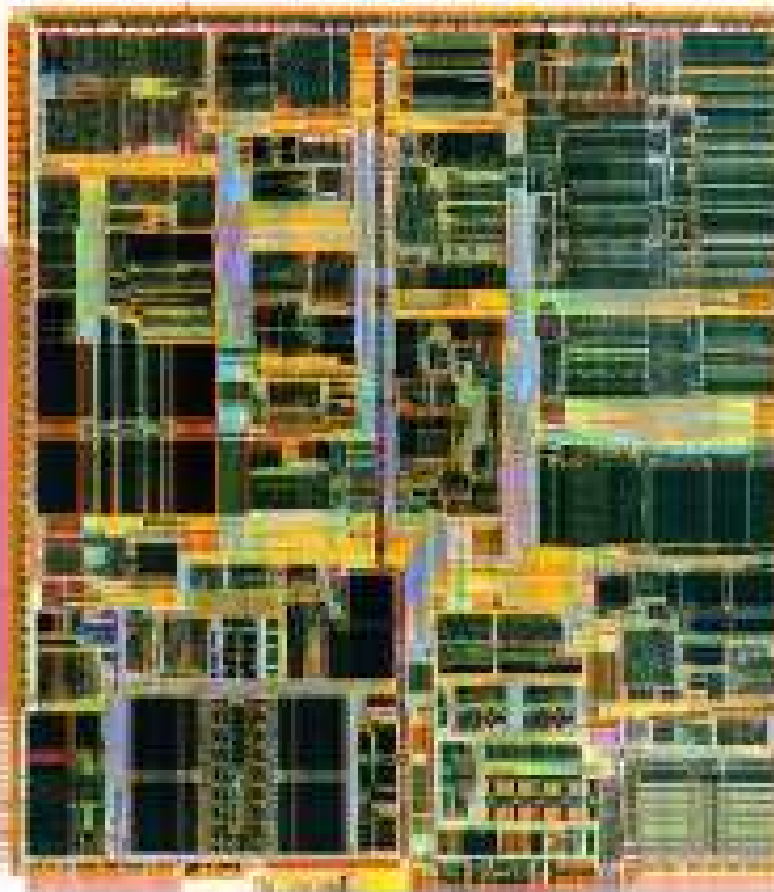


— 100 um





410 Million Transistors  
45 nm process  
Clock Speed 2.93 GHz



■  $10 \times 10^{-6} \text{ m}$

