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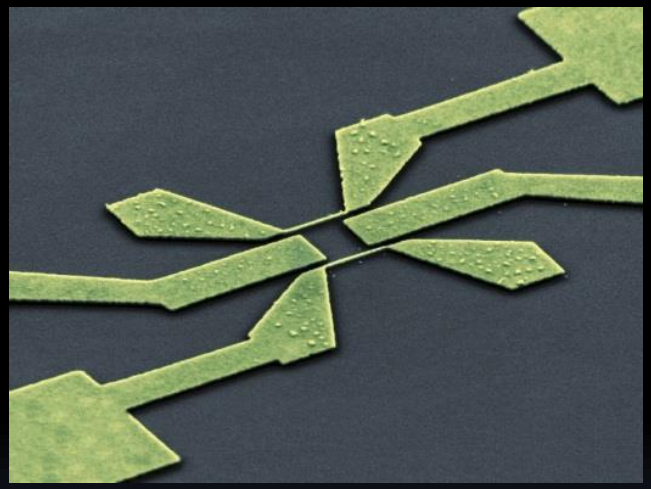


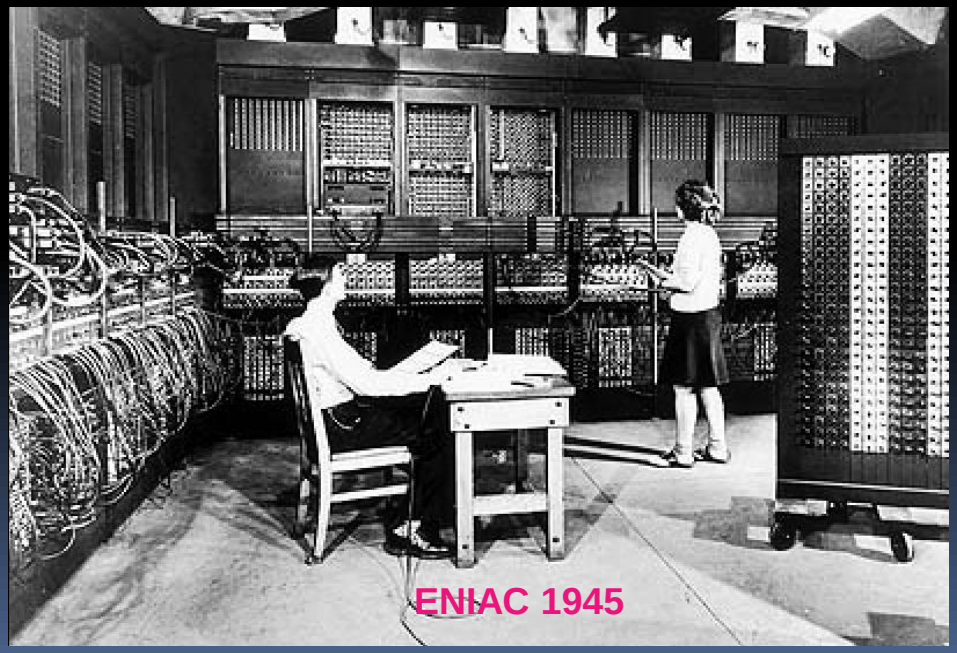
DALLA FISICA DELLA MATERIA ALLA TECNOLOGIA

UNO SGUARDO SULLE NANOSCIENZE

LA POTENZA DELLE NUOVE IDEE

"*Penso che ci sia un mercato mondiale per, forse, cinque computer*"

T.J.Watson, fondatore IBM, 1943

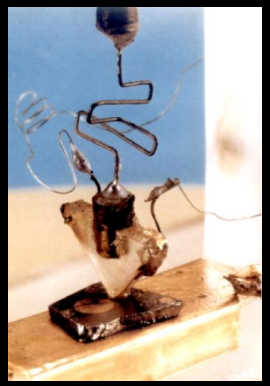


ENIAC 1945

18000 valvole
200 kW
200 mq

LA RIVOLUZIONE TECNOLOGICA

Valvola termoionica



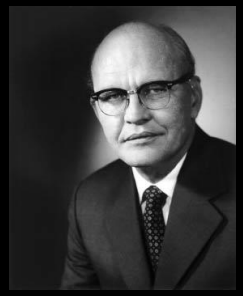
Transistor a semiconduttore *(1947)*

Circuito integrato (1958)

Information and Communication Technology

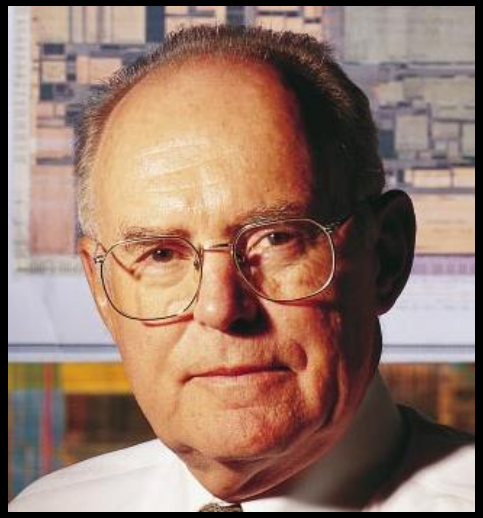
Nobel

W.B.Shockley, J.Bardeen
W.H.Brattain, Nobel 1956



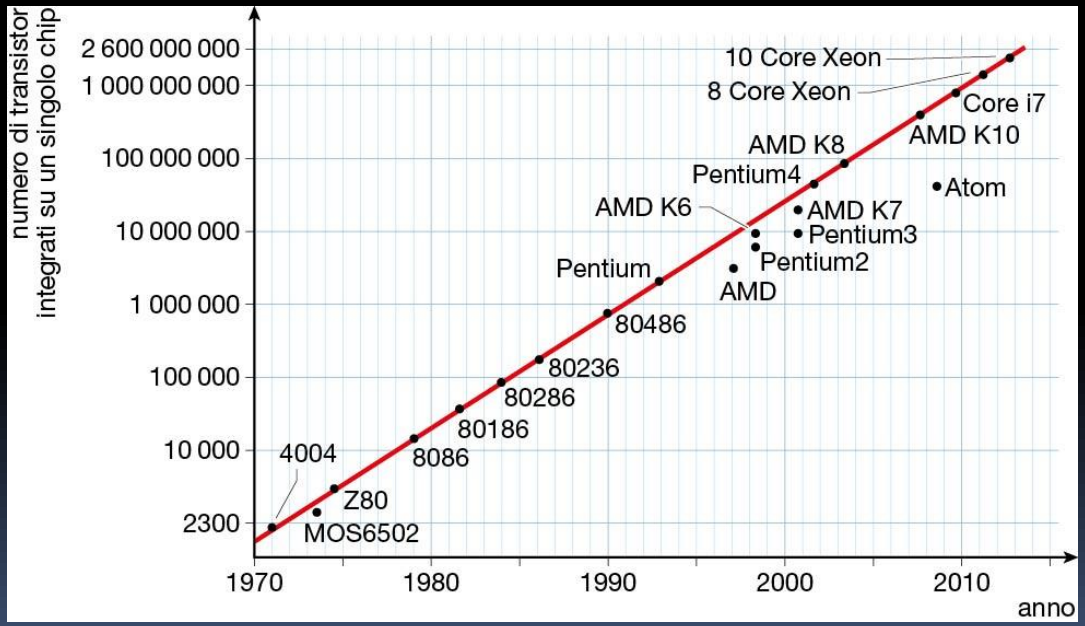
J. S. Kilby, Nobel 2000

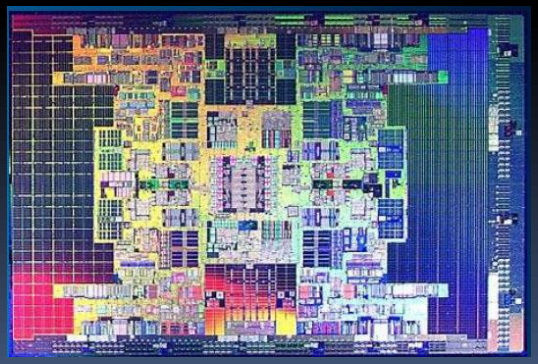
LA LEGGE DI MOORE



"Ogni 2 anni la complessita' (il numero di transistor) raddoppia"

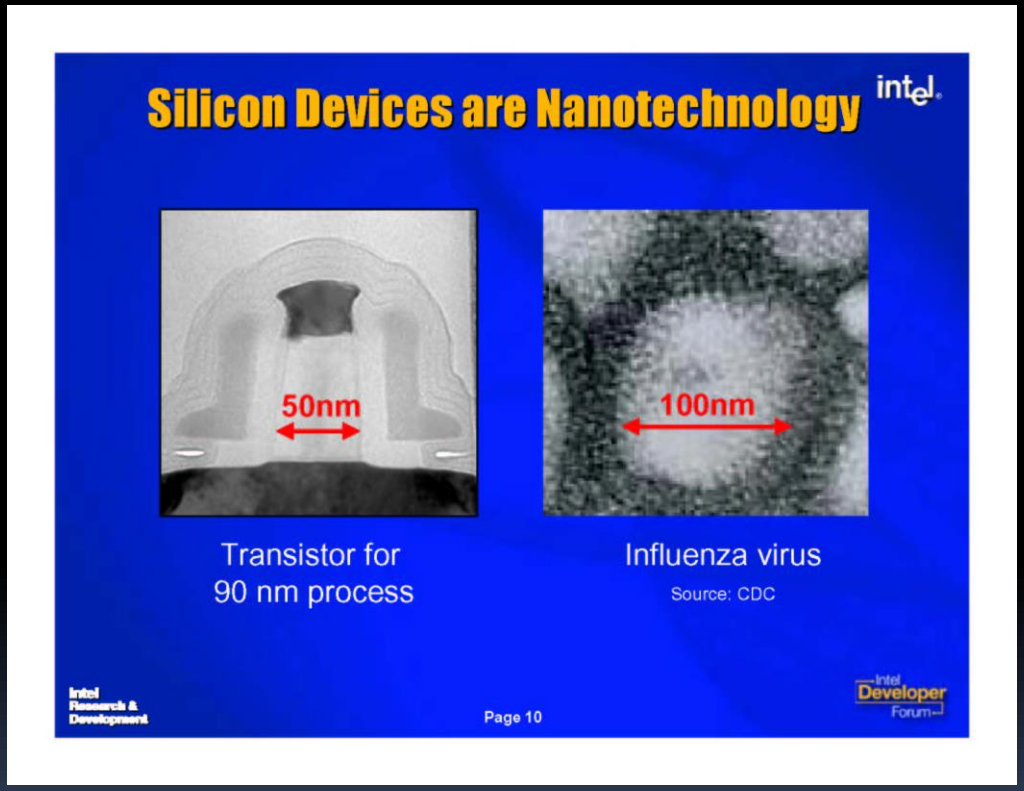
Gordon Moore



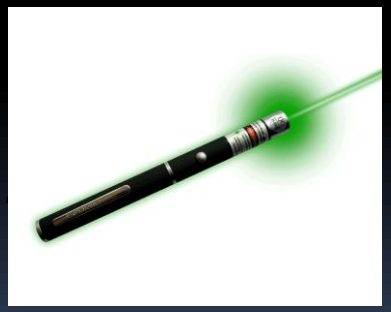


Intel Itanium (2008)

LA NANOTECNOLOGIA IN TASCA



32nm technology



DI PIÙ O DIVERSO?

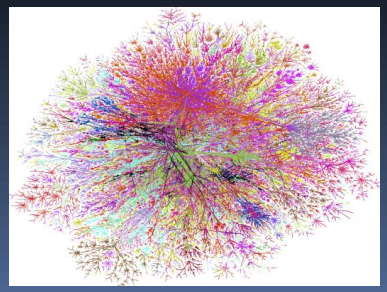
"Che bisogno ha una persona di tenersi un computer in casa?"

K.Olsen, fondatore Digital, 1977

Apple II, 1977

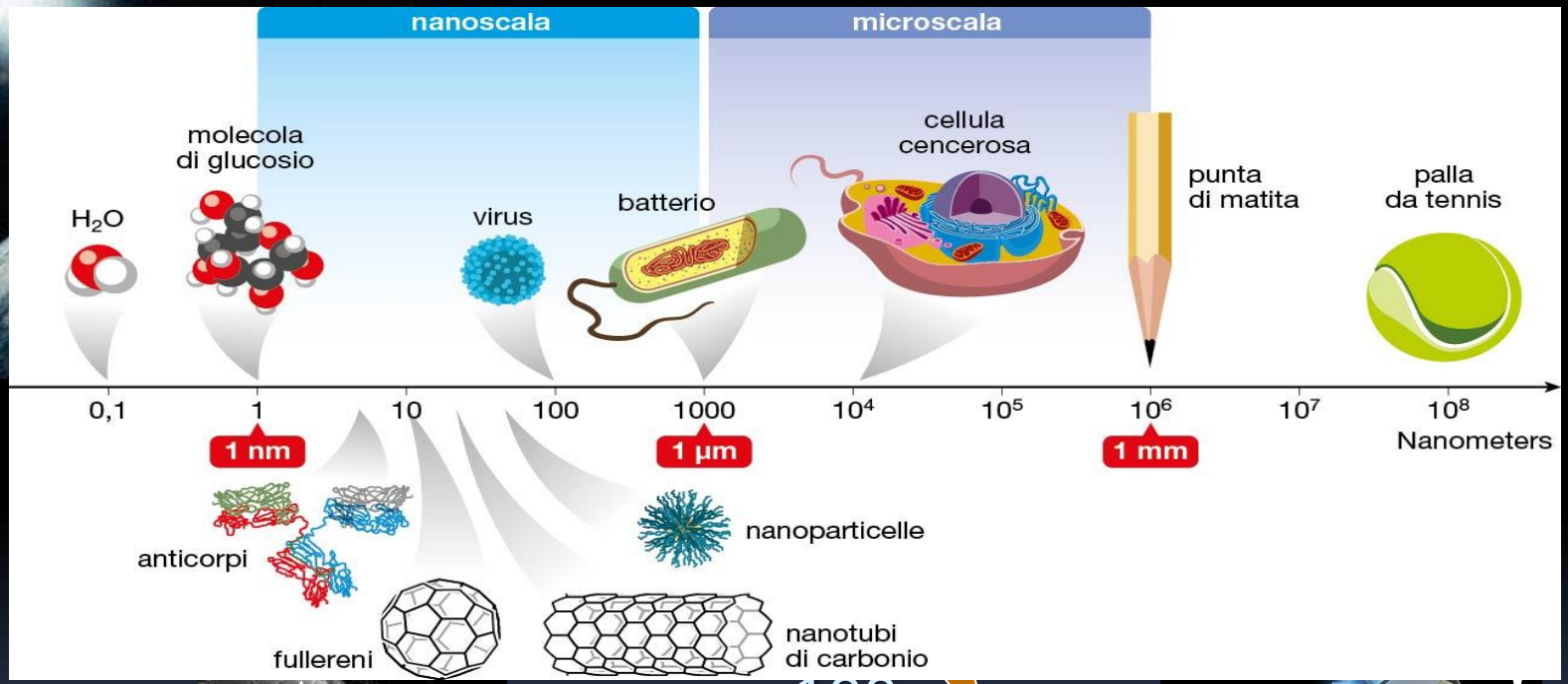
"640K dovrebbero essere sufficienti per chiunque"

B. Gates, fondatore Microsoft, 1981



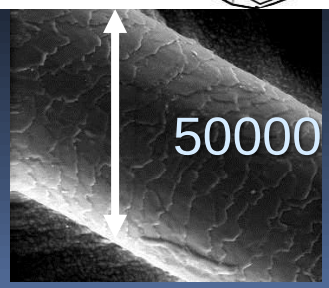
World Wide Web

LA NANO SCALA



1 nm

100 milioni



50000 nm

Nobel

LE NANOSCIENZE

- Studiano le proprieta' di sistemi con dimensioni intorno a 10 – 100 nm (da poche migliaia a un milione di atomi)

R Feynmann
Nobel 1965

Un oggetto nanometrico non è solo "molto piccolo"

Le caratteristiche di un materiale alla nanoscala ne determinano le proprietà

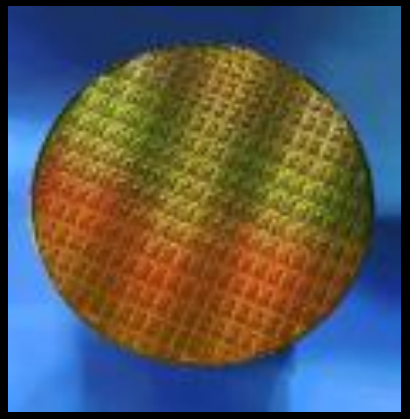
Modificare un materiale in modo controllato alla nanoscala significa pre-determinarne le proprietà

"There is plenty of room at the bottom."

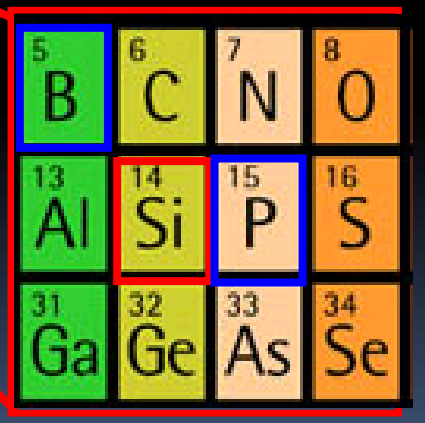
R. Feynmann, 1959

AUREA MEDIOCRITAS – I SEMICONDUTTORI

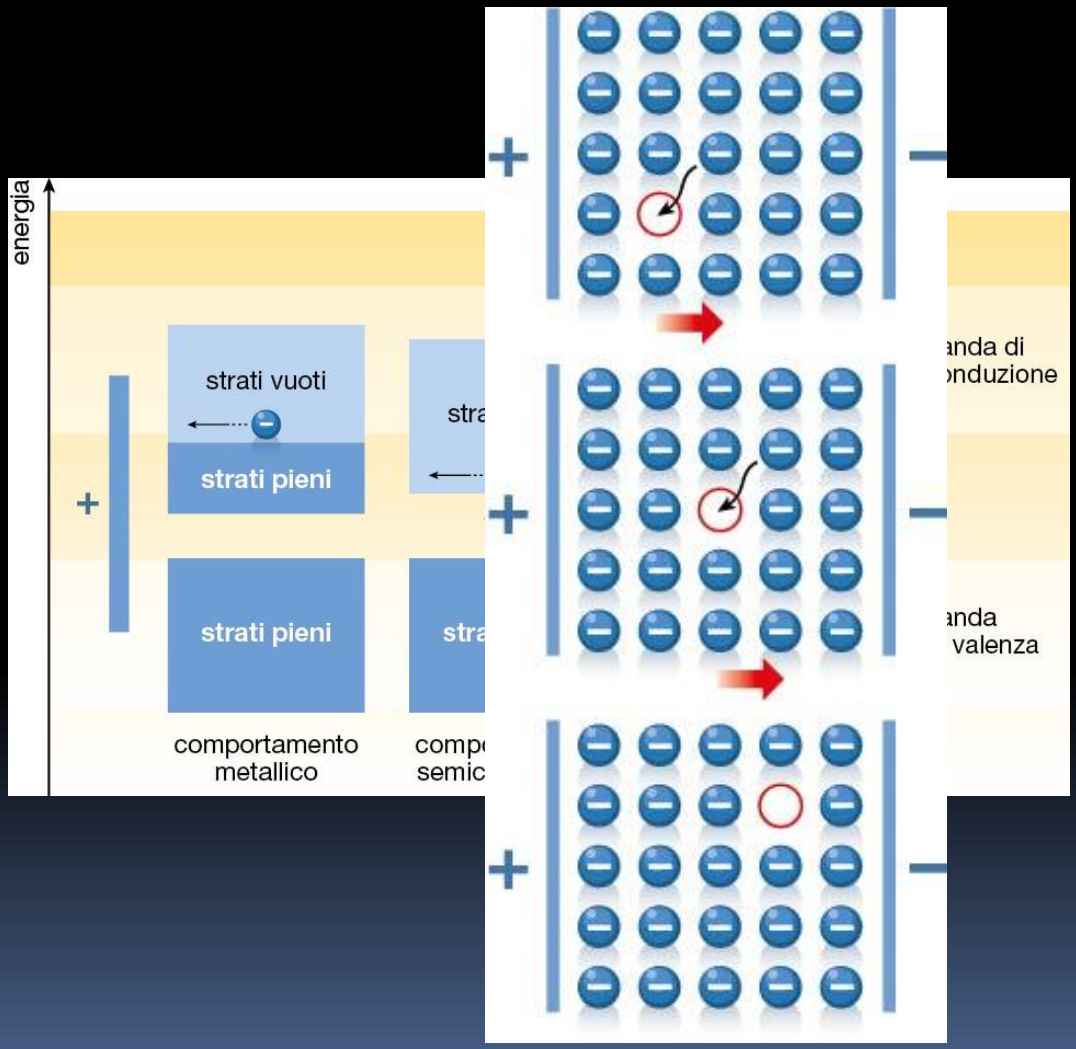
- Ne' buoni conduttori, ne' buoni isolanti

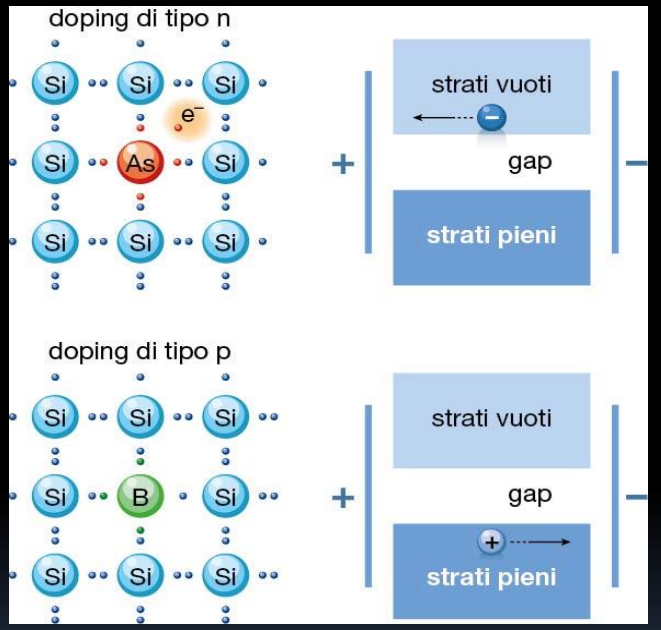


1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Unq	105 Unp	106 Unh	107 Uns	108 Uno	109 Une	110 Unn								
			58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
			90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	

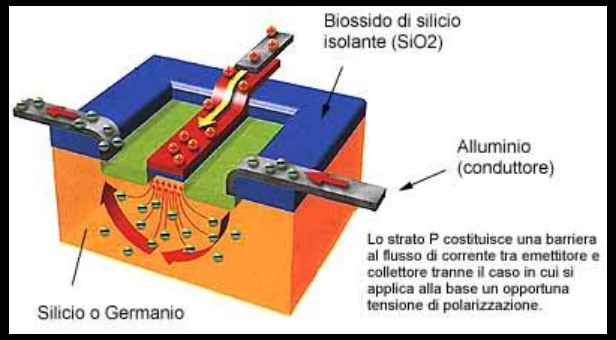


LA TEORIA QUANTISTICA DEI SOLIDI





IL MATTONE - IL TRANSISTOR



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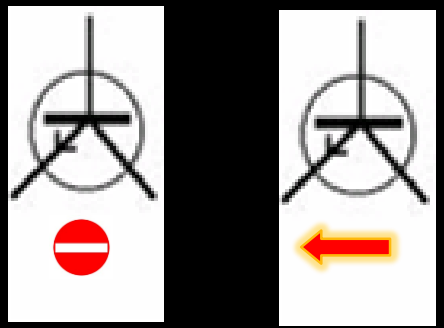

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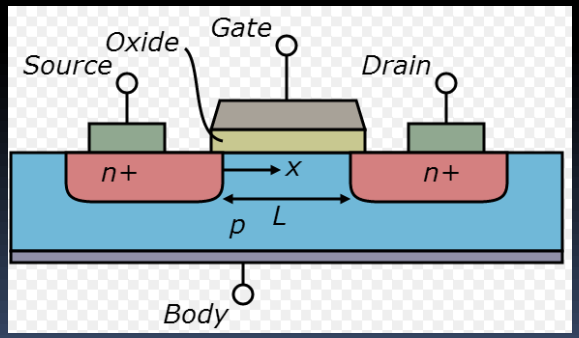
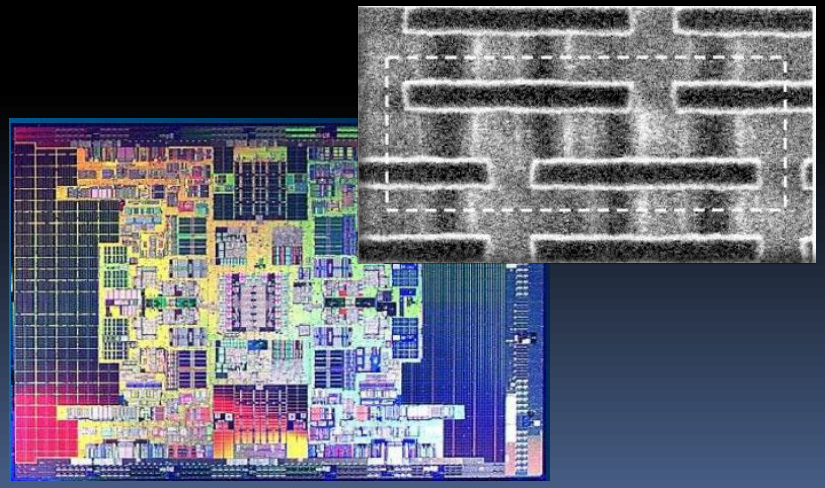
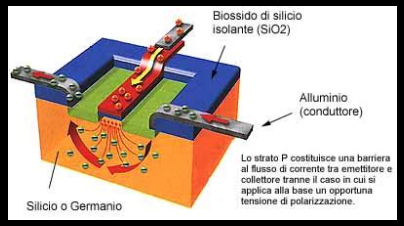
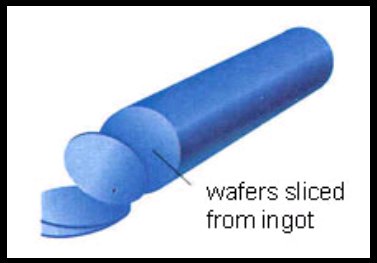
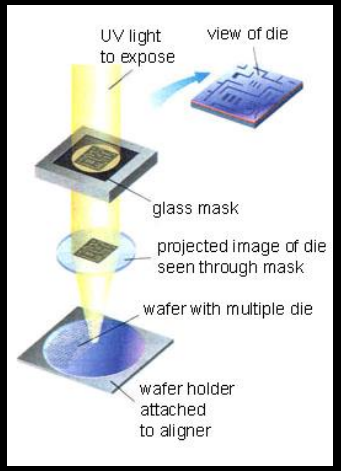


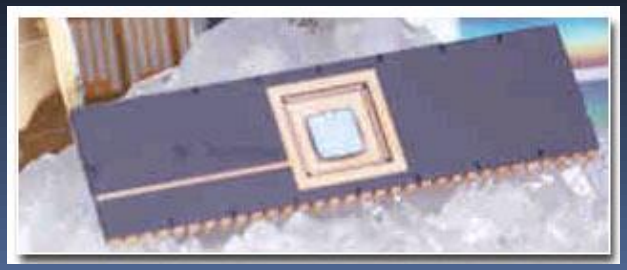


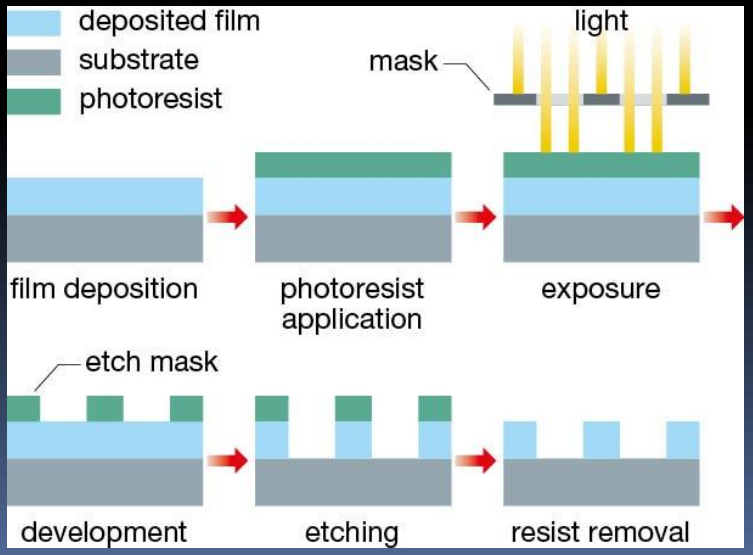
DAL GRANDE AL PICCOLO



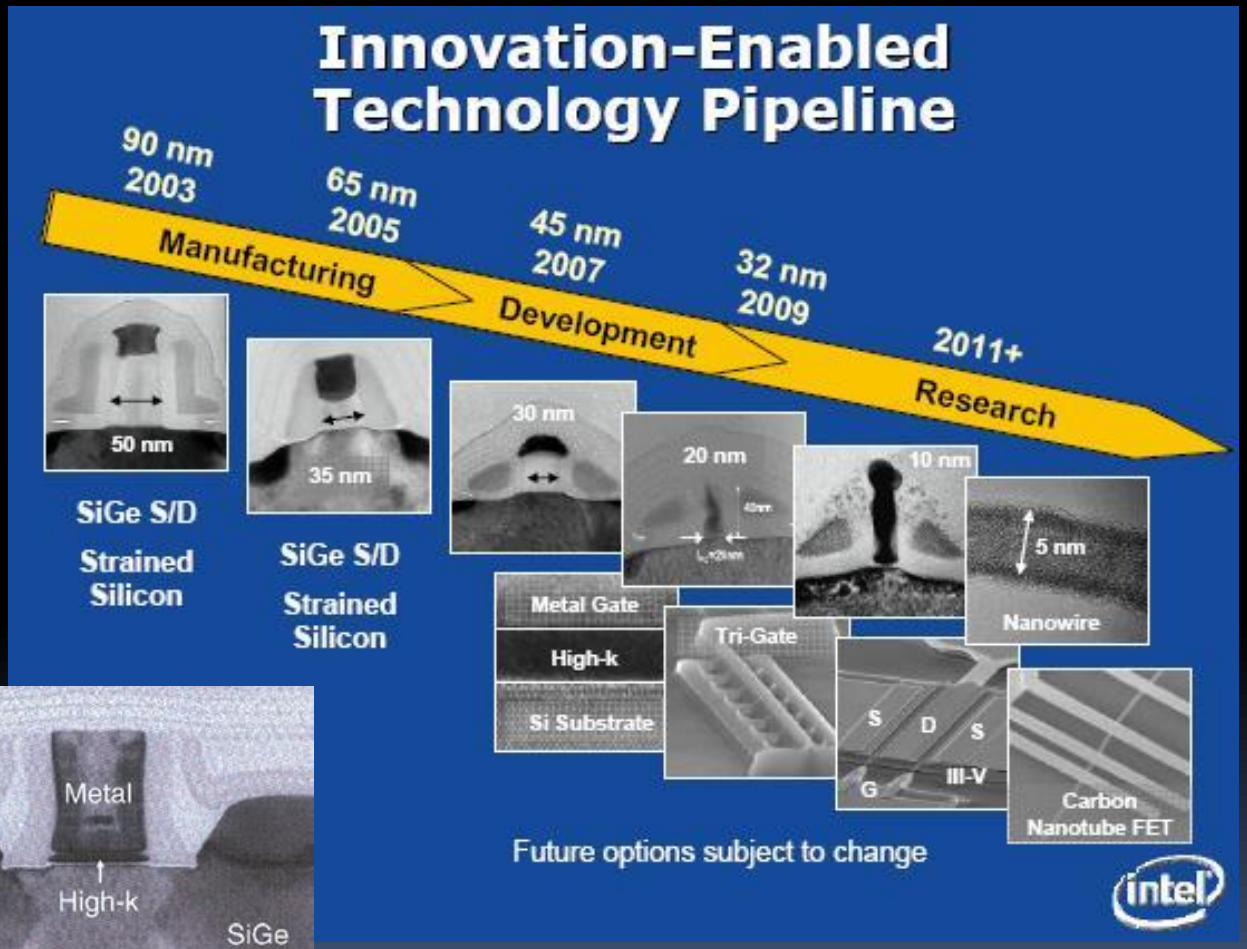


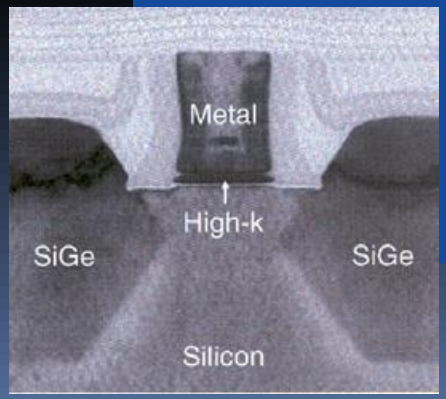






FISICA O NANOTECNOLOGIA?





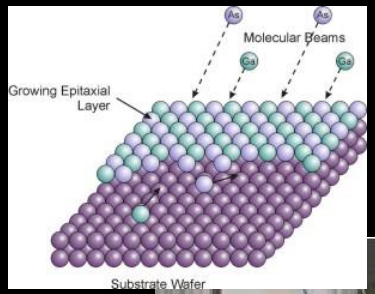
Semiconductor manufacturing processes

10 µm — 1971
3 µm — 1975
1.5 µm — 1982
1 µm — 1985
800 nm — 1989
600 nm — 1994
350 nm — 1995
250 nm — 1997
180 nm — 1999
130 nm — 2002
90 nm — 2004
65 nm — 2006
45 nm — 2008
32 nm — 2010
22 nm — 2012
14 nm — est. 2015
10 nm — est. 2017
7 nm — est. 2020
5 nm — est. 2022

Half-nodes

V • T

UNA GRANDE OPPORTUNITA'
NUOVI MATERIALI QUANTISTICI



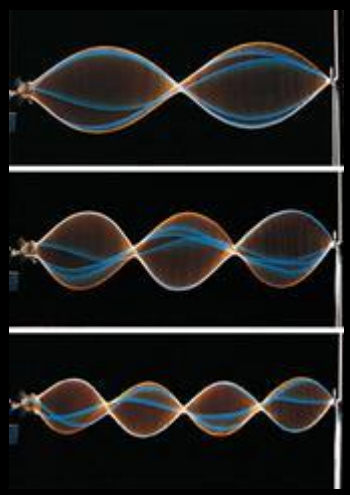
Nobel

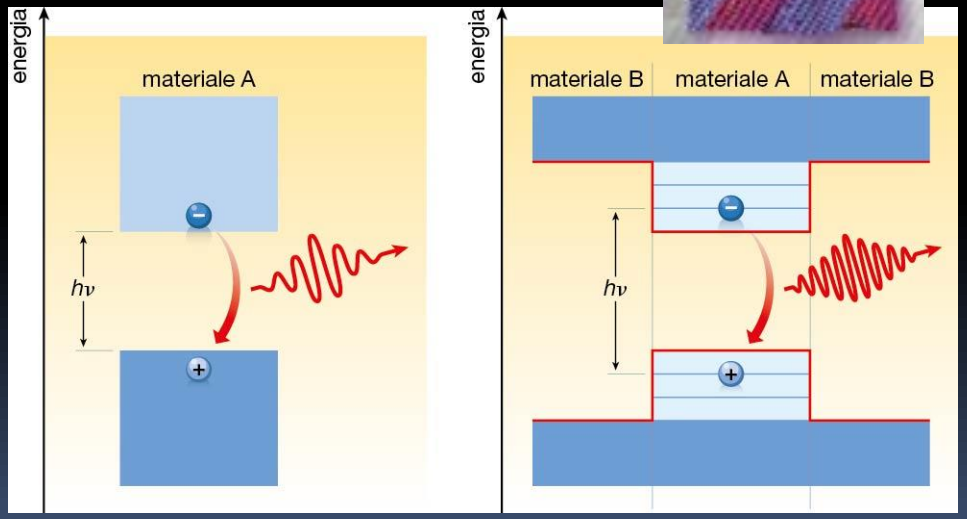
Leo Esaki
Nobel 1973

ONDE DI ELETTRONI

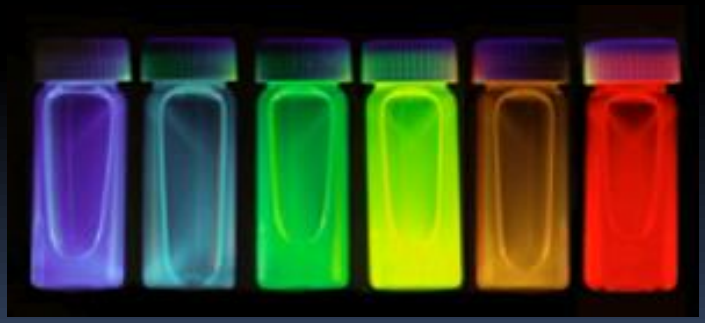
I principi della meccanica quantistica

Gli elettroni alla nano-scala si comportano come onde





Il ‘suono’ degli elettroni: la luce

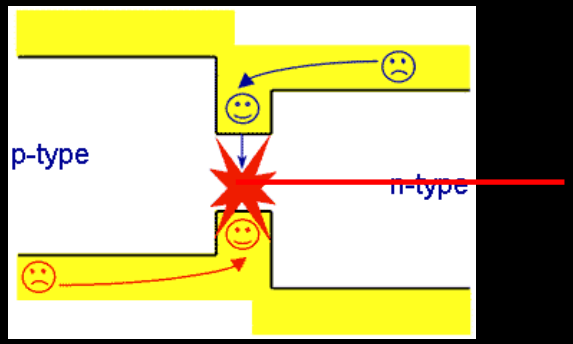


UNA NUOVA GENERAZIONE DI LASER

Nobel

Alferov Kroemer
Nobel 2000

LASER e LED a pozzi quantici

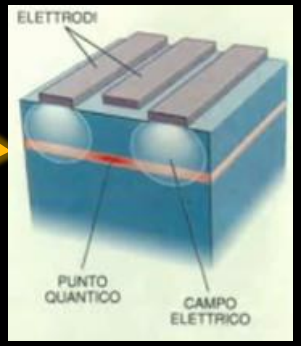


Emissione alla frequenza desiderata

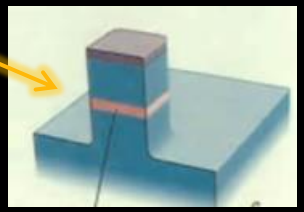
Alta efficienza

PUNTI QUANTICI

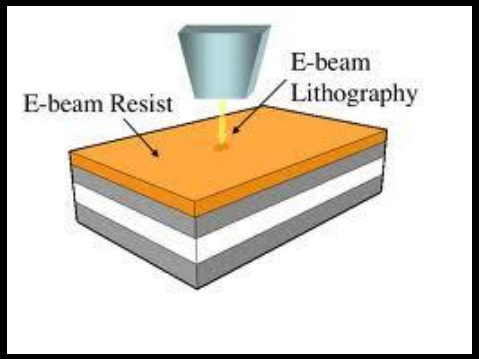
pozzo quantico

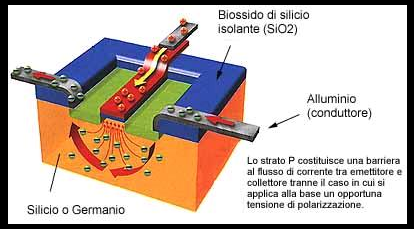


punto quantico

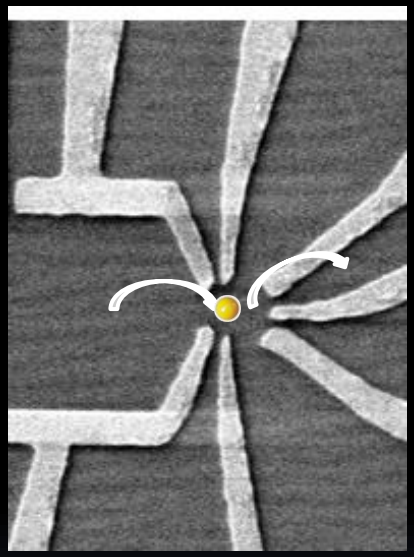


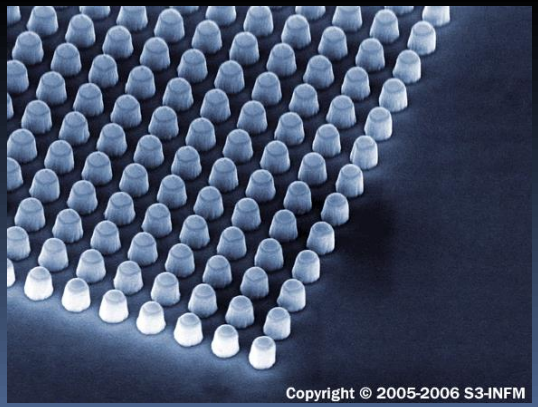
Litografia a fascio elettronico





Transistor a singolo elettrone





Trappole elettroniche

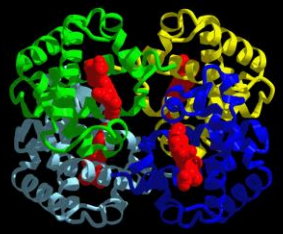
DAL GRANDE AL PICCOLO

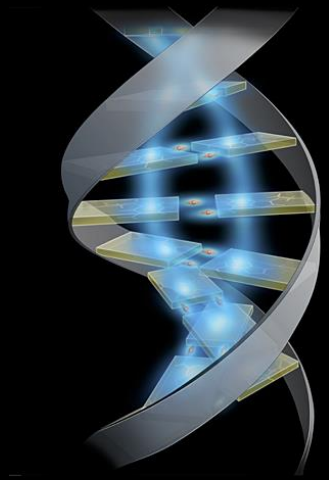
TOP-DOWN

"Scolpire" i dispositivi dal materiale

Attuale tecnologia dei semiconduttori

DAL PICCOLO AL GRANDE





BOTTOM-UP

"Assemblare" mattonicini (unità funzionali) nanoscopici

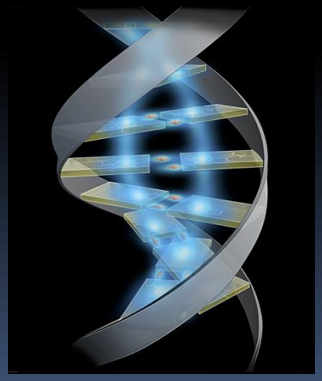
Futura tecnologia elettronica ?

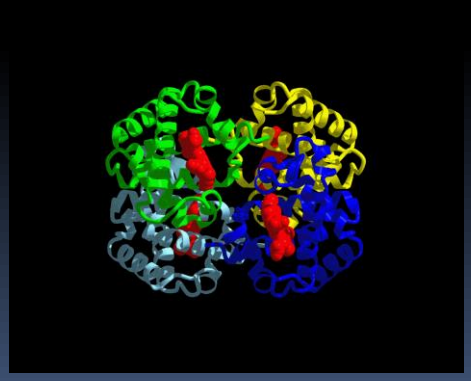
FUNZIONI

autoaggregazione

funzioni elettriche

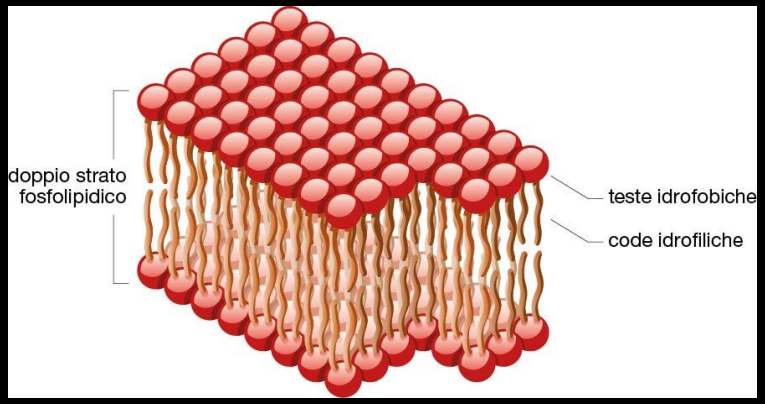
riconoscimento

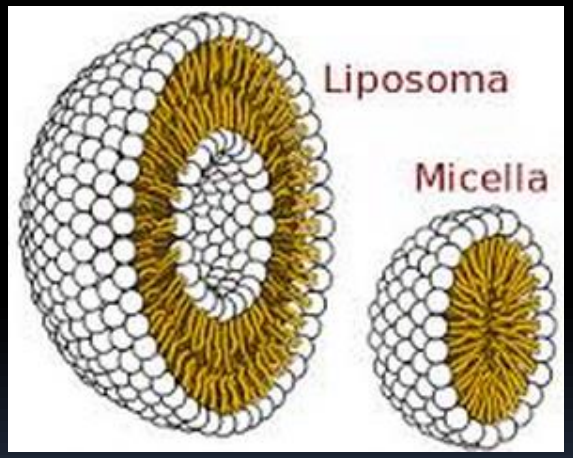




NANOSTRUTTURE MOLECOLARI AUTOASSEMBLATE

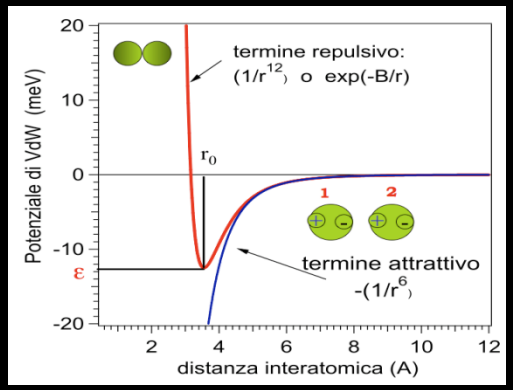
Membrana cellulare

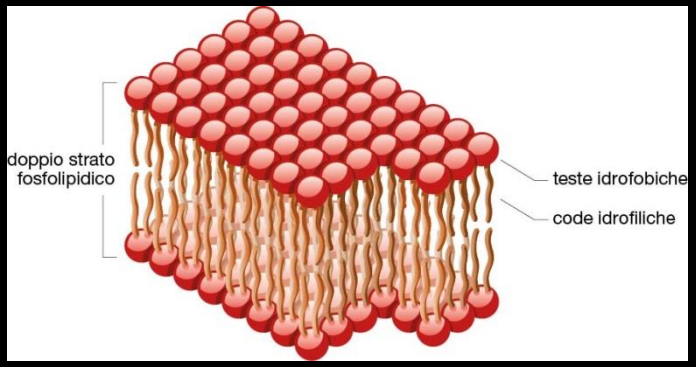




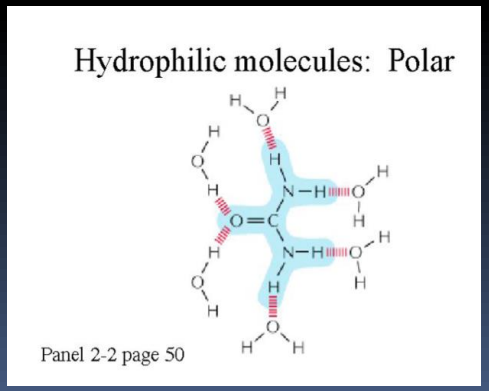
DRIVING FORCES

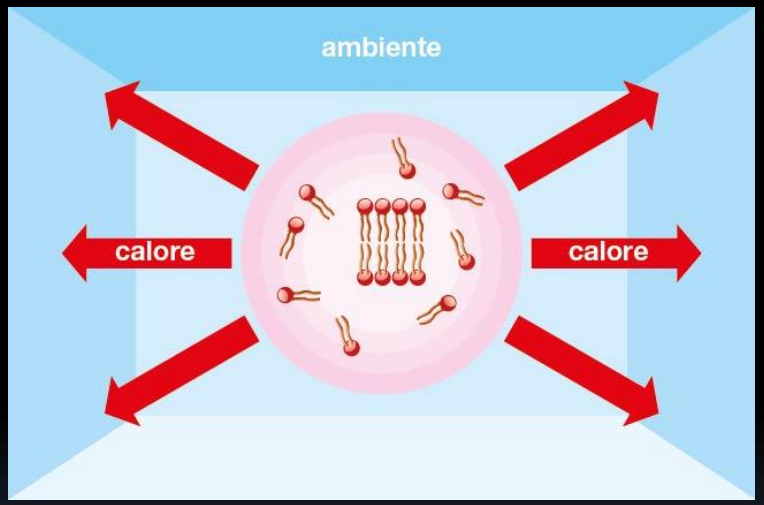
Forze dipolari





Idrofilia



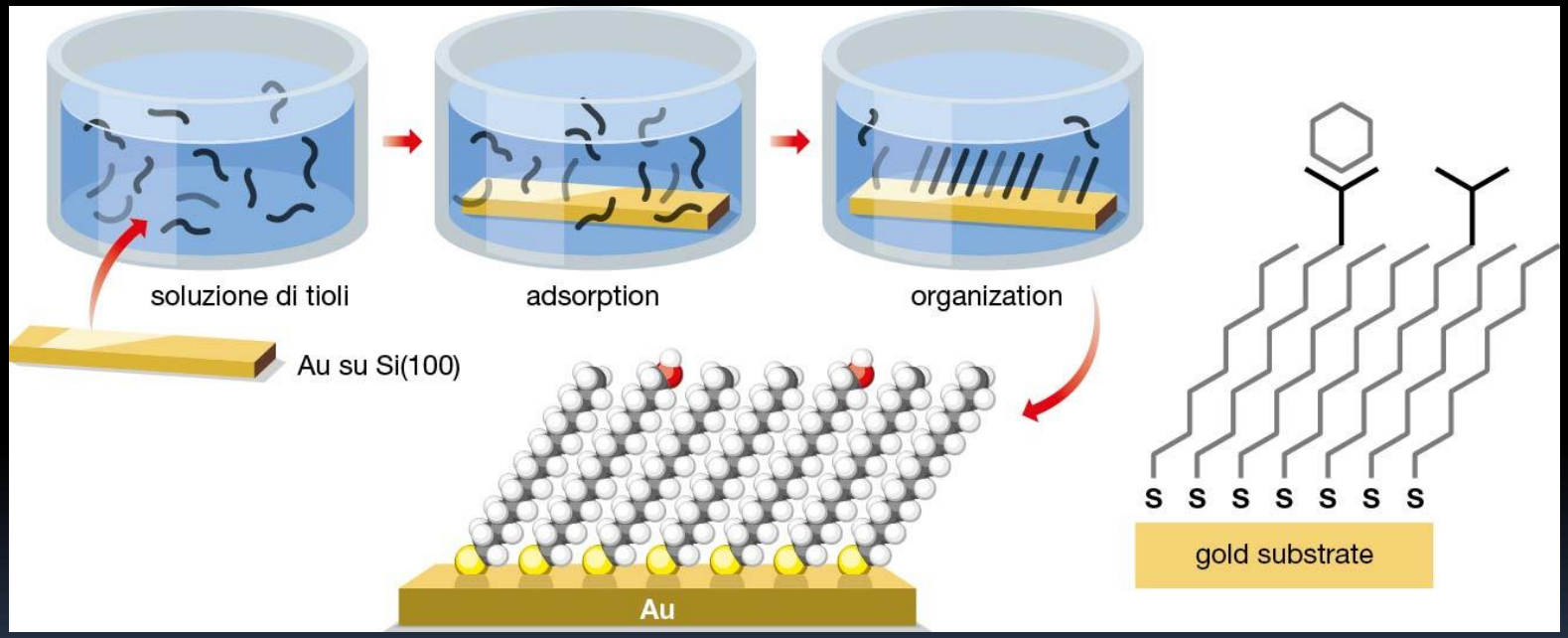


Trasformazione esotermica

- dimuisce l'entropia del sistema
- aumenta l'entropia dell' «universo»

UNA PIATTAFORMA MOLECOLARE

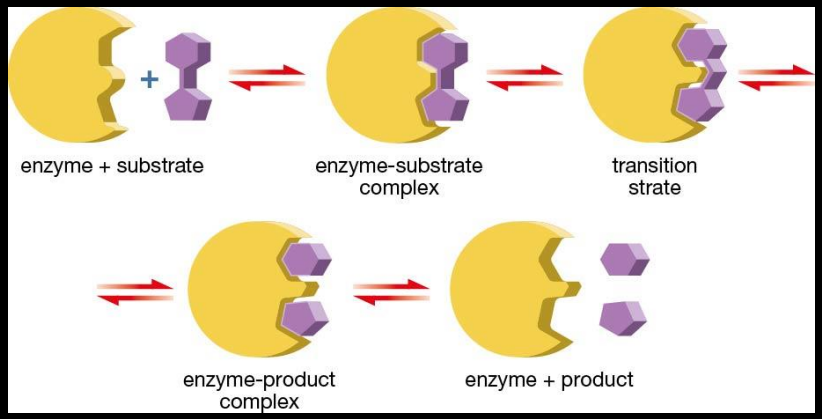
Autoaggregazione Funzionalizzazione Riconoscimento

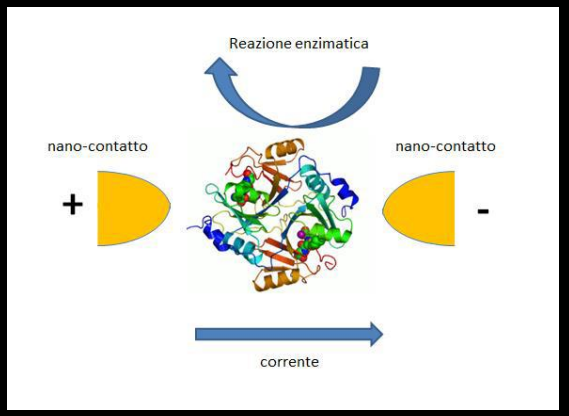


Self-assembled monolayer

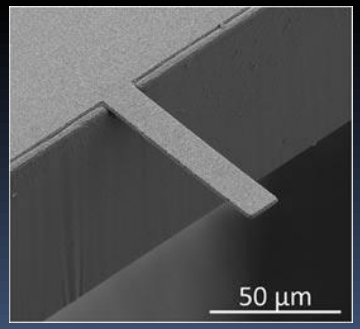
SENSORI MOLECOLARI

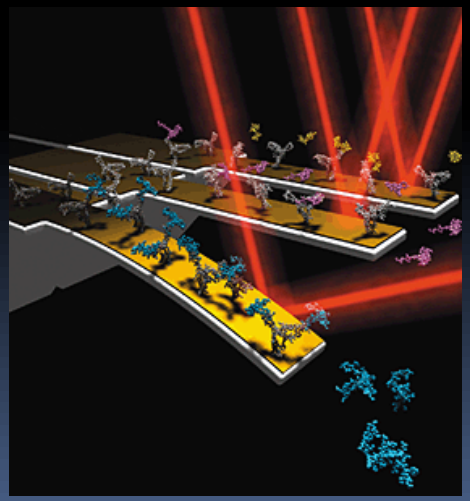
Attività enzimatica





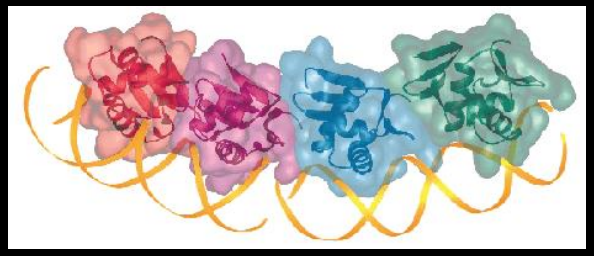
Micro bilance



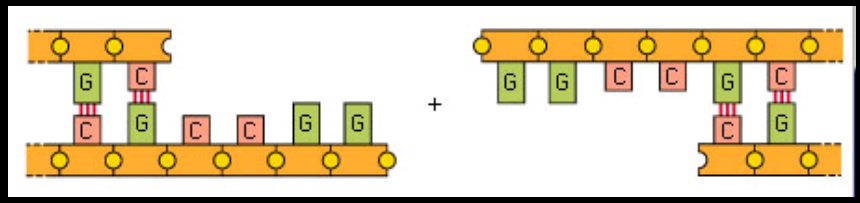


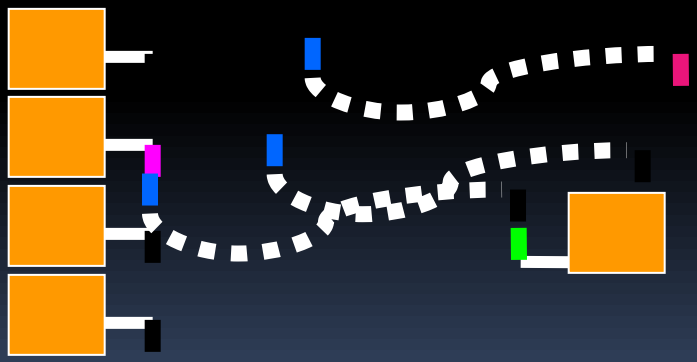
ELETTRONICA BIO-MOLECOLARE

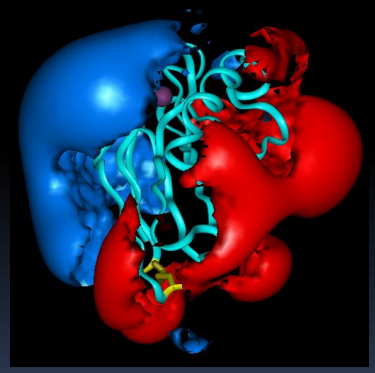
FUNZIONE



RICONOSCIMENTO





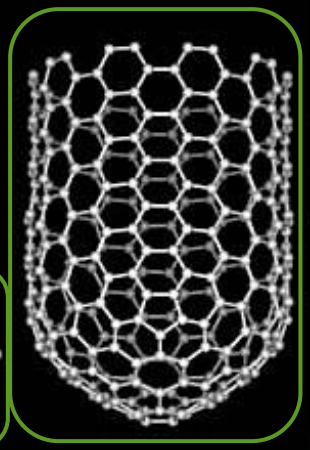
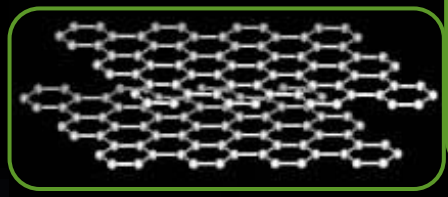


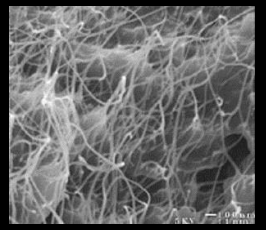
ALLA NANO-SCALA...

… si determinano molte proprieta' macroscopiche

conduttività
durezza
attrito
colore

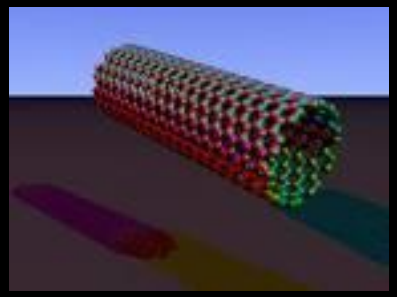


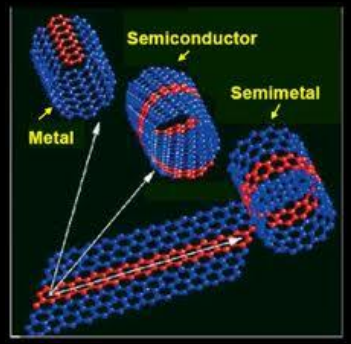




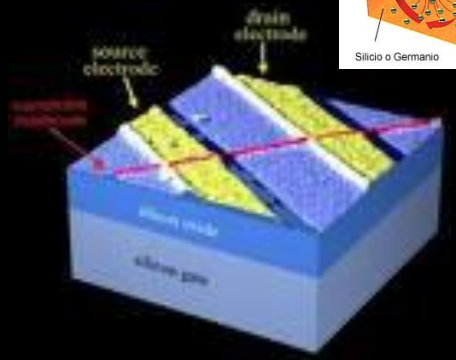



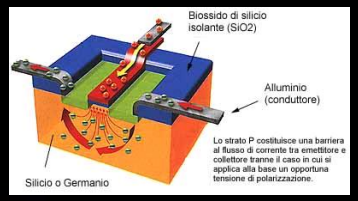

UNA NUOVA ETA' DEL CARBONIO ?

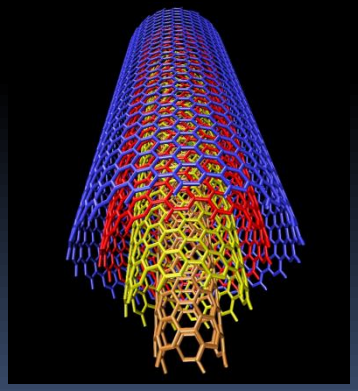
nano-tubi

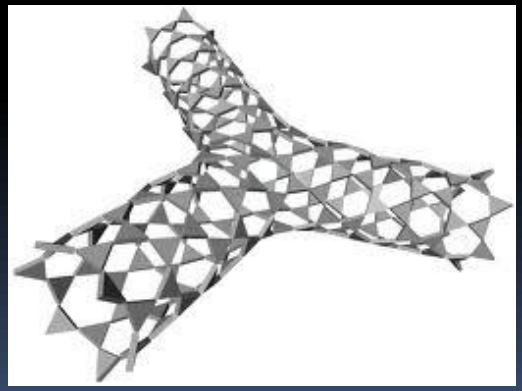


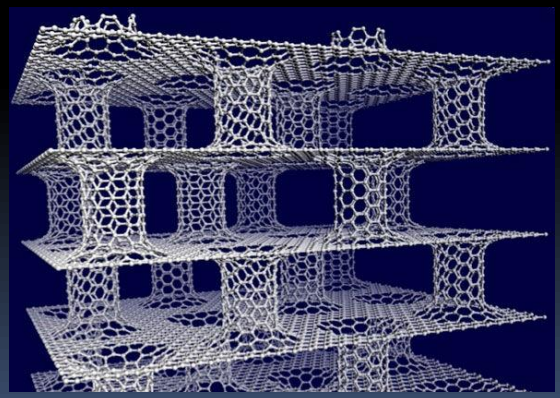






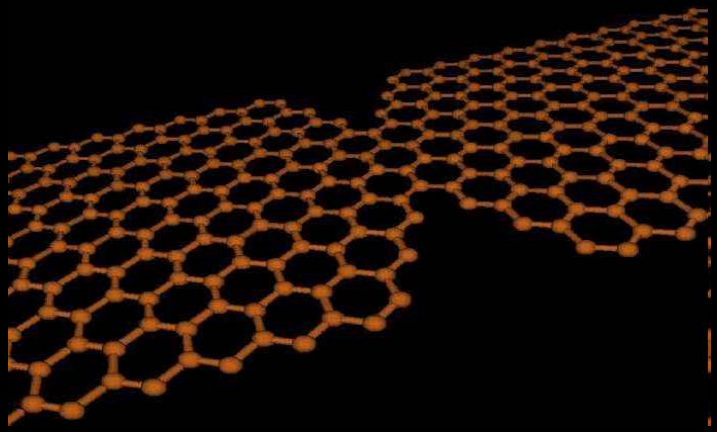


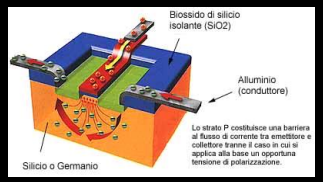


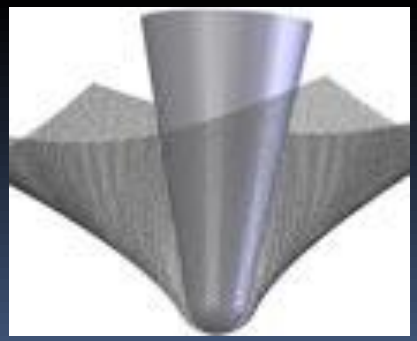


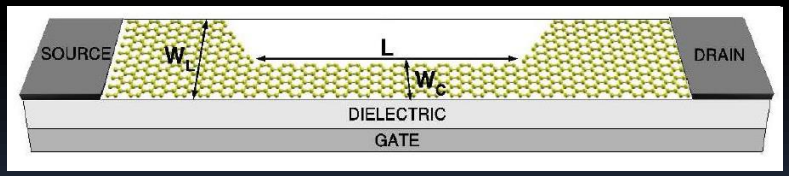
AND THE WINNER IS …

grafene









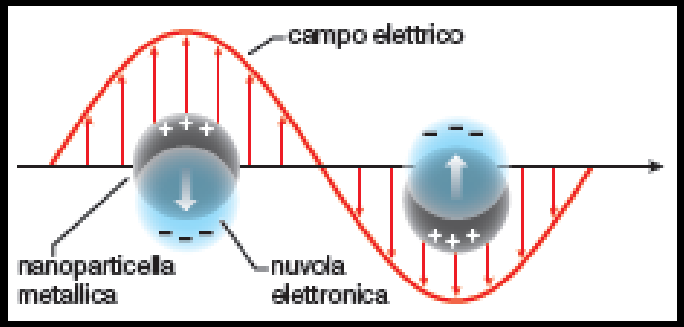
Nobel

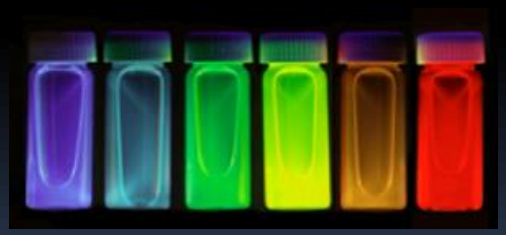
A Geim, K Novoseov,
Nobel 2010

➡ Geim, Kim Le Scienze 478 (2008)

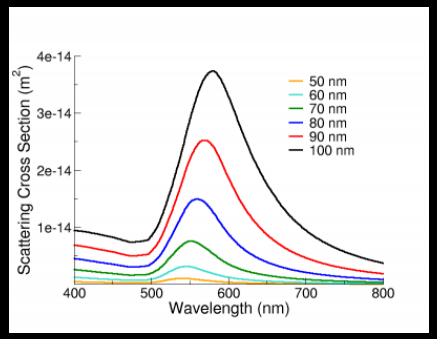
GIALLO COME L'ORO

Localized Plasmon Resonance (LPR)

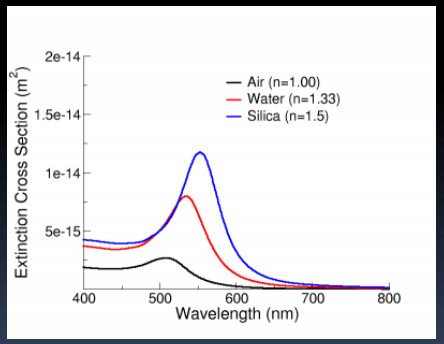




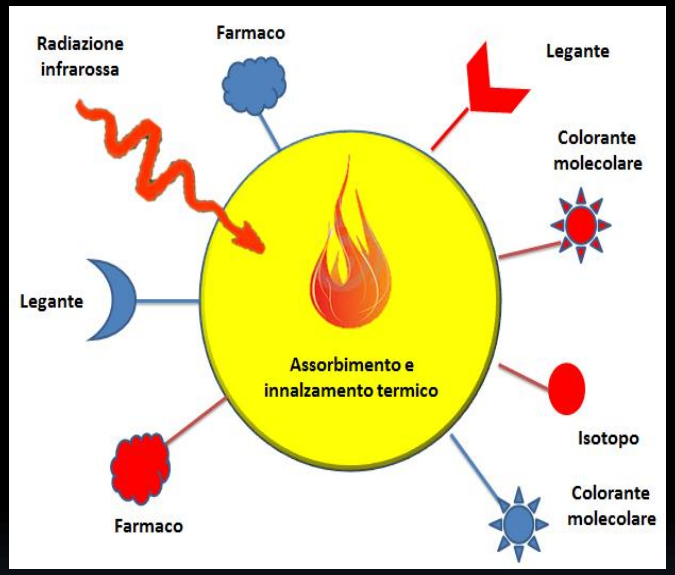
Dimensione



Ambiente

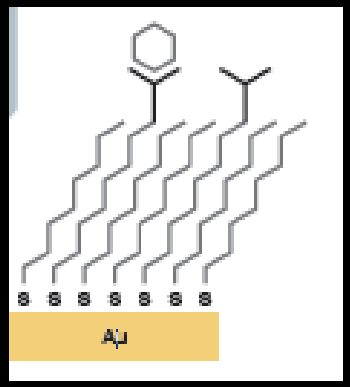


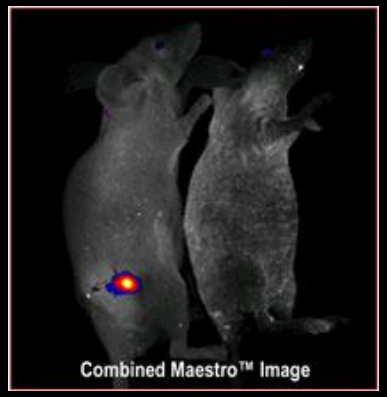
NANO-MEDICINA



Piattaforma teragnostica

Funzionalizzazione





Terapia fototermica

Accumulazione in tessuti patologici

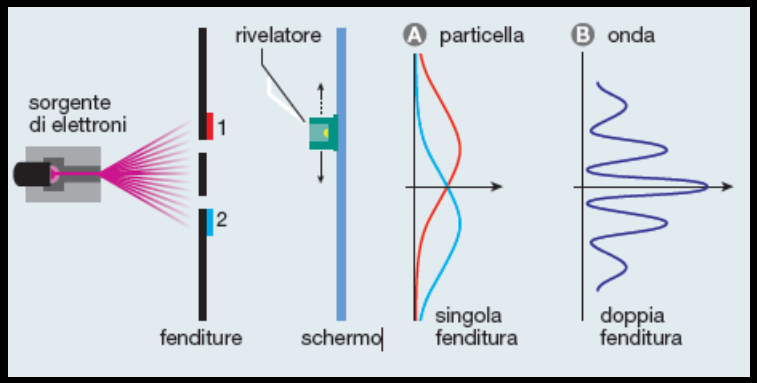
Pelle trasparente a frequenze NIR -> assorbimento LPR e riscaldamento

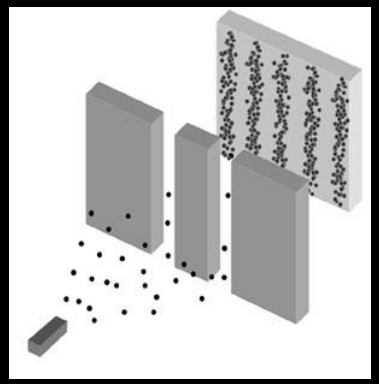
Distruzione selettiva tessuti

Rilascio controllato di farmaci

Tracciamento selettivo per imaging diagnostico

IL PRINCIPIO DI SOVRAPPOSIZIONE





Due livelli di un atomo, il valore dello spin di un elettrone, ecc.

$$|0\rangle \qquad |1\rangle \qquad |Q\rangle = \alpha|0\rangle + \beta|1\rangle$$

IL SACRO GRAAL - COMPUTER QUANTISTICI

Computazione classica $Q = 0,1$ *bit*

0,+V

Computazione quantistica $|Q\rangle = \alpha|0\rangle + \beta|1\rangle$ *qu-bit*

N qu-bit: 2^N configurazioni

$$|000\rangle, |001\rangle, |010\rangle, |011\rangle, |100\rangle, |101\rangle, |110\rangle, |111\rangle$$

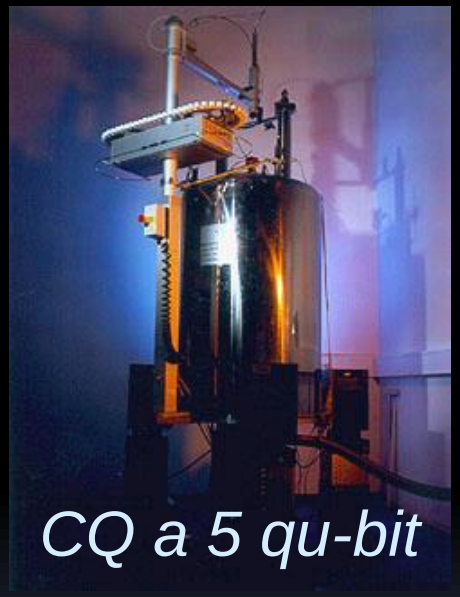
PARALLELISMO QUANTISTICO

Un registro quantistico può esistere in una sovrapposizione di 2^N configurazioni

Una sequenza di operazioni su un registro di qu-bit equivale a una sequenza su 2^N bit

	ricerca in una lista	*fattorizzazione*
Classico	$O(expN^{1/3})$	$O(N)$
Quantistico	$O(N^3)$	$O(N^{1/3})$

IL “CQ” ESISTE



CQ a 5 qu-bit

Compiti eseguiti fino ad ora

Fattorizzazione del numero 15

Correzione di un bit (5 qu-bit)

Per avere la potenza di calcolo di un moderno PC occorrono alcune decine di qu-bit

PERCHE' NON HO UN "CQ" SUL TAVOLO

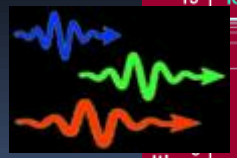
COERENZA

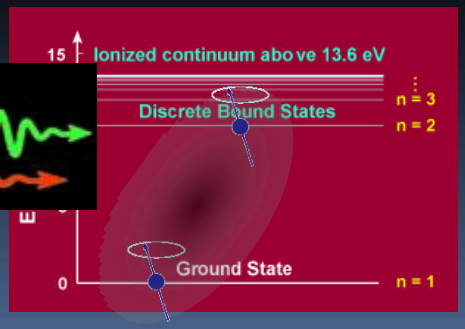
L'interazione con l'ambiente (compreso il processo di misura) distrugge la coerenza quantistica

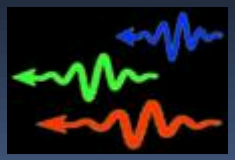
SCALABILITA'

$|1\rangle$

$|0\rangle$

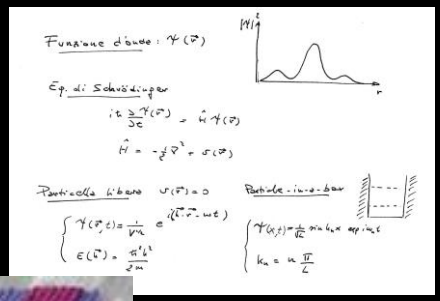


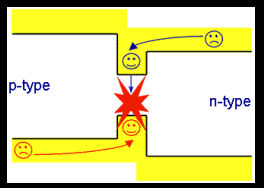




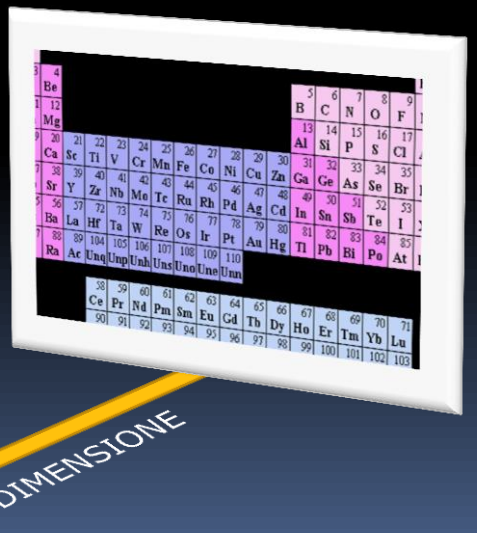
IDEE-CHIAVE

Il ruolo della meccanica quantistica
- Da schema interpretativo a strumento di progettazione di nuovi materiali

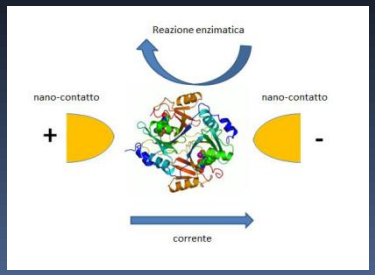




Le proprietà dipendono dalle dimensioni
- Un nuovo asse nella tavola di Mendeleev



La (nano) struttura dei materiali ne determina la funzione



www.NANOLAB.unimore.it

Portare le nanoscienze in classe

Hands-on, inquiry based science education

Ogni modulo incentrato su una idea-chiave delle nanoscienze

Sito web – video guide, indicazioni didattiche, background reading

Kit e corsi di aggiornamento

Temi

Immagini (*) estratte dal testo

Nanoparticelle – Size matters
Superfici nanostrutturate – La gerarchia delle forze
Materiali intelligenti – Struttura e funzione
Polimeri conduttivi a effetto tunnel – Il ruolo della meccanica quantistica

outreach.fim.unimore.it

Stage

Prepa

Innov

Orientamento

Divulgazione scientifica, laboratori, seminari

Newsletter

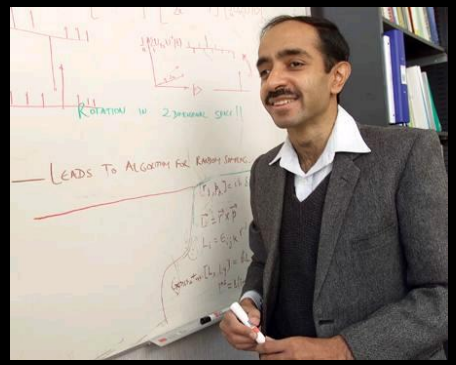
COSA PUO' FARE DI PIU' UN "CQ"

Un computer quantistico può eseguire più velocemente

ricerca in una lista

classico $O(\exp(N^{1/3}))$

quantistico $O(N^3)$

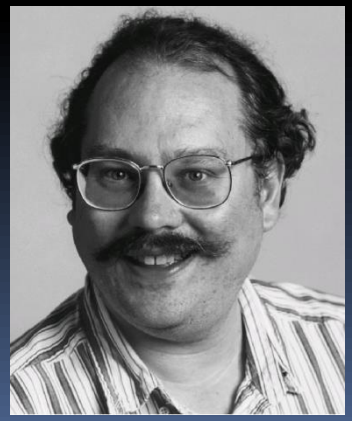


Lov Grover

fattorizzazione di numeri interi

classico $O(N)$

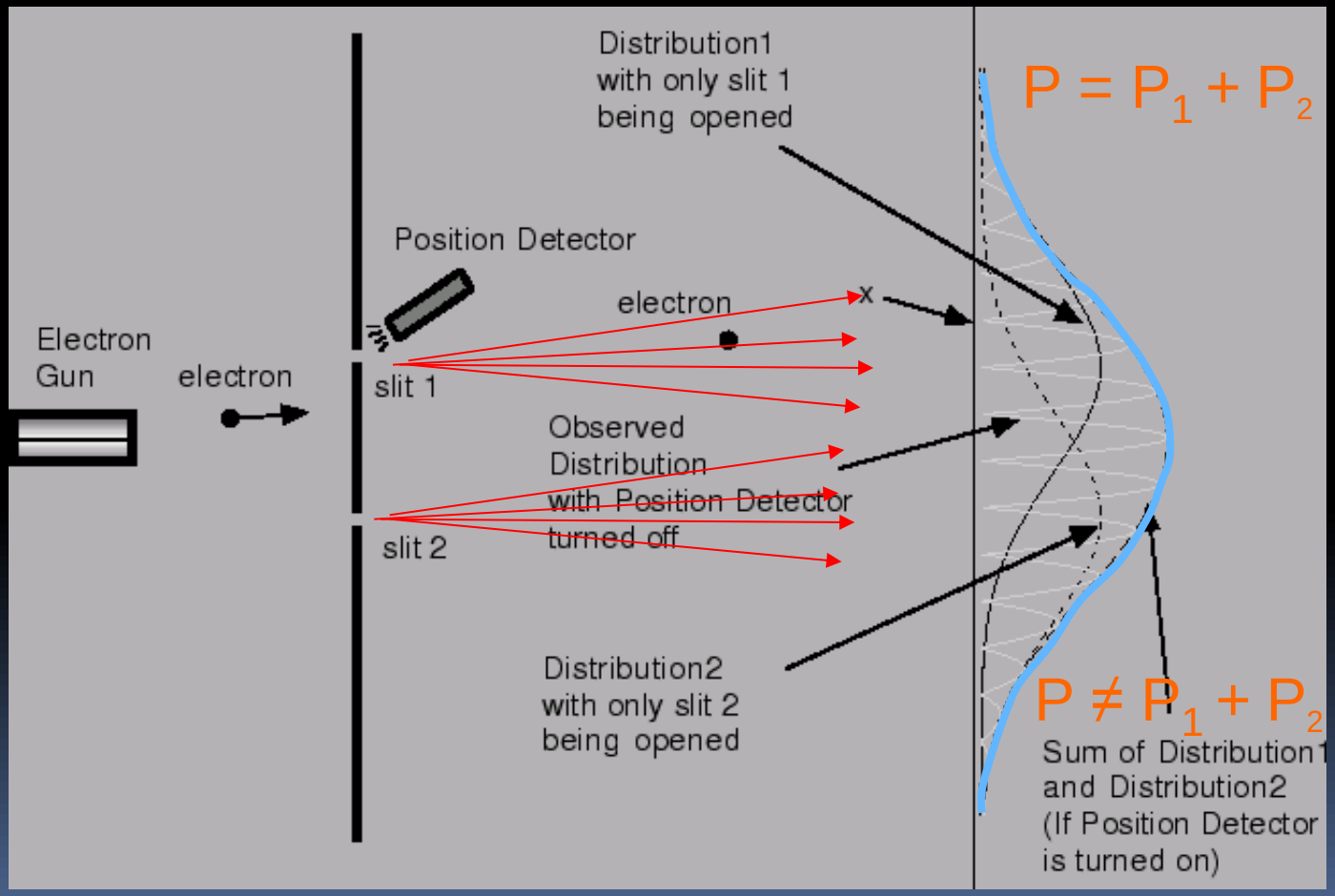
quantistico $O(N^{1/3})$

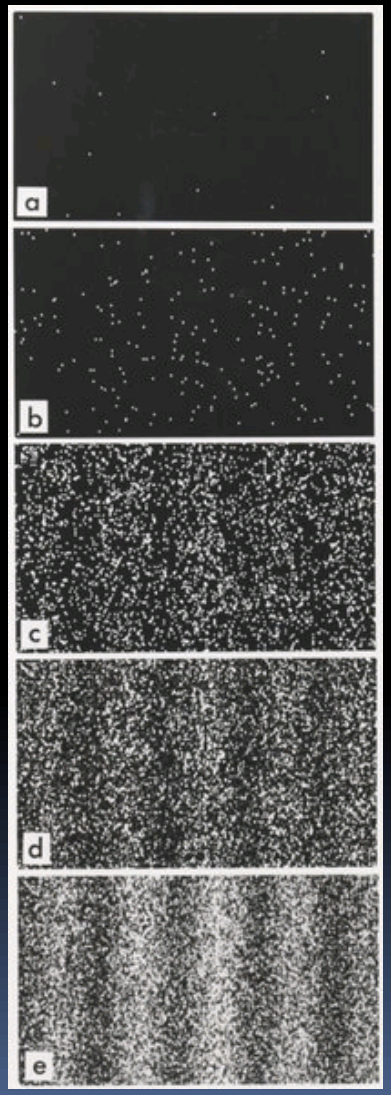


Peter Shor

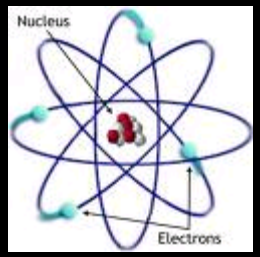
L'ESPERIMENTO PIU' BELLO DEL MONDO

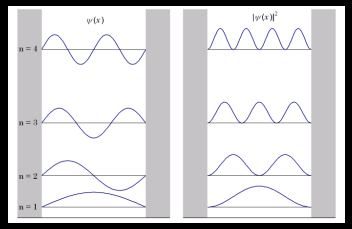
Gli elettroni formano una figura di interferenza come delle onde!

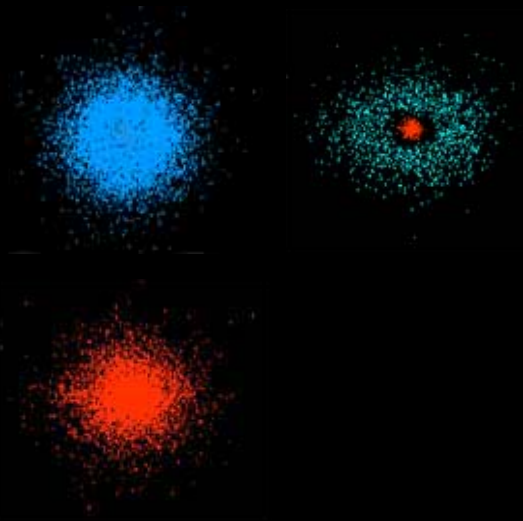




I LIVELLI ATOMICI

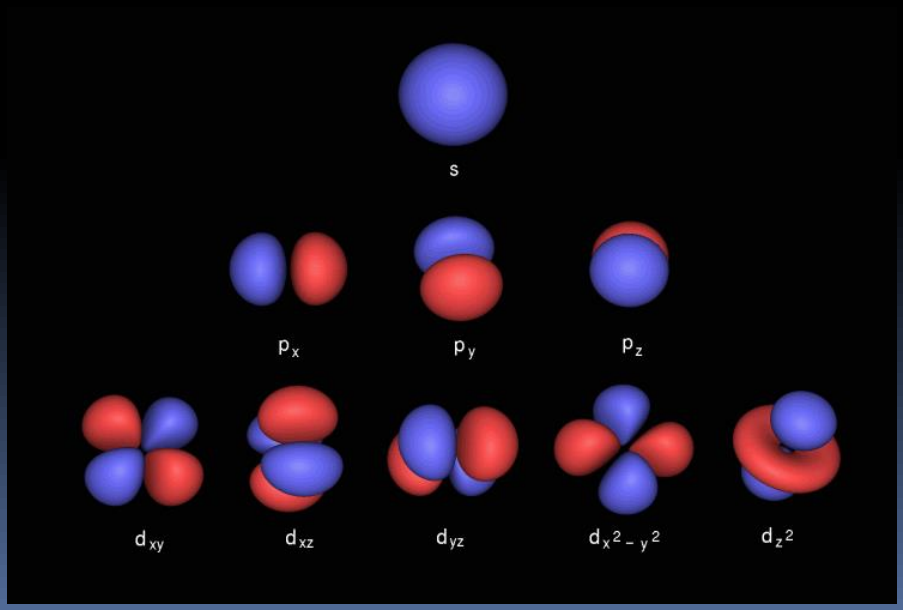


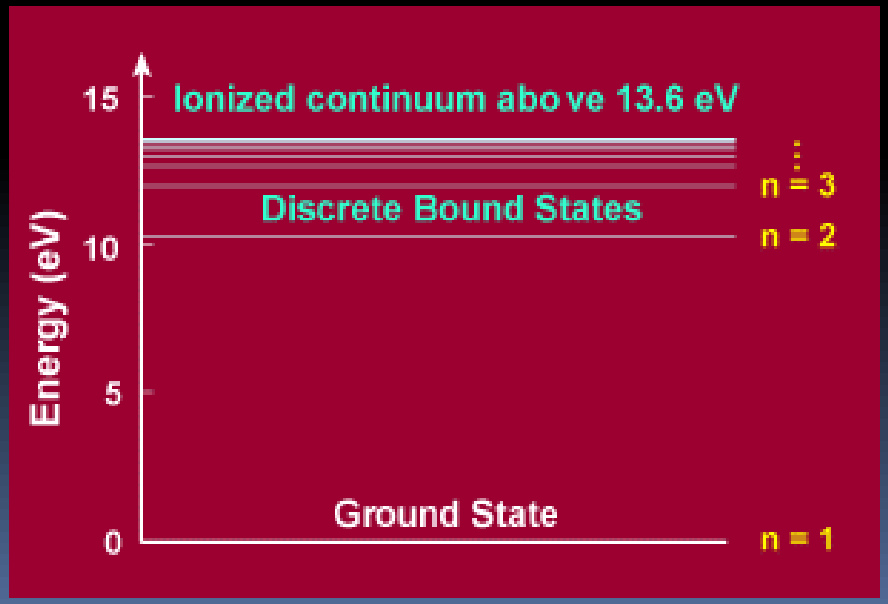




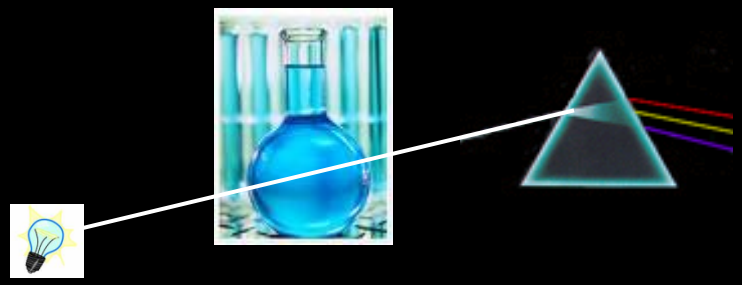
2s

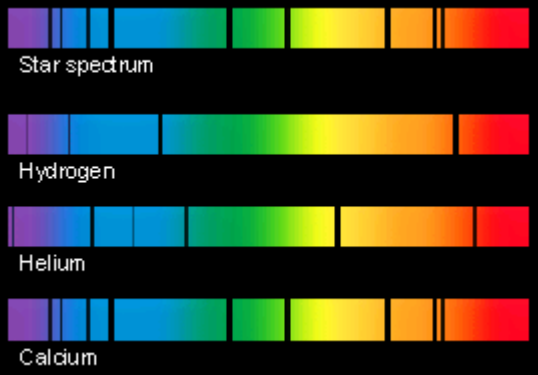
1s



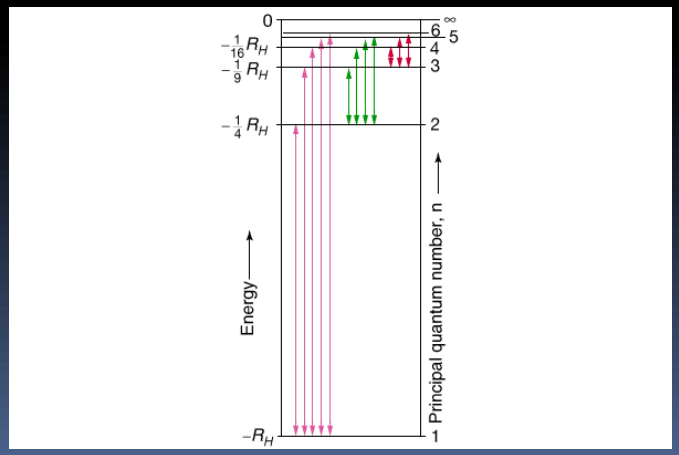


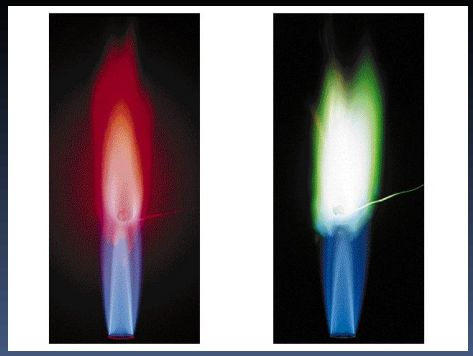
SPETTRI ATOMICI





Ora sappiamo perche' gli atomi assorbono solo specifiche frequenze e possiamo cacolarne le frequenze con estrema precisione

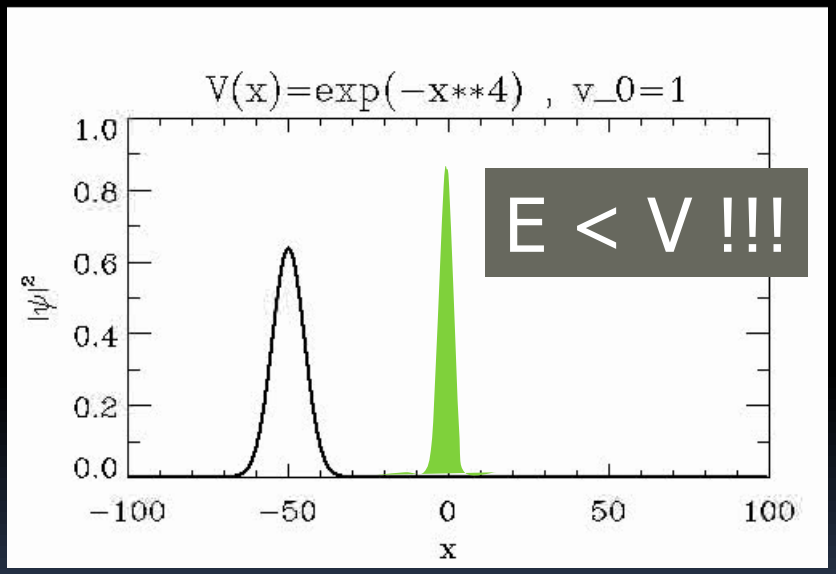




PALLINE CHE ATTRAVERSANO I MURI

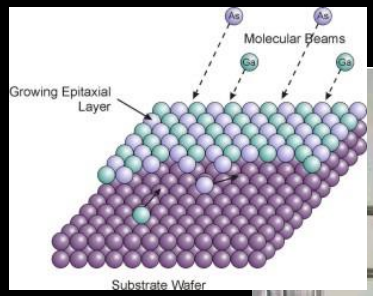
IL TUNNELING QUANTISTICO

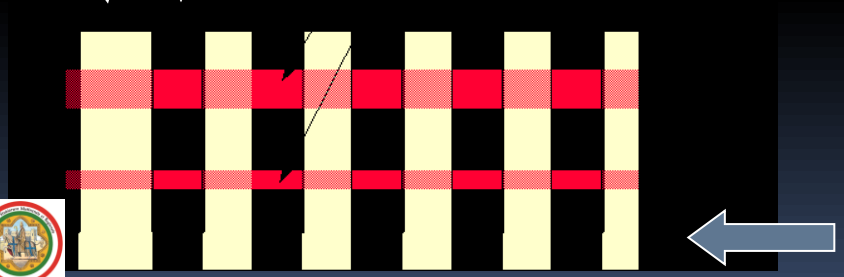
Tunneling della funzione d'onda

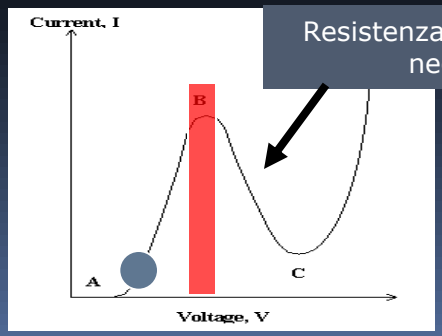


I SUPER-RETICOLI DI ESAKI

Leo Esaki
Nobel 1973

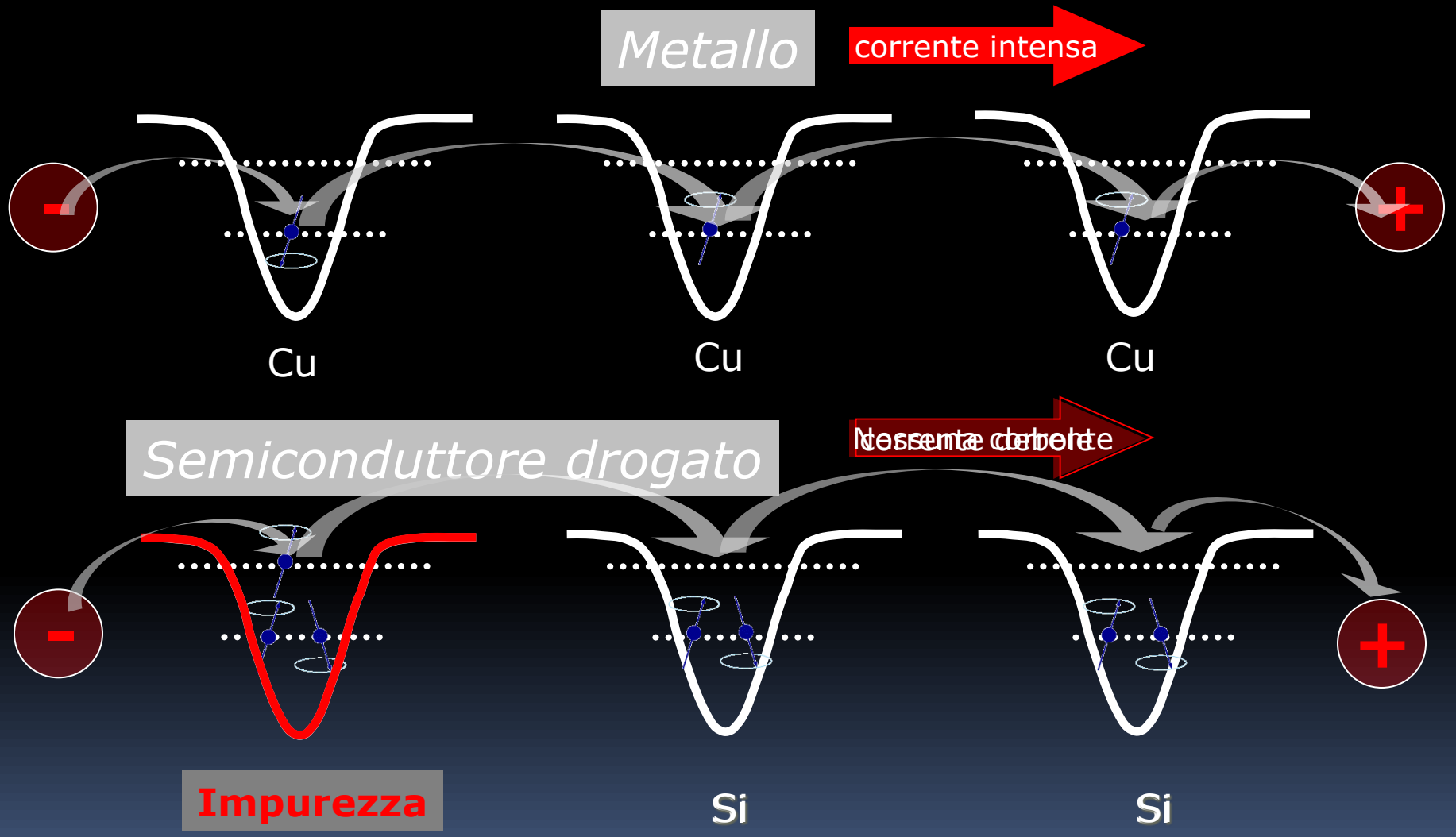






Resistenza differenziale negativa

LA TEORIA QUANTISTICA DEI SOLIDI

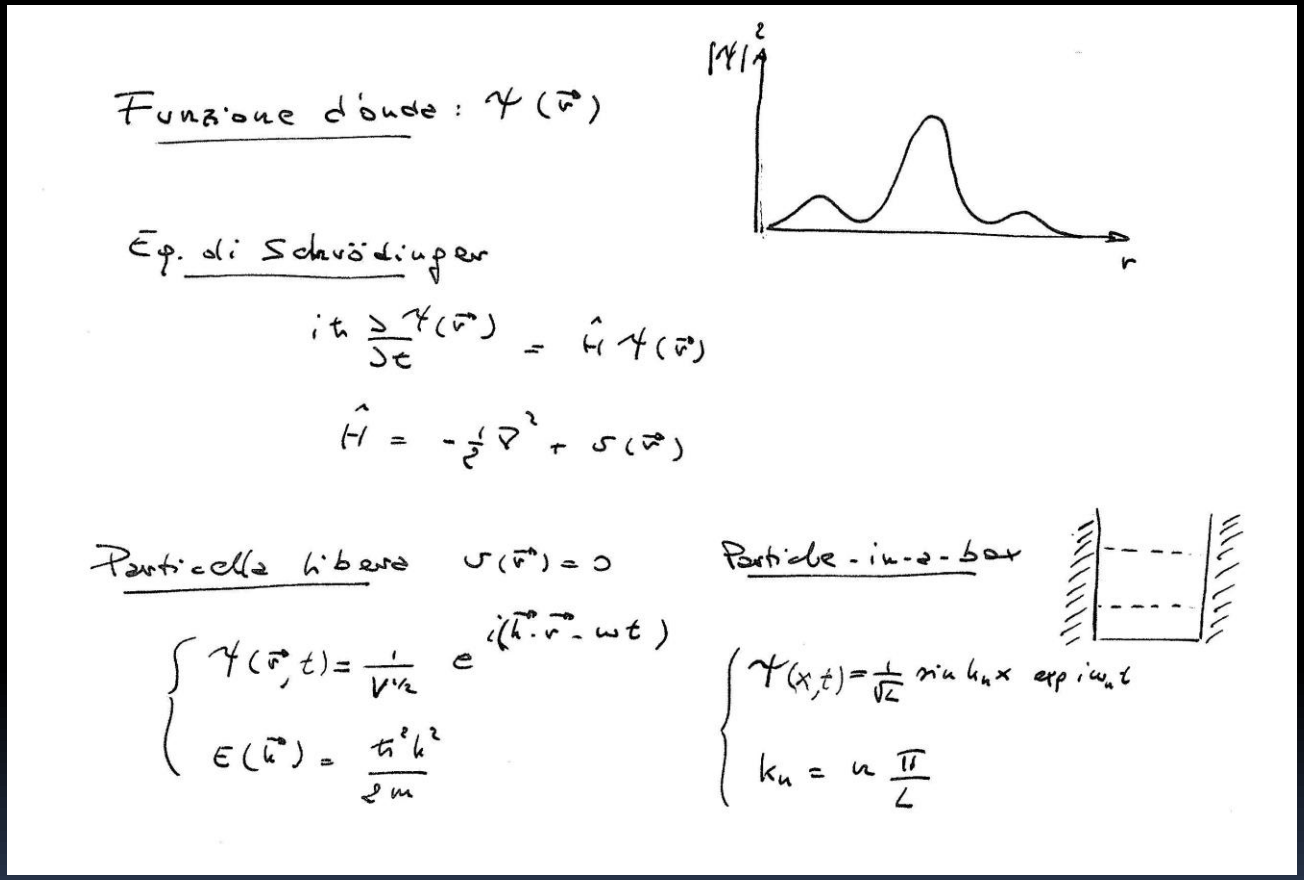


IL RUOLO DELLA MECCANICA QUANTISTICA

- Perché alcuni materiali conducono bene, altri male o nulla
- Perché alcuni materiali SUPER-conducono
- Cosa limita la conduzione, come possiamo cambiare questo stato di cose e trarne vantaggio

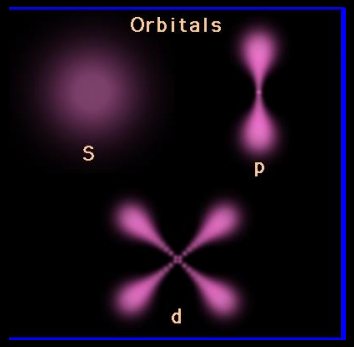
- Perché alcuni materiali assorbono la luce e altri no
- Perché la luce che assorbono o emettono ha un determinato colore

IN MEDIAS RES - LA MECCANICA QUANTISTICA



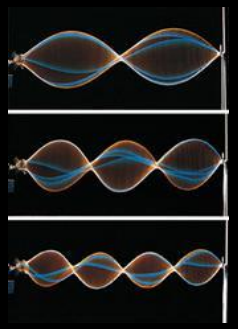
"I think that I can safely say that nobody understands quantum mechanics." R. Feynmann, Nobel 1965

I PRINCIPI DELLA MECCANICA QUANTISTICA



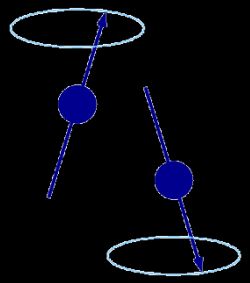
Principio di quantizzazione dell'energia

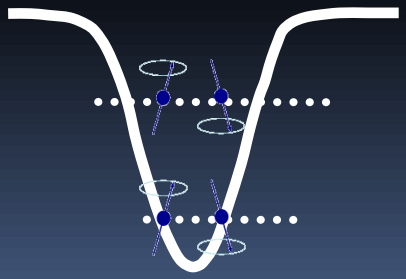
- In un atomo sono permesse solo certe orbite/energie



Ogni elettrone è dotato di spin

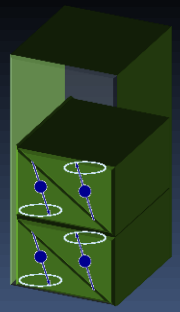
- Lo spin può assumere solo due valori



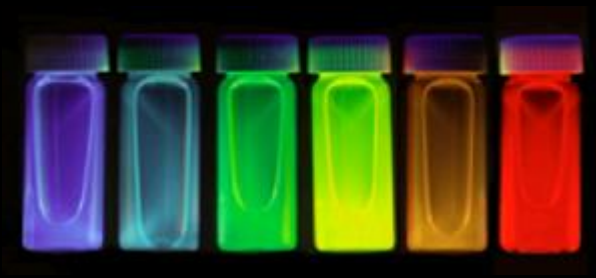


Principio di esclusione di Pauli

- Ogni livello può essere occupato da un solo elettrone per spin



PUNTI QUANTICI COLLOIDALI



Ampio spettro di eccitazione

Emissione a singole frequenze

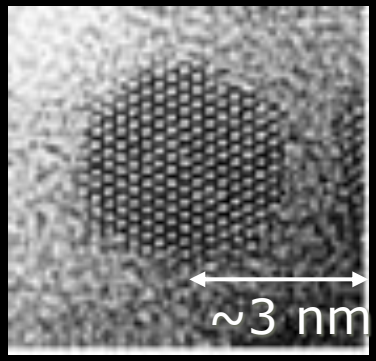
Emissione alla frequenza desiderata

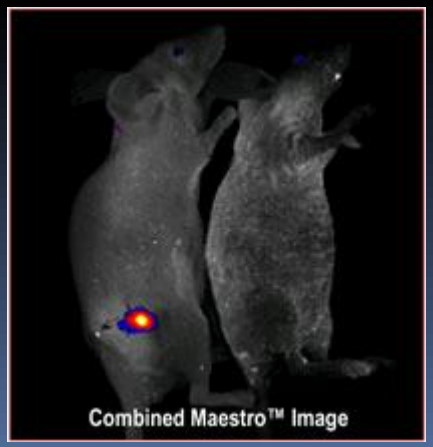
Lunghi tempi di fluorescenza

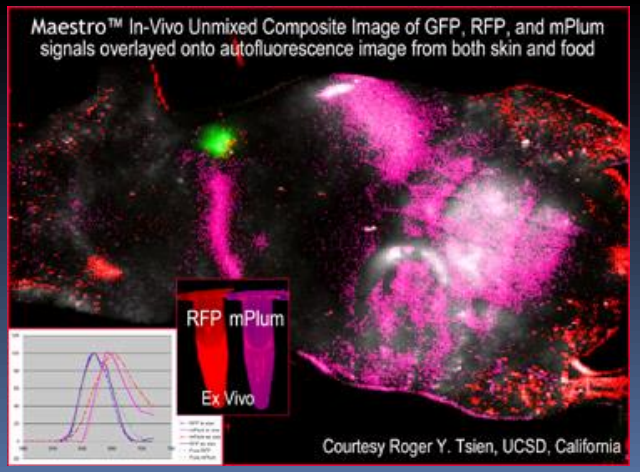
bio-compatibilità

Rivelazione di singole molecole in-vivo

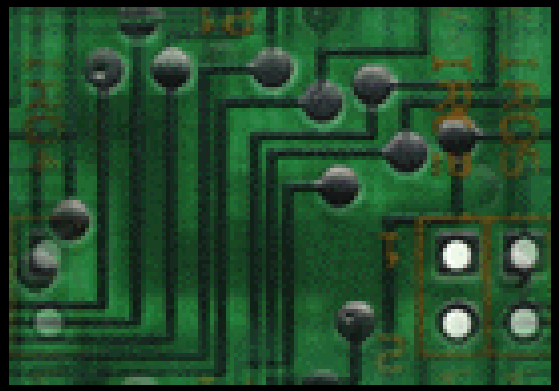
Colorazione cellulare per fluorescenza

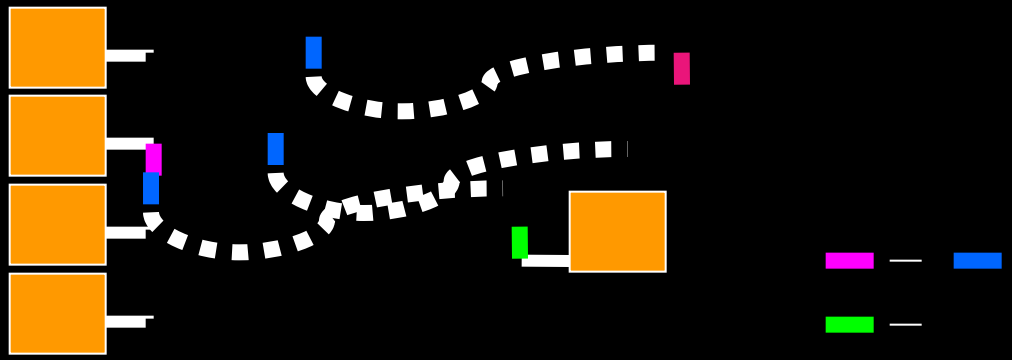


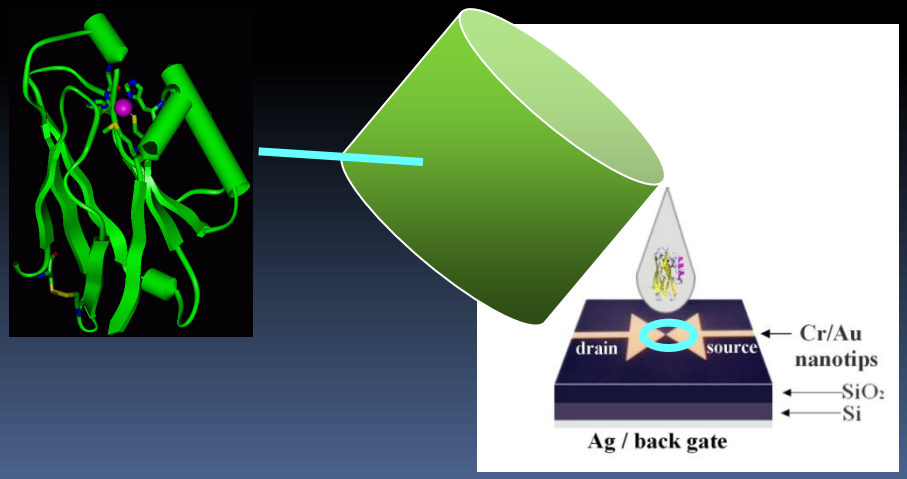




ELETTRONICA BIOMOLECOLARE







RIDONDANZA

AUTO-AGGREGAZIONE