Development of nanoelectronics

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Basic information about the subject

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What does it mean „nano”?

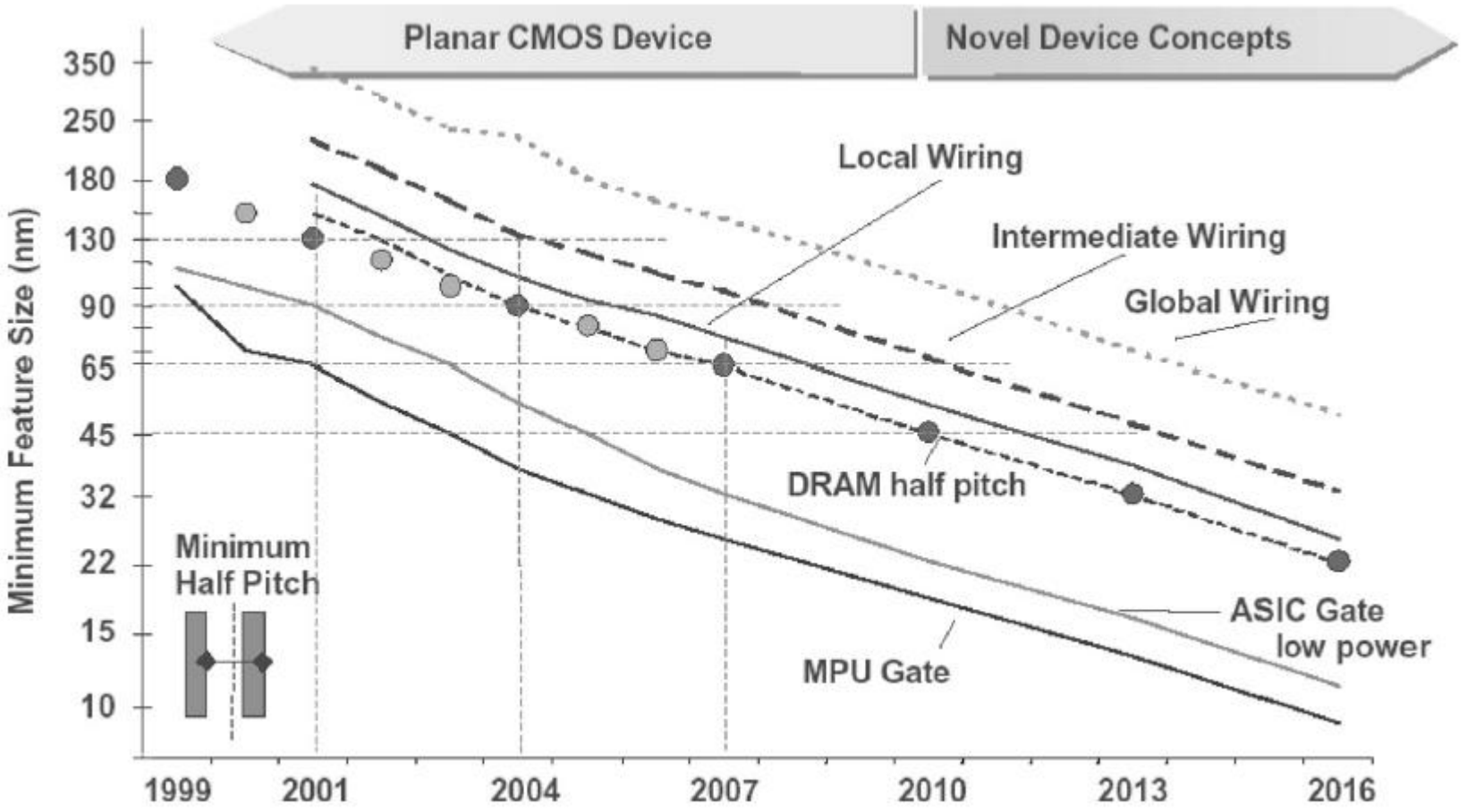
- It comes from the Greek word "nanos" and means dwarf.
- In the technical world, it is the prefix to units and denotes the multiplier 10^{-9}
- On a 1 nm length section, approx. 20 H atoms fit next to each other

How did it start?

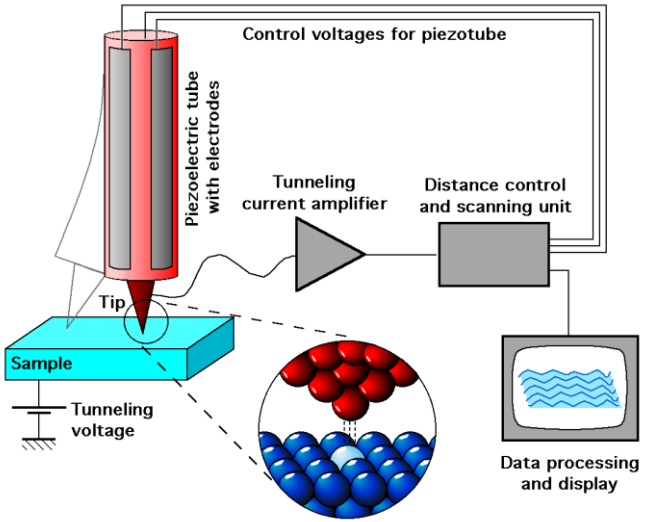
- On December 29, 1959, Richard P. Feynman gave a lecture at Caltech entitled „There is plenty of room at the bottom”
- In this, he proves that they are not far from technologies that would allow the information contained in all the books in the world to be stored by the atoms of a cube whose side size is ~ 0.1 mm.
- Less than 100 atoms would be needed to store one bit of information. → *nano scales*

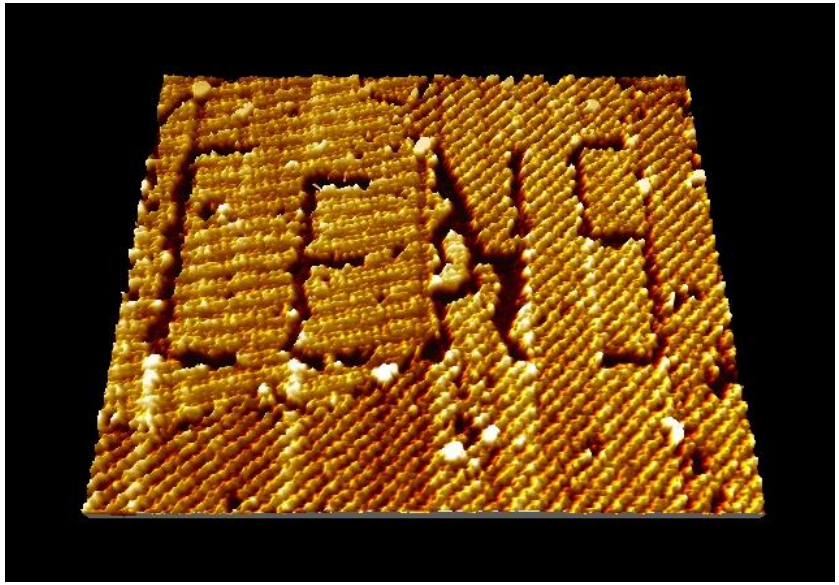
… and the sequel

- in electronics, after the discovery of the transistor in the 1960s, the *miniaturization competition* begins
- 1965 - *Moore's Law* - the lowest cost electronic circuits double in complexity and can be built on a single chip. The law is timeless: in 2010, the typical transistor size was ~ *70 nm*.


Planar CMOS Device
Novel Device Concepts
Minimum Feature Size (nm)
350
250
180
130
90
65
45
32
22
15
10
1999
2001
2004
2007
2010
2013
2016
Local Wiring
Intermediate Wiring
Global Wiring
DRAM half pitch
Minimum
Half Pitch
ASIC Gate
low power
MPU Gate

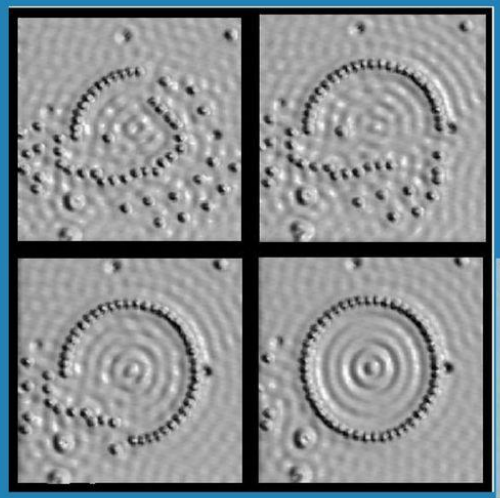
- in the 60s, the raw materials for electronic circuits were *Si* and *Ge*
- 90s heterostructure semiconductors *GaAs* and *AlAs*
- 2000s - scanning tunneling microscope, femtosecond laser - *"we can see clearly in the nano world"*
- 2010 → *organic semiconductors*
  nano – machines
  optoelectronics on the atomic level
  manipulation of individual atoms



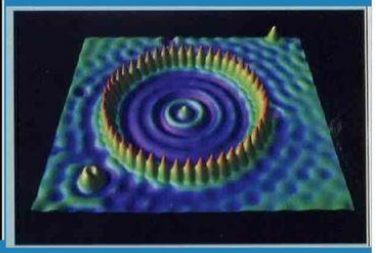


Kvantum karám (D. Eigler et al.)

(ez már majdnem „művészi teljesítmény” ...)



Az állóhullám-szerkezet, csak a karám teljes bezárása után alakul ki.



„QUANTUM world"

- the behavior of systems consisting of a few atoms can only be described correctly by *quantum theory*
- the nano world is by it's nature a QUANTUM world

$$\hat{H}\Psi(\vec{r},t) = i\frac{h}{2\pi}\frac{\partial}{\partial t}\Psi(\vec{r},t)$$

Thank You!

Next week we will continue and START!

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