Gruppo Tecnico Interregionale

CLP REACH

REGIONE AUTONOMA FRIULI VENEZIA GIULIA

REACH_MANOMATERIALI E MICROPLASTICHE

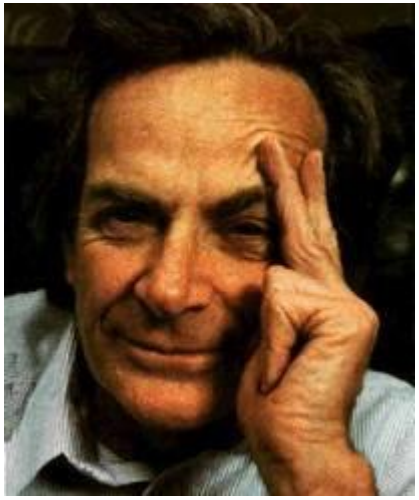
Udine 12 dicembre 2019

NANOMATERIALI E NANOTECNOLOGIE

Lucia Pasquato

Università degli Studi di Trieste

il mondo «nano»: l'inizio



There's Plenty of Room at the Bottom

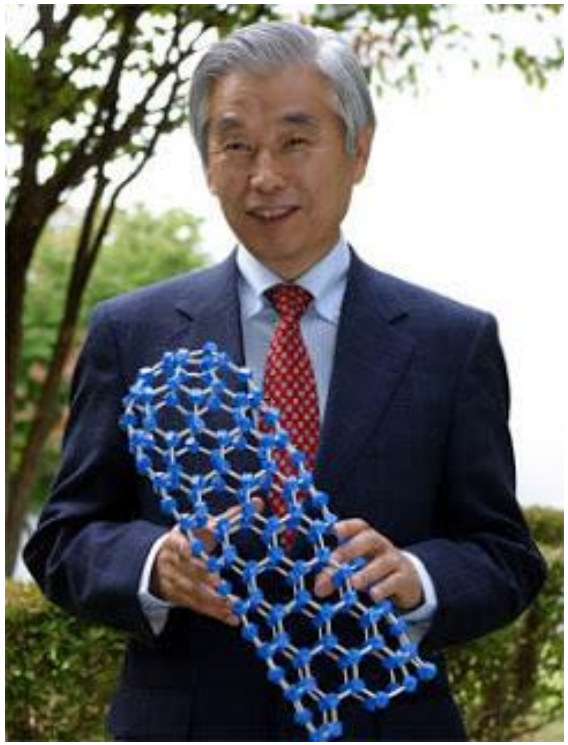
December 29, 1959 at the Annual Meeting of the American Physical Society at Caltech

il Professor Richard Feyman (premio Nobel per la Fisica nel 1965) presenta una lecture visionaria, su:
"*making, manipulating, visualizing and controlling things on a small scale,*"

"*Why cannot we write the entire 24 volumes of the Encyclopaedia Brittanica on the head of a pin?* "
"*..... and there is no question that there is enough room on the head of a pin to put all of the Encyclopaedia Brittanica.*"

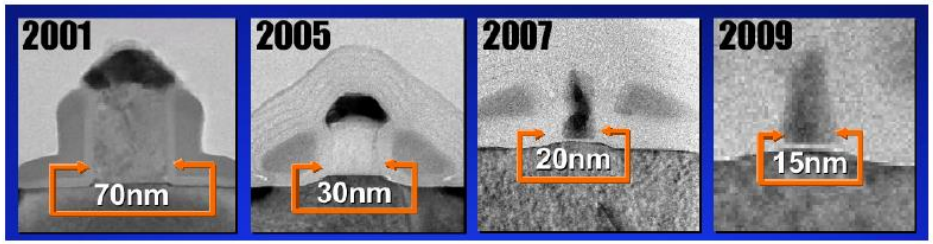
il mondo «nano»: l'inizio

Nel **1974** Professor **Norio Taniguchi,** of the Tokyo Science University, introduced the term "**nanotechnology"** to describe a process exhibiting characteristic control on the order of a nanometer: "Nano-technology' mainly consists of the processing of separation, consolidation, and deformation of materials by one atom or one molecule."



nanoelettronica

Much of the motivating force and technology for nanotechnology came from integrated circuit industry



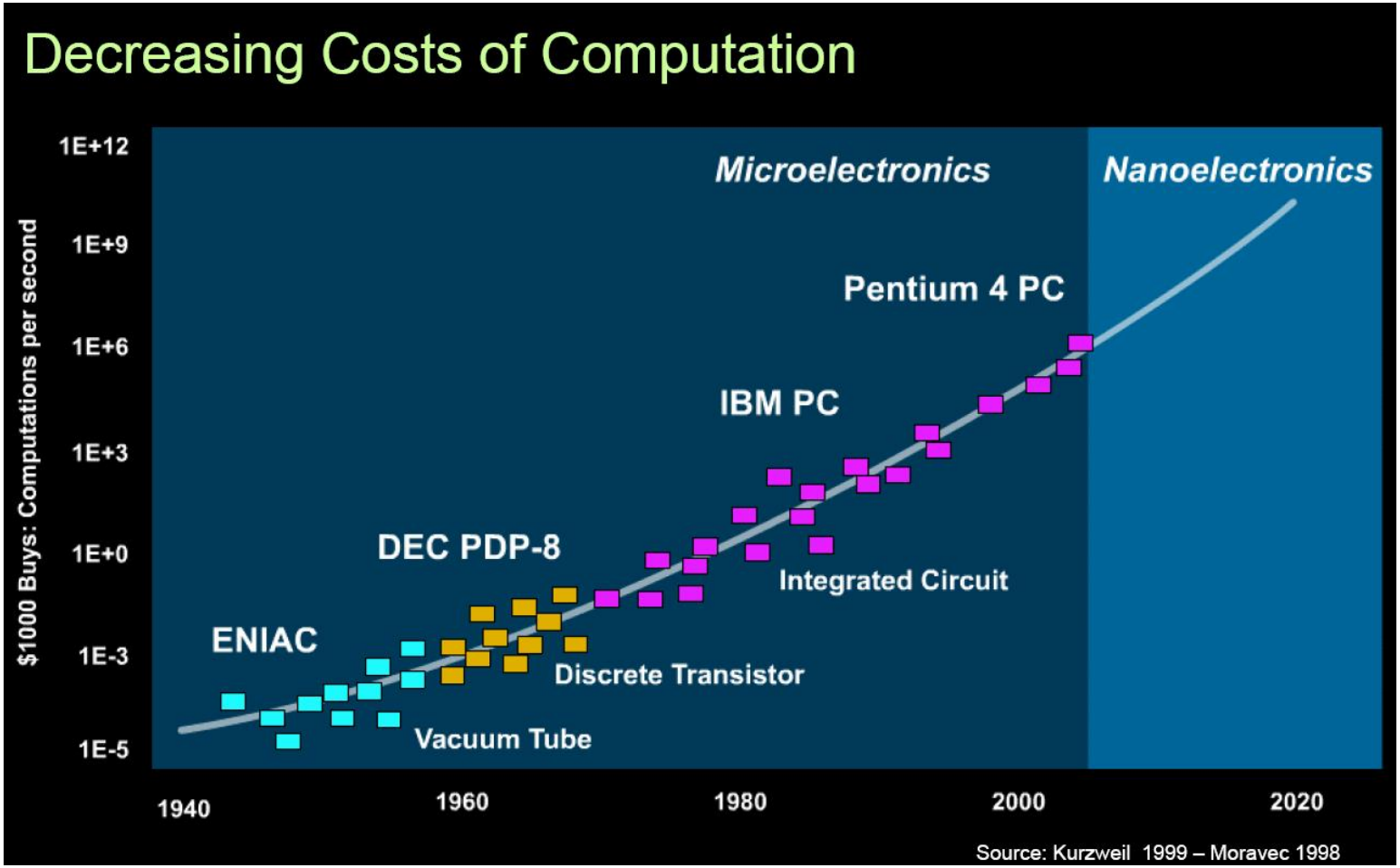
Intel's transistors

As with the fabrication of integrated circuits, nanotechnology is based on building structures and systems at very small sizes

- to enhance performance and produce new properties and applications

- for many types of systems (mechanical, biological, chemical, optical) in addition to electronic

nanoelettronica



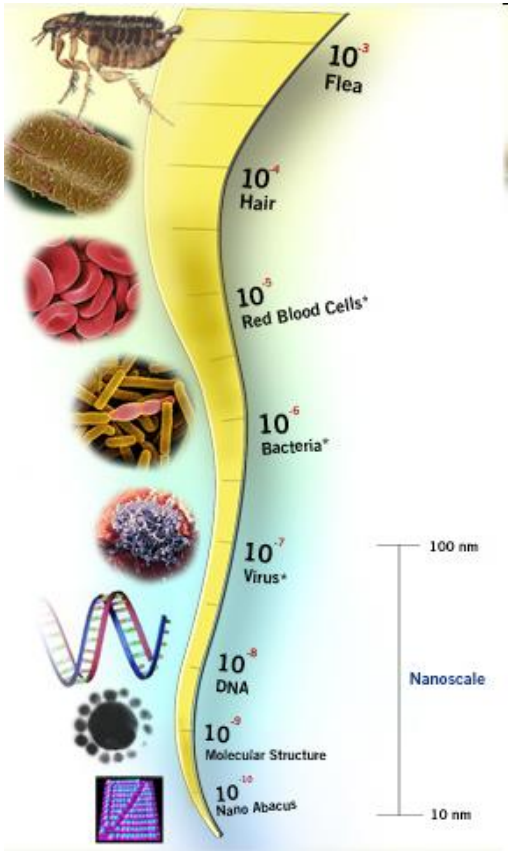
Nanoscienze

- "**Nano**"– dalla parola greca "νάνος" (piccolo di statura o gnomo) in ambito scientifico significa **10^{-9}**, cioè un bilionesimo di metro, o nanometro (nm).
- **Nanoscienza** si riferisce a quella parte della scienza che consente di manipolare strutture chimiche e biologiche con dimensioni che vanno a 1 a 100 nm.
- I mattoni della nanoscienza possono essere formati da poche centinaia a milioni di atomi. In questa scala emergono nuove proprietà – elettriche, meccaniche, ottiche, chimiche e biologiche – che sono diverse rispetto allo stesso materiale in dimensioni maggiori o in molecole.
- La nanoscienza riguarda la creazione di nuove nanostrutture chimiche e biologiche, lo scoprire e il comprendere le loro nuove proprietà e, in definitiva, imparare a organizzare le nuove nanostrutture in sistemi e dispositivi funzionali più grandi e complessi.
- La nanoscienza è un nuovo modo di pensare alla costruzione di materiali e dispositivi complessi con un completo controllo della funzionalità della materia e del suo assemblaggio su scala nanometrica.

quanto piccolo è un nanometro?

- oggetti nella scala dei nanometri hanno almeno una dimensione (lunghezza, altezza, profondità) tra 1 e 999 nm.

unità di misura	*abbreviazione*	*descrizione*
metro	**m**	**unità base SI della lunghezza**
centimetro	cm	$1x10^{-2}$ m (0.01 m)
millimetro	mm	$1x10^{-3}$ m (0.001 m)
micrometro	μm	$1x10^{-6}$ m
nanometro	nm	**$1x10^{-9}$ m** **la billionesima parte di 1 metro** **o 10 Å**



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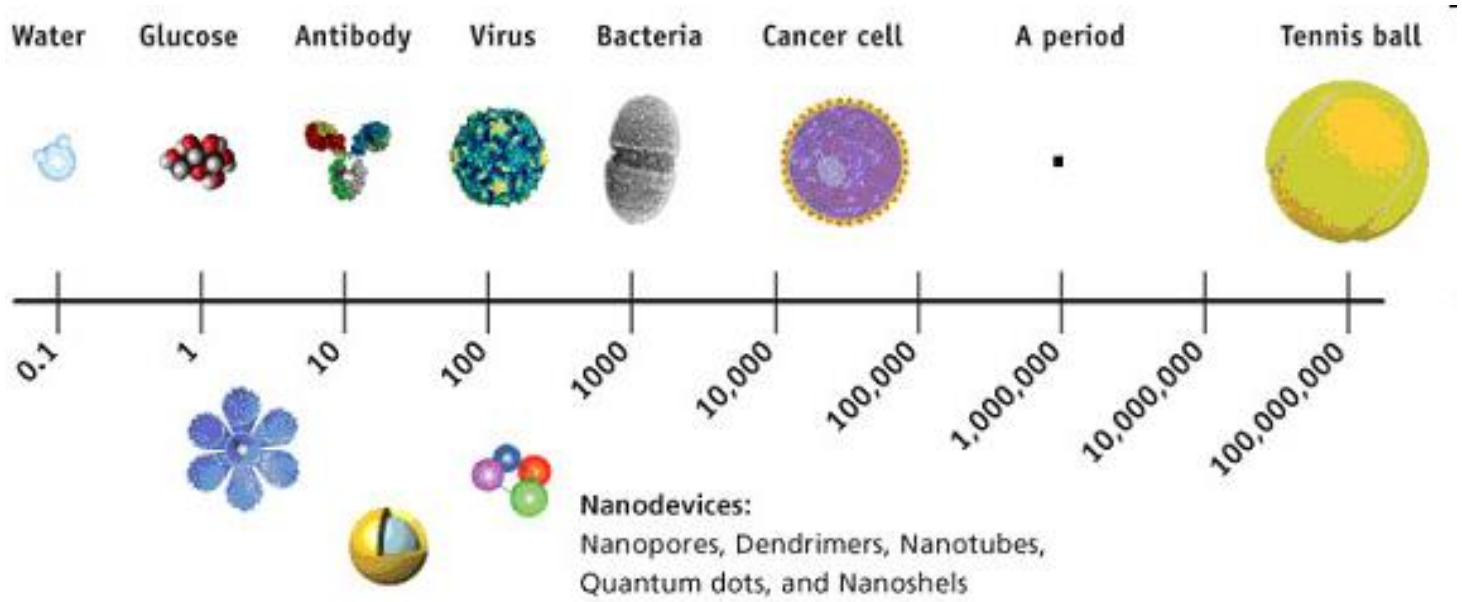
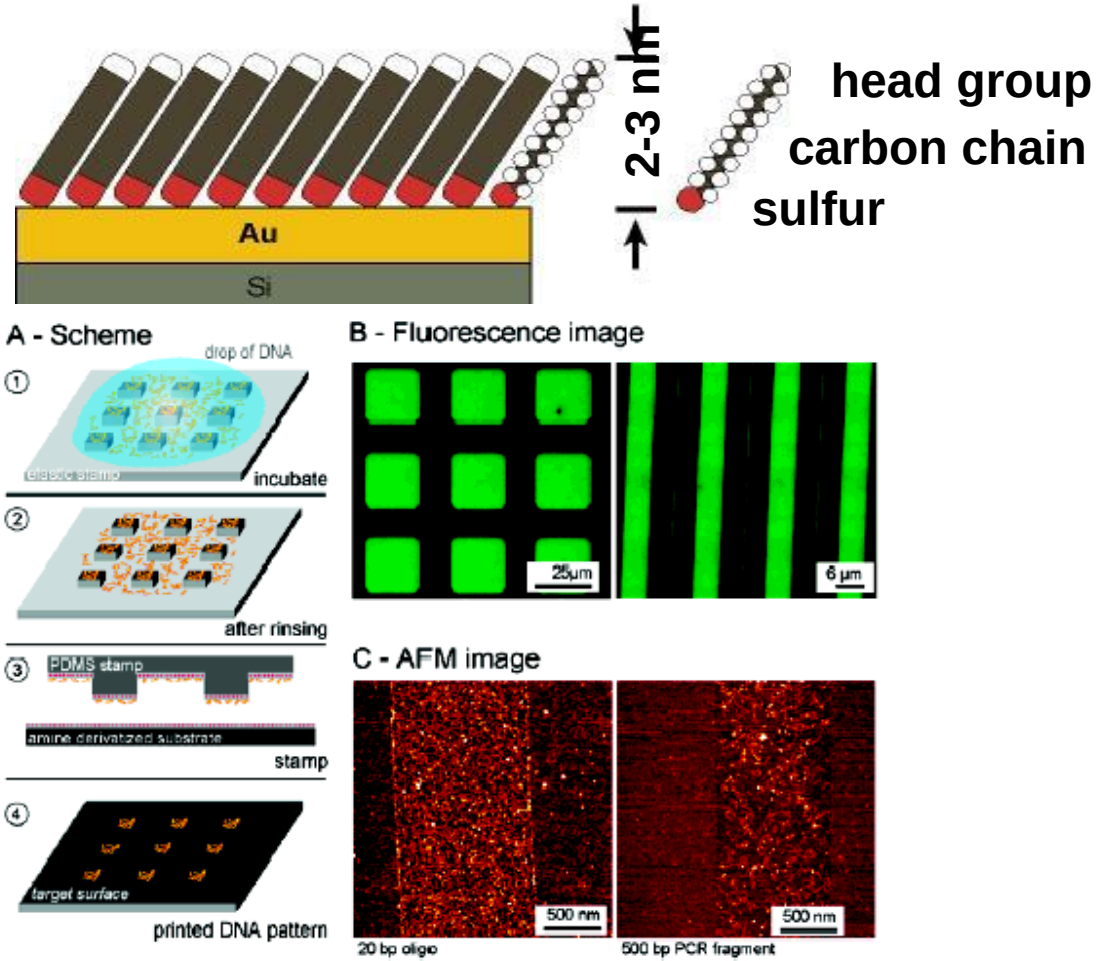
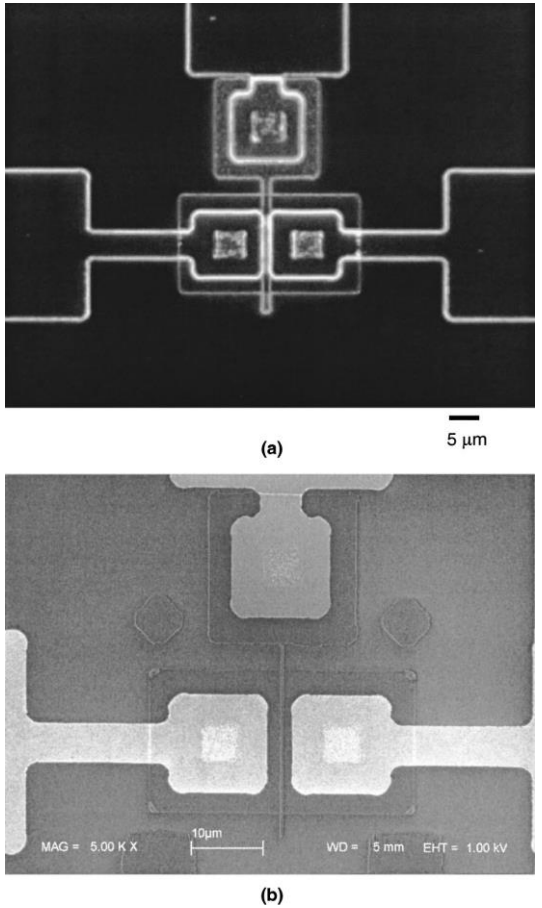


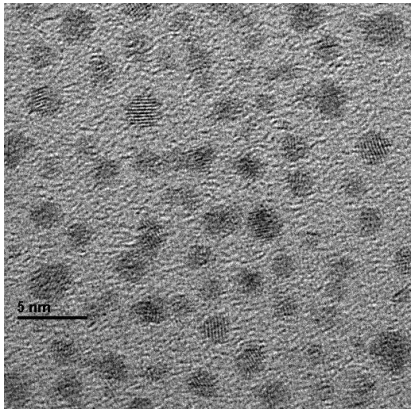
Nanomateriali



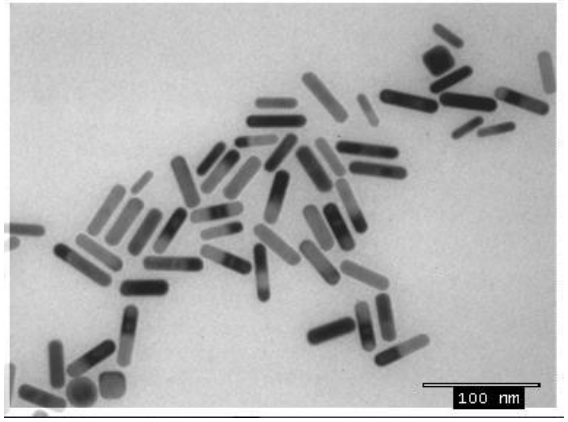
60-nm transistors



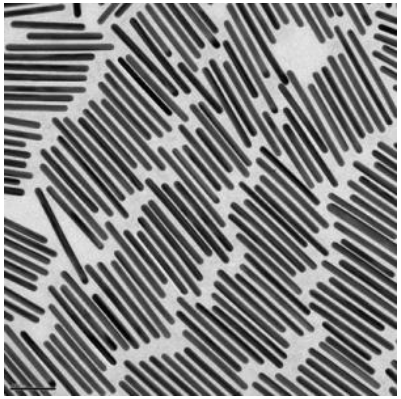
Nanomateriali



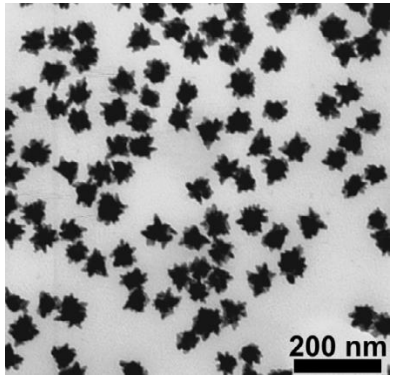
Nanoparticles – quantum dots



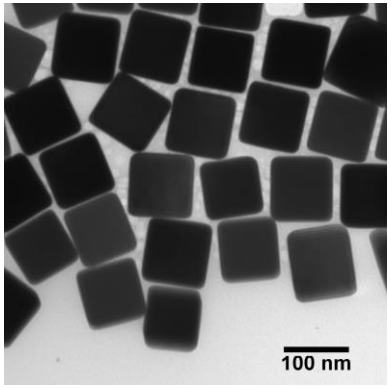
nanorods



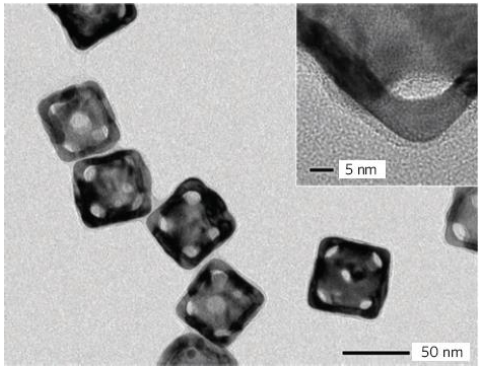
nanowires



Au nanostars

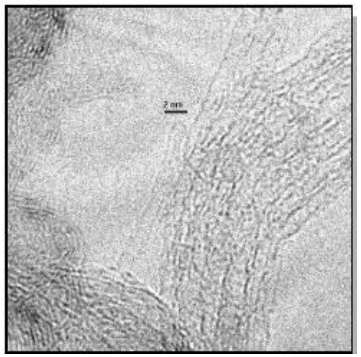


Ag nanocubes



Au nanoboxes

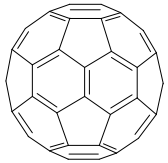
Nanomateriali



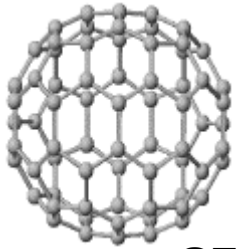
SWCNT, MWCNT

T = 1 (trasparenza elettronica)

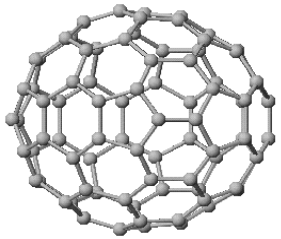
FULLERENI



C60

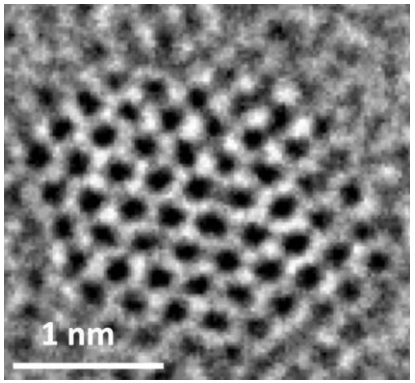


C70



C84

GRAFENE

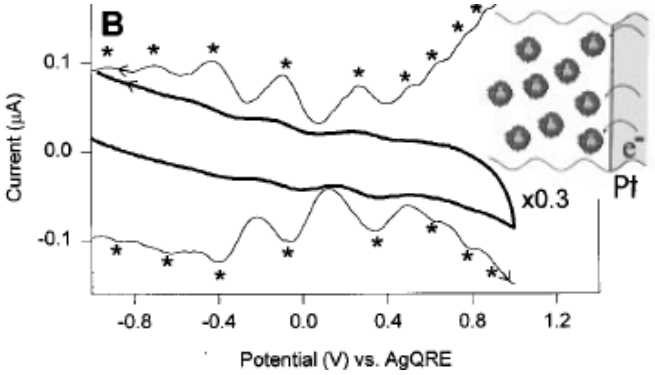


CARBON QDs

cosa hanno di speciale i nanomateriali?

Optical Properties

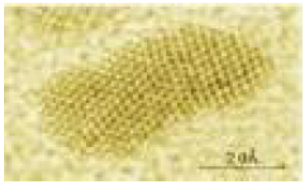
Electronic Properties

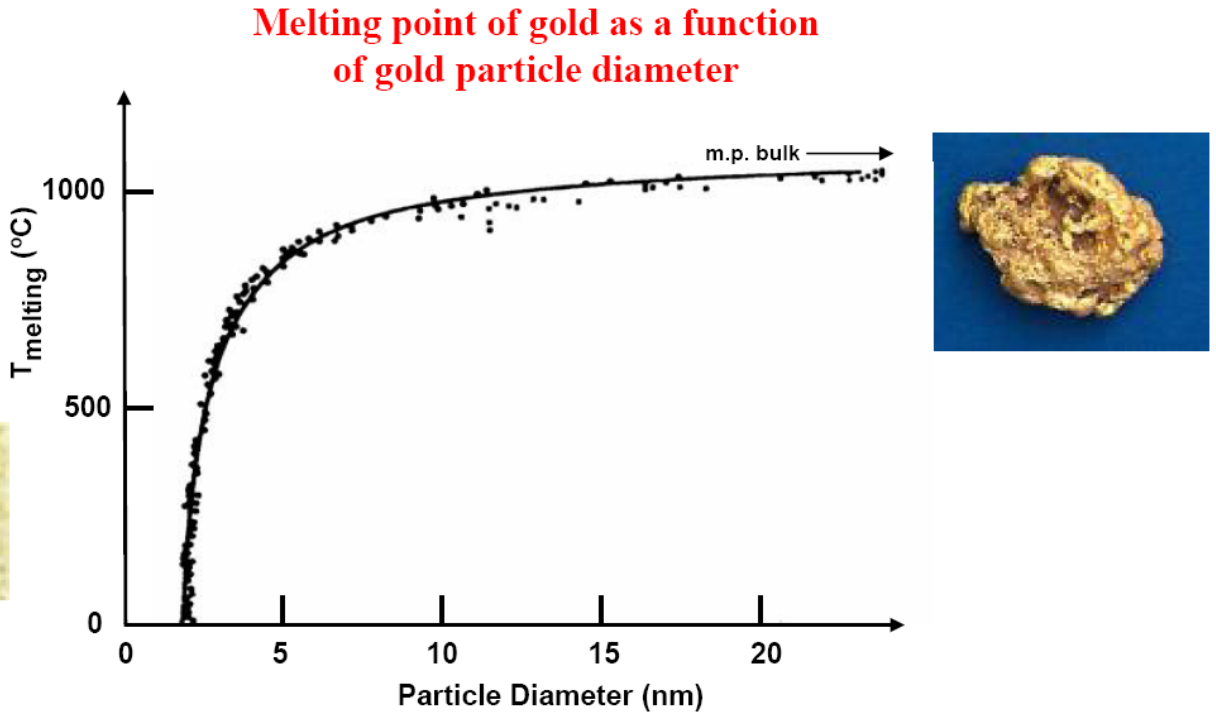


I materiali nella scala dei nanometri presentano proprietà differenti rispetto allo stesso materiale in scala maggiore!

cosa hanno di speciale i nanomateriali?

- The melting point of gold decreases rapidly as the particle dimension reaches the nanometer scale.





Reference: Buffat and Borel, Phys. Rev. A, vol. 13, p. 2287,1976.

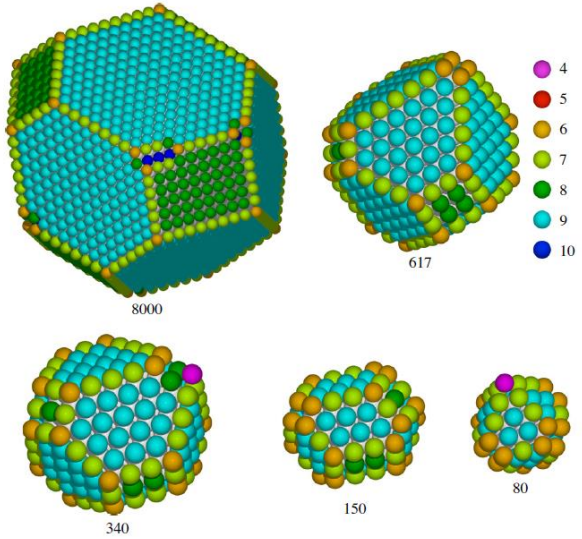
cosa hanno di speciale i nanomateriali?

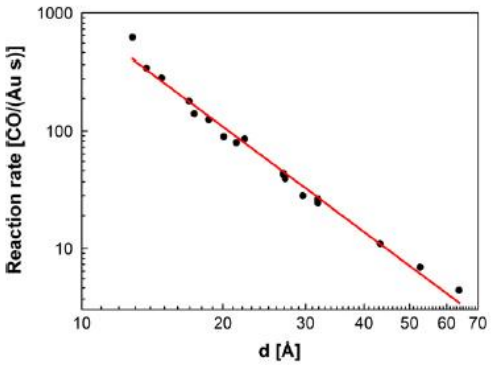
- Il rapporto tra area superficiale e massa è molto elevato:

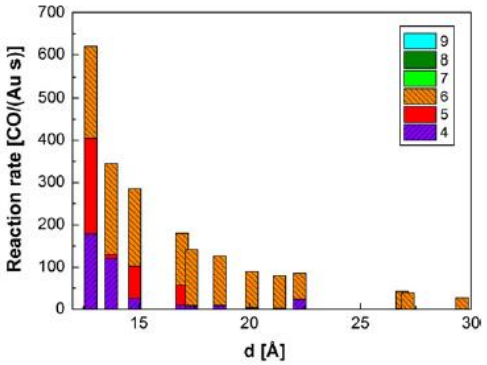
  gli atomi di superficie esperimentano una tensione superficiale o energia libera specifica di superficie.

  Quindi c'è una tendenza a minimizzare l'energia superficiale aumentando la reattività del sistema.

  Per es. nanoparticelle di oro sono **ottimi catalizzatori**





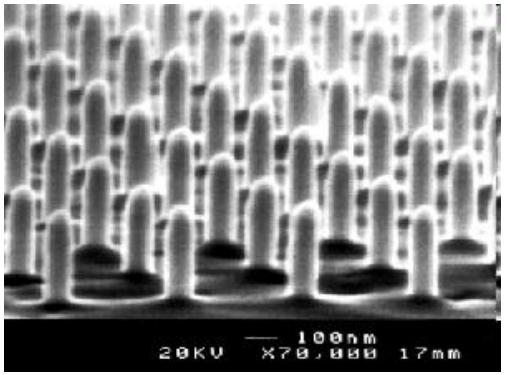


S.H. Brodersen et al. / Journal of Catalysis 284 (2011) 34–41

come si preparano: approccio **top-down**

approccio **top-down**: ricavare un oggetto più piccolo da uno più grande.

Questa tecnica comporta la riduzione delle dimensioni di un materiale fino a 10-100 nm.

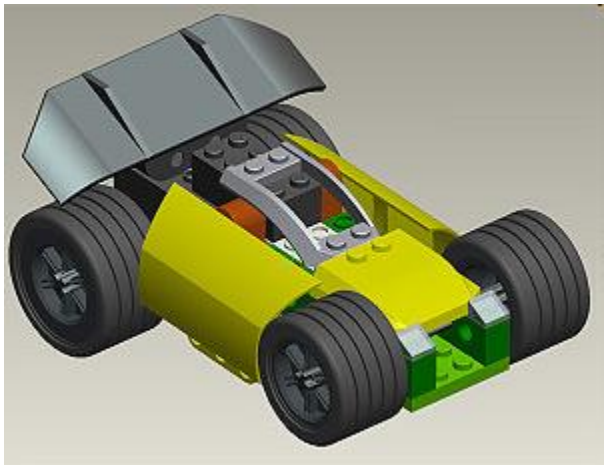


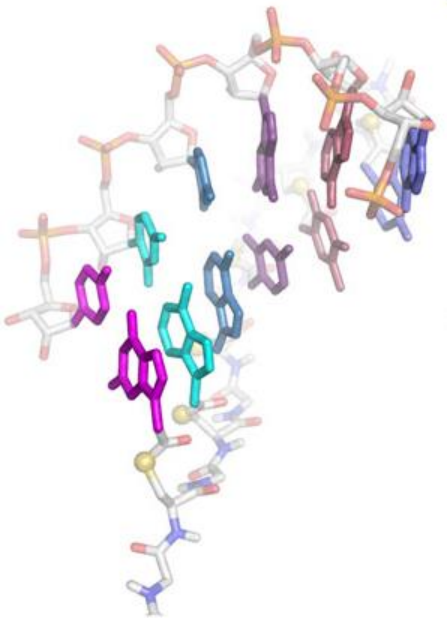
i dispositivi sono fabbricati da materiali macroscopici
attraverso un attento controllo dei processi di miniaturizzazione a livello atomico.

come si preparano: approccio **bottom up**

costruire dal basso usando elementi unitari, “building blocks”, per formare oggetti di dimensioni maggiori.

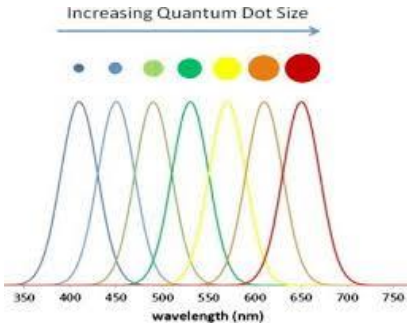
Il prodotto finale si ottiene assemblando progressivamente gli elementi costitutivi – atomi, ioni, molecole, nanoparticelle – per formare congegni, dispositivi, macchine a livello molecolare.





importanza della dimensione

- influenza il meccanismo di uptake,
- la formazione della protein corona
- tossicità
- proprietà ottiche



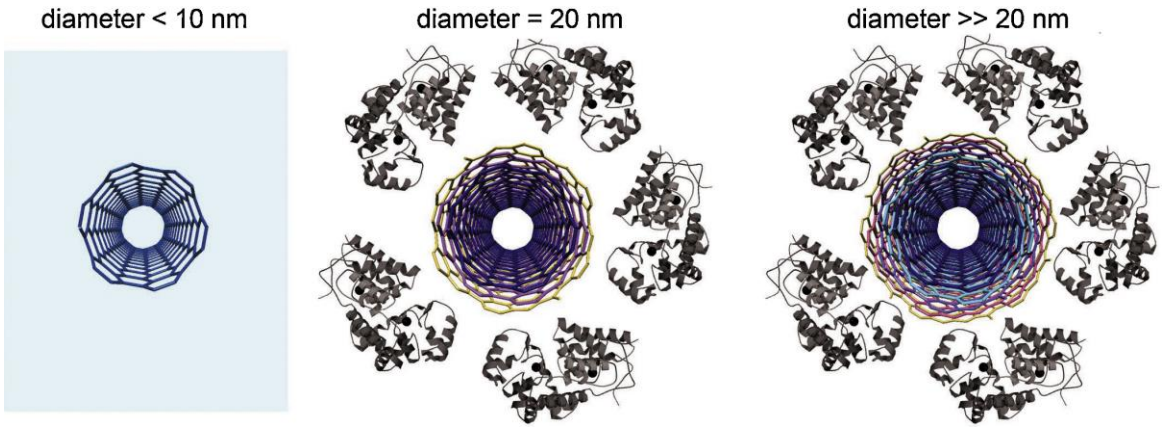


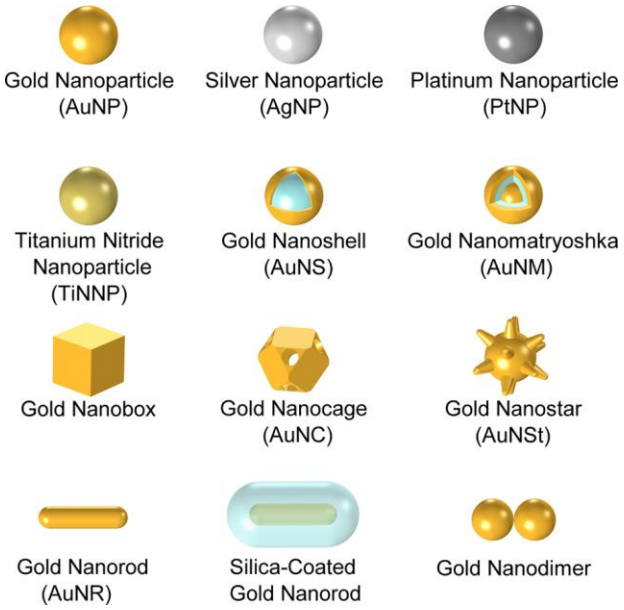
FIGURE 5

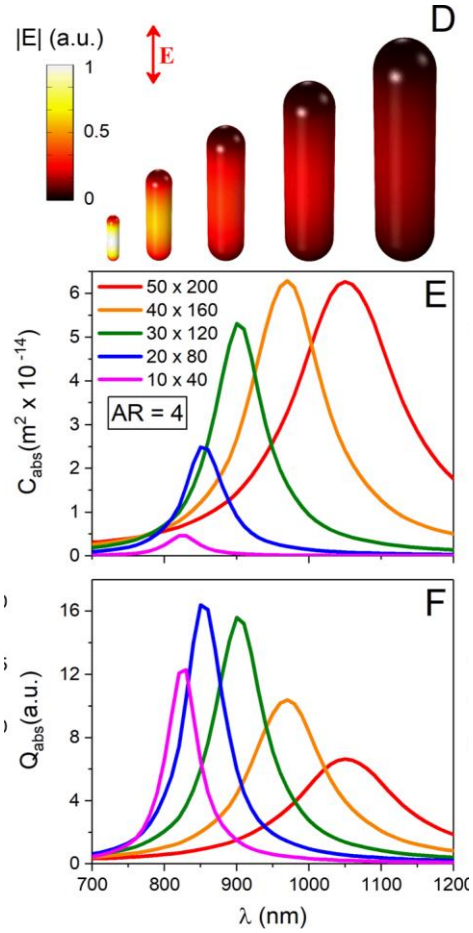
Formation of a protein corona around CNTs depends on the diameter of the tube. Nanotubes narrower than 10 nm (left) virtually bind no proteins on their surface, while for tubes with a diameter equal to or larger than 20 nm (center and right, respectively) formation of a protein corona is independent from the tubes width.

importanza della forma

forma, morfologia

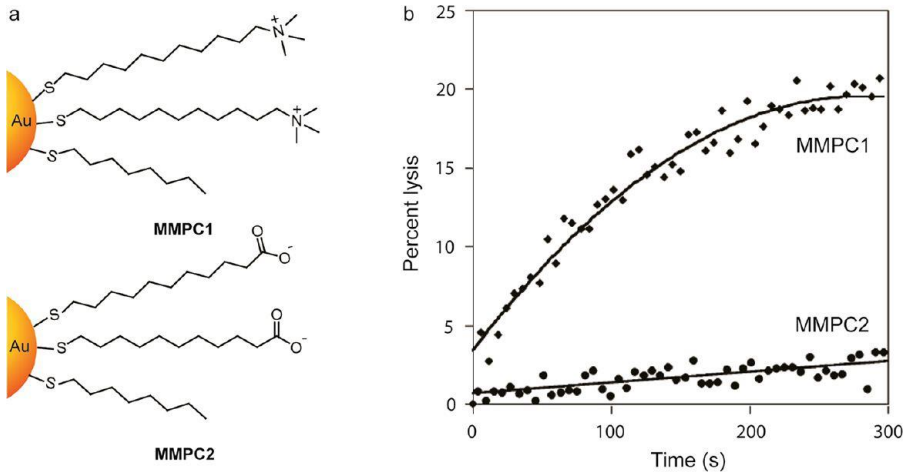
cambia l'area superficiale, la reattività, l'interazione con l'ambiente circostante proprietà optoelettroniche diverse





importanza della chimica di superficie

- chimica di superficie

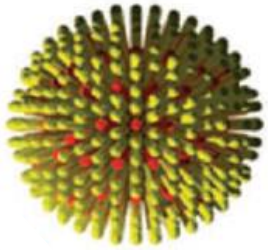


Effect of functionalized NPs on the disruption of lipid bilayers. (a) Surface functionalized MMPC1 and MMPC2. (b) Comparison of cationic MMPC1 and anionic MMPC2 (220 nM) in disrupting vesicles with an overall negative charge (SOPC/SOPS, L-R-stearoyloleoyl-phosphatidylcholine/L-R- stearoyl-oleoyl-phosphatidylserine)

V.M. Rotello et al. ACCOUNTS OF CHEMICAL RESEARCH 681–691, 2013.

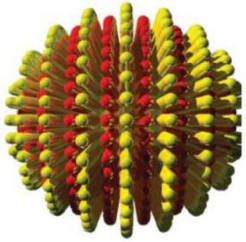
importanza dell'organizzazione di monostrati misti

unstructured AuNPs



2:1 MUS/brOT

striped AuNPs



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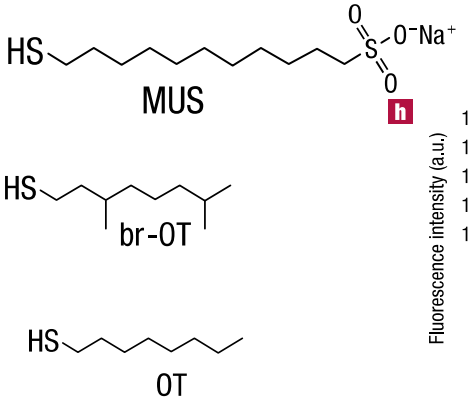
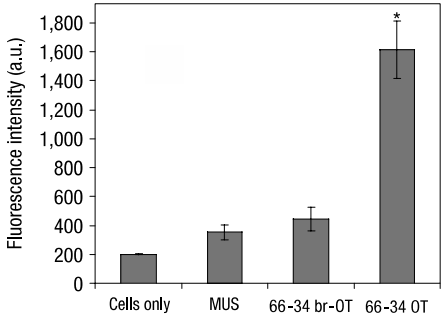
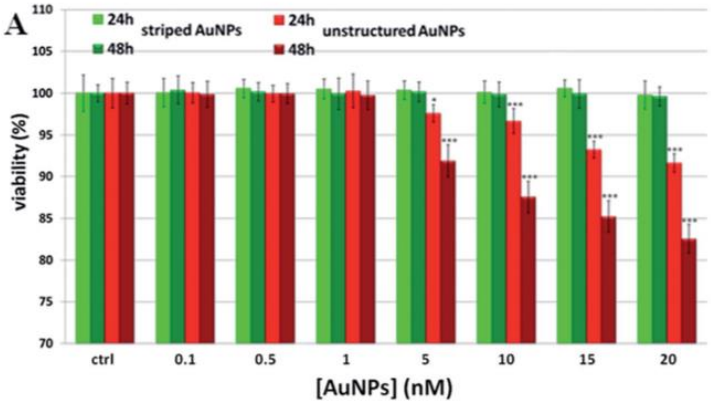
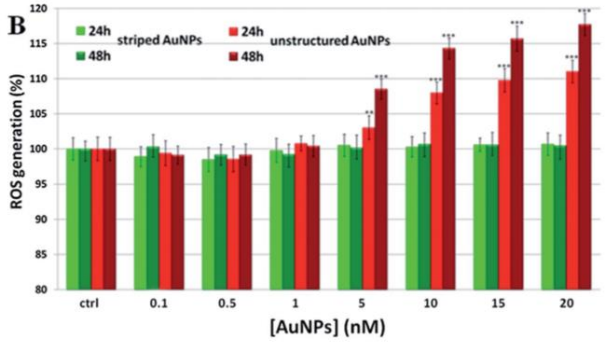




F. Stellacci *et al. Nature Mater.* **2008**, *7*, 588.

cellular uptake





F. Stellacci, P. P. Pompa *Nanoscale* **2014**, *6*, 7052.

nanotecnologie

Nanotechnology is …

«…research and technology development at the atomic, molecular or macromolecular levels, in the length scale of approximately 1 –100 nm …»

National Science Foundation

"nanotechnology is the understanding and control of matter at the nano-scale, at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications. Encompassing nanoscale science, engineering, and technology, nanotechnology involves imaging, measuring, modeling, and manipulating matter at this length scale."

National Nanotechnology Initiative, May 20, 2012

nanotecnologie

- Le nanotecnologie operano in un ambito d'investigazione **multidisciplinare**, coinvolgendo molteplici settori di ricerca, tra cui:

  biologia molecolare,

  chimica,

  scienza dei materiali,

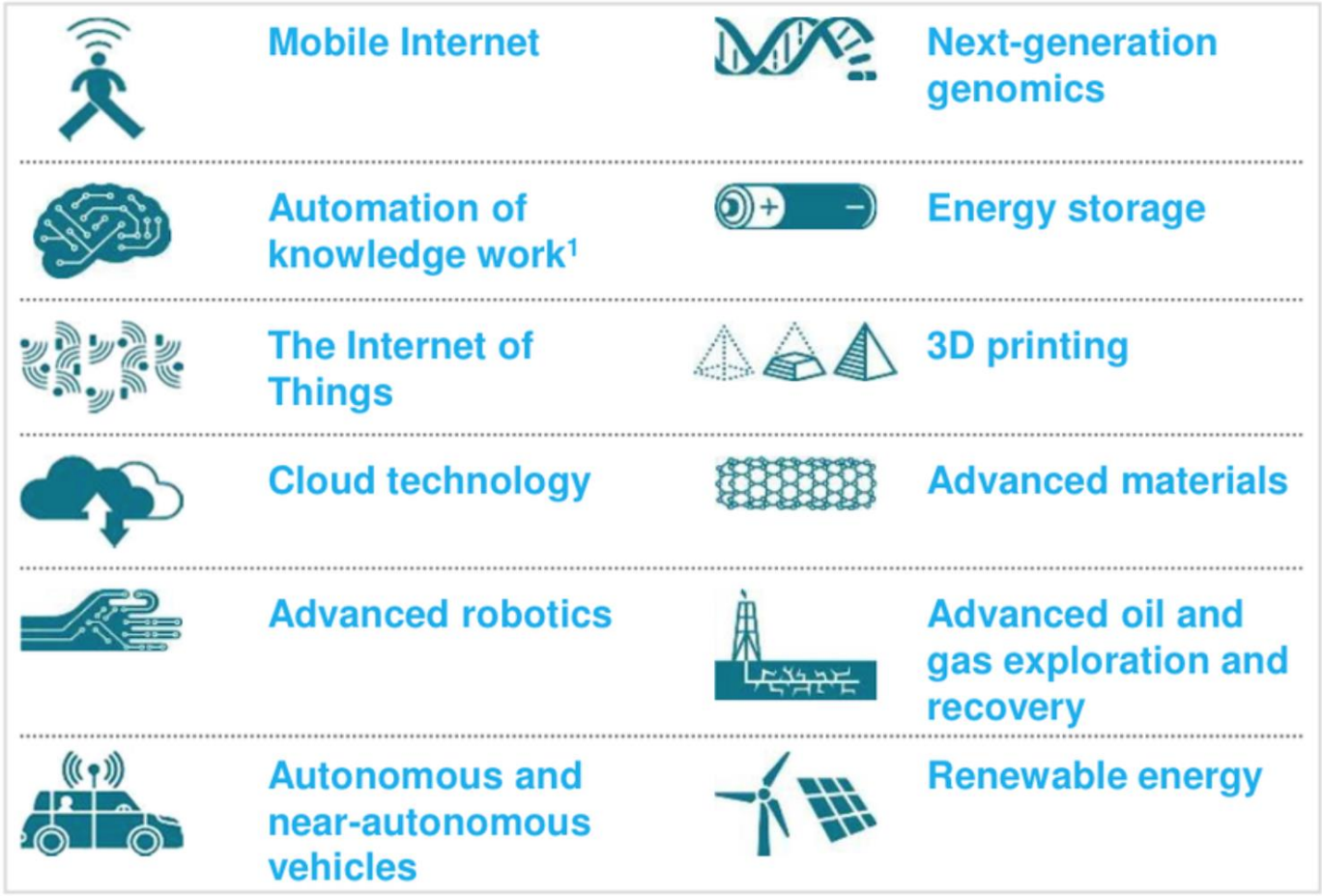
  fisica (sia applicata che di base),

  ingegneria meccanica,

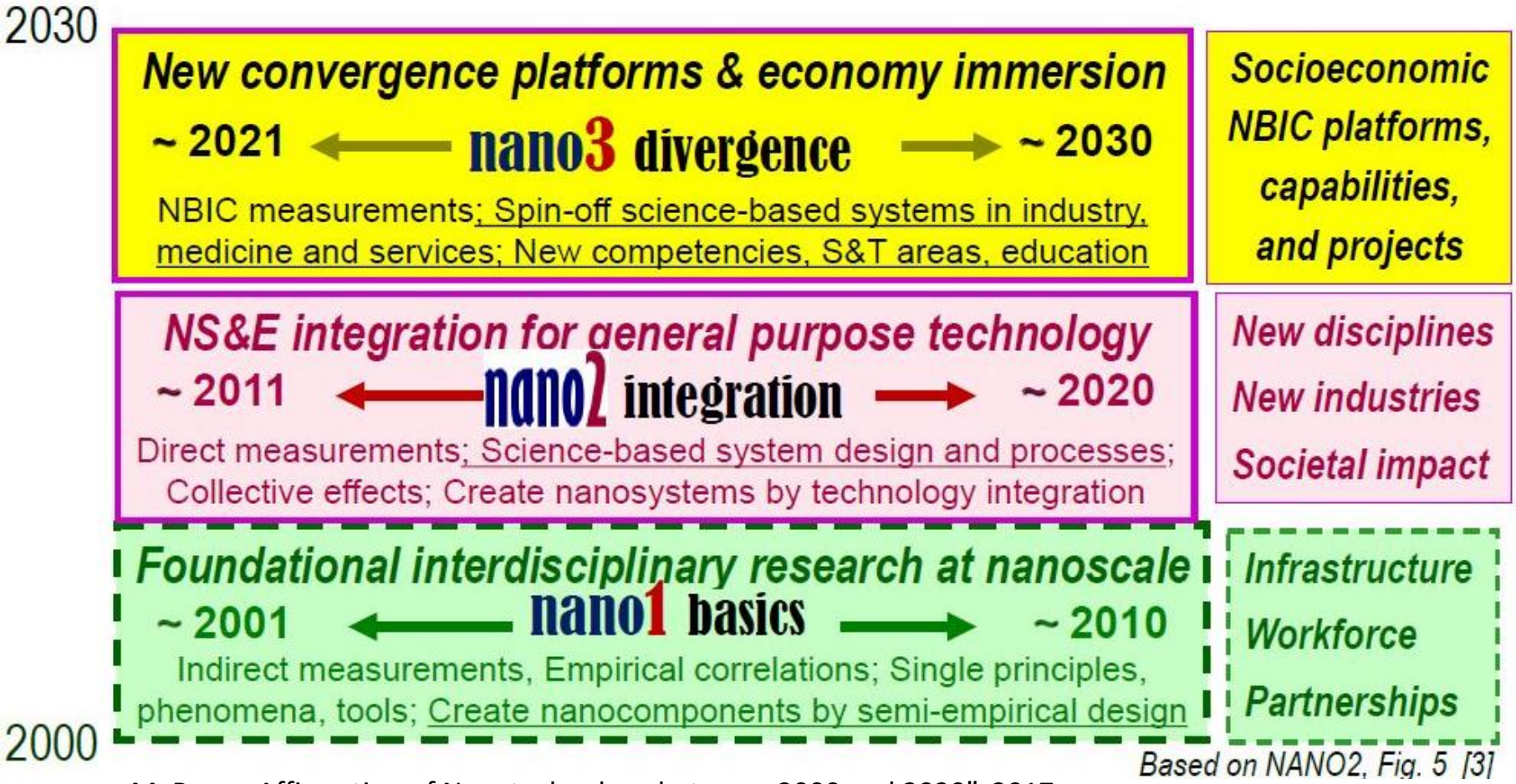
  ingegneria chimica ed elettronica

e' una tecnologia pervasiva

nanotecnologie



evoluzione delle nanotecnologie



M. Roco «Affirmation of Nanotechnology between 2000 and 2030", 2017

Established industrial applications

- Particles as chemically inert additives - used in pigments, polymer fillers and surface finishing
  - Carbon, titania and silica polymer fillers
  - 2D particles as polymer fillers
  - Effect pigments, dyes and UV protection
  - Processing aids
  - Functional surfaces

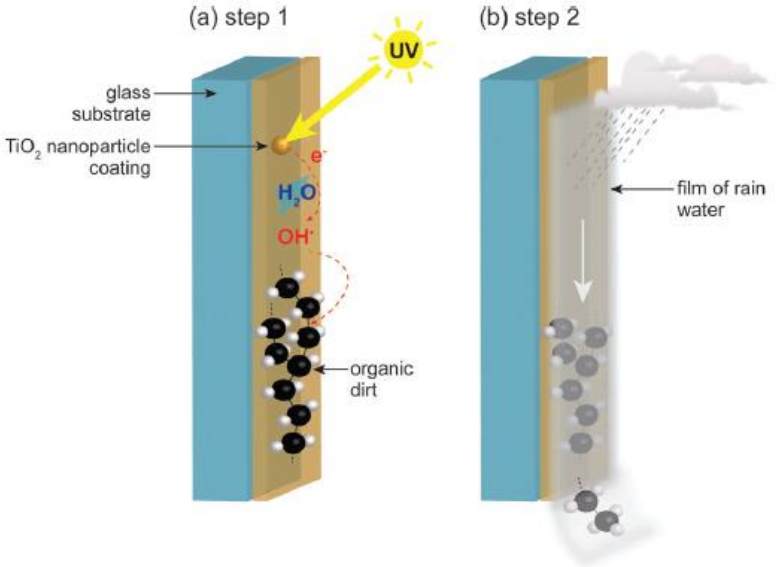


Fig. 9 Self-cleaning window or car glass (*e.g.* Pilkington Activ™) functions in two steps: (a) a photo-catalytic coating containing TiO_2 nanoparticles reacts with UV light and breaks down organic matter (dirt). (b) The organic residues are then easily washed from the hydrophilic surface by rain water.

Established industrial applications

- Chemically active particles:
  - Heterogeneous catalysis energy and pollution related applications
  - Biomaterials
  - Antimicrobial additives

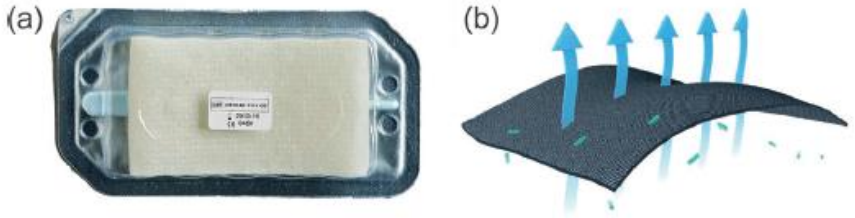
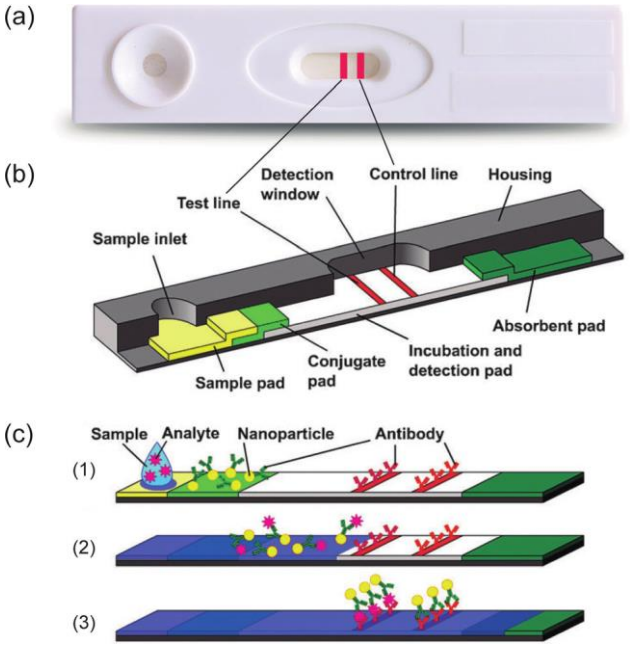


Fig. 10 (a) Antimicrobial polymer foil with silver/additive nanoparticles (Perlazid®, Perlen Packaging, Switzerland) and (b) antimicrobial textile with silver nanoparticles (active > silver™ technology, Schöller Textil AG, Switzerland) which inhibit the reproduction of odor-causing bacteria and improves the moisture management. (Reproduced with permission by Perlen Packaging and Schöller).

Biosensori usa e getta



dispositivo per il test di gravidanza che si basa sull'uso di nanoparticelle di oro

NPs for therapy and diagnosis

CYT-6091 gold NPs, 27 nm of diameter with TNF+ PEG

Doxil: pegylated liposomes+doxorubicin

SPIOs for MRI

AuroLase Therapy to treat by hyperthermia prostate cancer cells

trattamenti nanotecnologici per superfici

2D SAM per trattamento vetri, anticalcare

Trattamento nanotecnologico antipioggia per parabrezza - Nanotech One 3360 125ml

Marchio: Clean Technology

materiali nanotecnologici

Easton CNT (carbon nanotube) baseball bat

ArcticShield "stink-proof" socks with silver nanoparticles

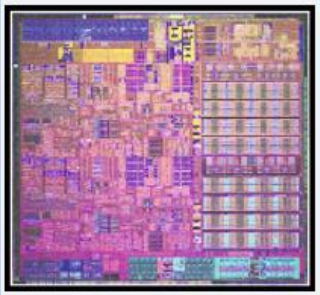
Nano Wear sunblock with TiO_2/ZnO_2 nanoparticles

IPOD Nano with 50nm features in memory chip

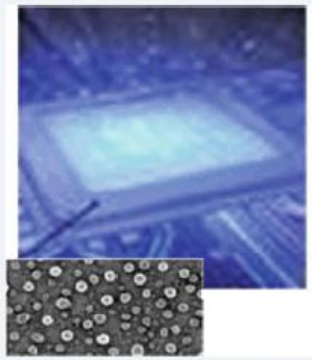
LacVert Nano hydrating cream

Zelens Fullerene C-60 (buckyball) Face Cream to "attract and neutralise the damaging free radicals"

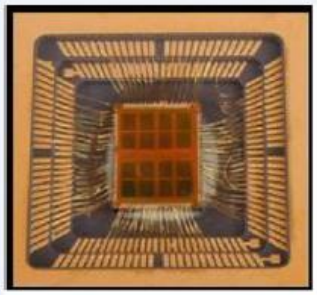
II. Nanoelectronic and nanomagnetic components incorporated into common computing and communication devices, in production in 2010



32 nm complementary metal oxide semiconductor (CMOS) processor technology by Intel (2009), (gate length of 30 nm) with high-K / metal gate. This technology is used to make integrated circuit (IC) chips that will be available in a wide variety of laptop, desktop, and server computer systems, giving higher speed, higher density, and lower power.

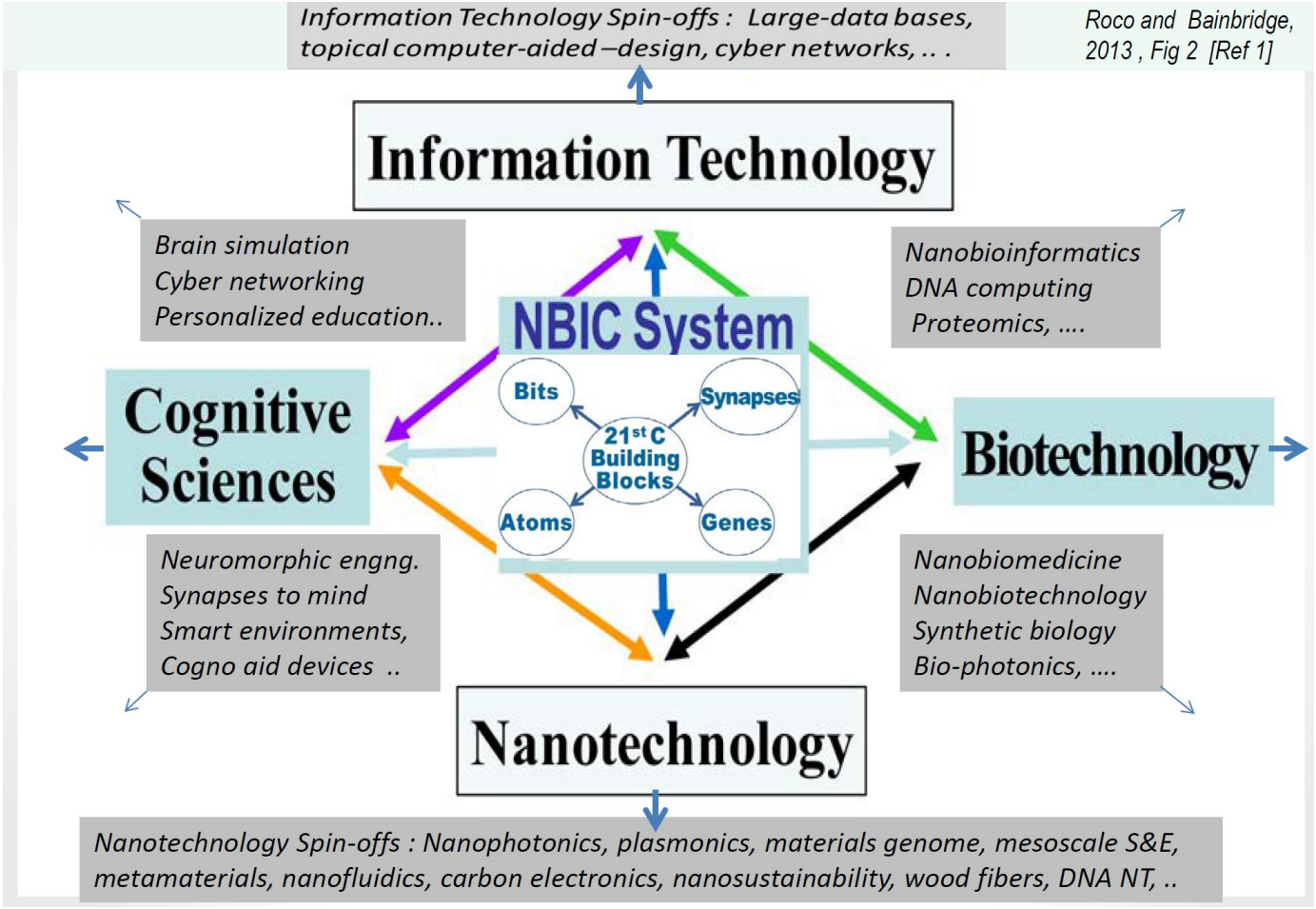


90 nm thin-film storage (TFS) flash flexmemory by Freescale (2010) for next-generation microcontrollers, utilizing silicon nanocrystals as the charge storage layer. The nanocrystal layer enables higher-density arrays, lower-power operation, faster erase times, and improved reliability. Micro-controllers are the "brains" of a wide variety of industrial and consumer products.



16 megabit magnetic random access memory (MRAM) by Everspin (2010) is based on nanometer-scale magnetic tunnel junctions. These memories have many industrial and commercial applications, such as saving data during a system crash, enabling resume-play features, quick storage and retention of data encryption during shutdown, and retention of vehicle data in an accident for later analysis.

converging fundational technologies



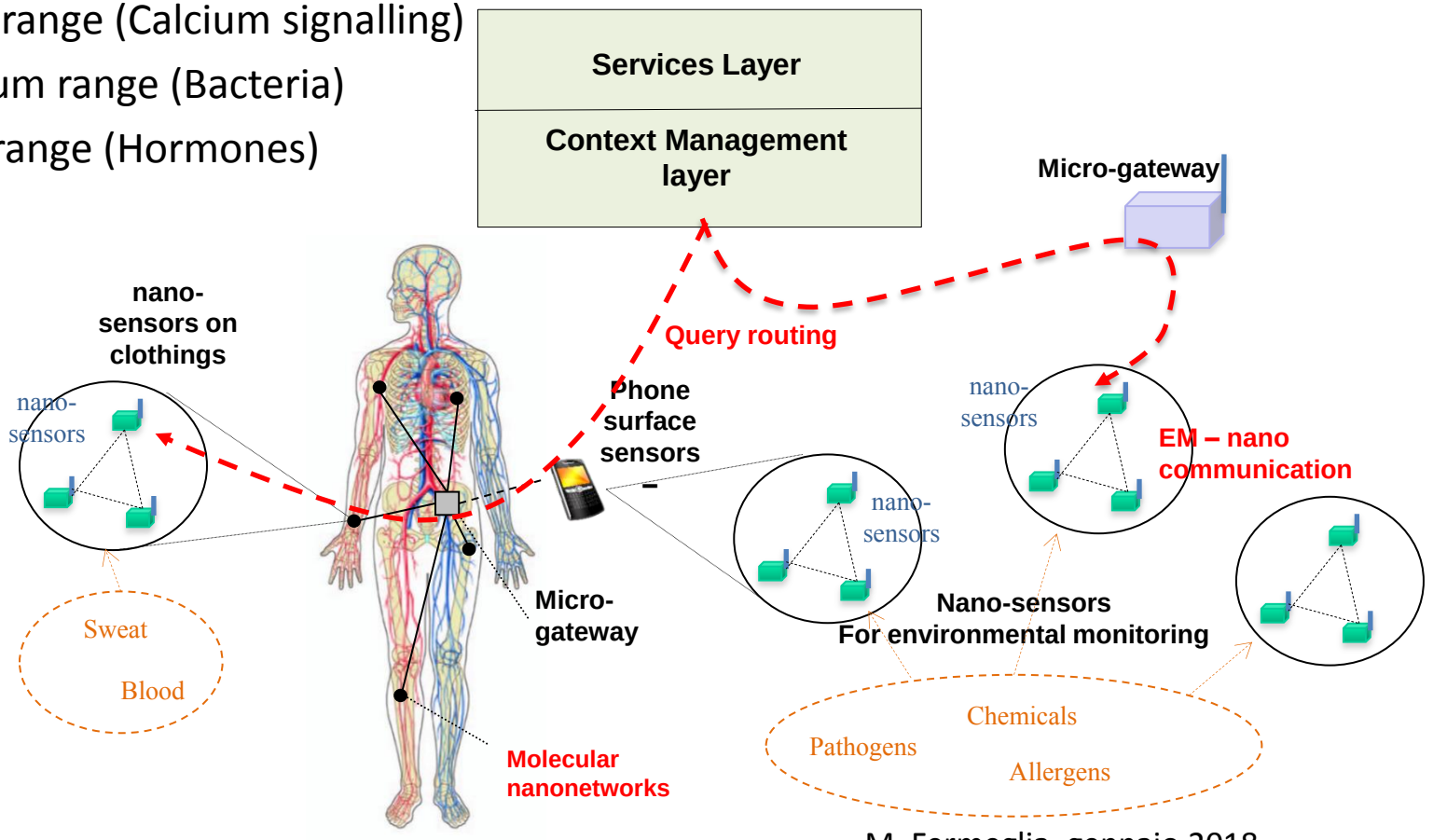
Internet of Nano Things (IoNT)

M. Fermeglia, gennaio 2018

- The internet of Nano things (IoNT) is a Nano scale network of physical objects that can interact with each other by Nano communication.
- Two broad Areas
  - Electromagnetic (EM) Nano Communications
    - Communication among Nano devices ranging in the size from 2 to 6 micrometers.
    - The components antennas, EM transceivers, and processors are used that are also built at Nano scale.
    - Antennas are built from grapheme material and communicate in THz band.
  - Molecular Communications
    - Sender Nano machines encode information into information molecules (e.g. DNA, proteins, peptides)
    - Information can be transmitted within a DNA component.
    - Ability to create communication systems and networks using biological components and processes that are found in nature.
    - Routing at micro gateway in molecular Nano networks is query based.

Internet of Nano Things (IoNT) for healthcare applications

- Molecular communicationnetworks
  - Short range (Calcium signalling)
  - Medium range (Bacteria)
  - Long range (Hormones)



M. Fermeglia, gennaio 2018

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ITALIA-SLOVENIJA
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NANO-REGION
Progetto strategico co-finanziato dal Fondo europeo di sviluppo regionale
Strateški projekt sofinancira Evropski sklad za regionalni razvoj

Nano-Region: una rete aperta per l'innovazione attraverso le nanotecnologie

- Obiettivo Complessivo del Progetto:

Sviluppo di una rete di centri di ricerca e parchi a vocazione nano-tecnologica focalizzata alla promozione del trasferimento tecnologico. La rete, rivolta alle imprese, offrirà accesso alle tecnologie abilitanti e contribuirà a creare una nuova cultura dell' innovazione, tramite un programma di eventi aperti mirati, un servizio di consulenze e di studi di fattibilità, rispondendo delle esigenze manifestate dalle singole imprese e stimolando la creazione di nuovi prodotti, mercati e imprese.

https://www.ita-slo.eu/it/nano-region

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Partners:

Consiglio Nazionale delle Ricerche – Istituto Officina dei Materiali CNR-IOM

Università Ca' Foscari Venezia – Dipartimento di Management

Tehnološki Park Ljubljana

Center odličnosti nanoznanosti in nanotehnologije - CO Nanocenter

Primorski Tehnološki Park d.o.o.

RRA Zeleni kras, d.o.o.

Università Ca' Foscari Venezia – Dipartimento di Scienze Molecolari e Nanosistemi (DSMN)

Univerza v Novi Gorici

Elettra-Sincrotrone Trieste S.C.p.A.

Universita' di Trieste – Dipartimento di Scienze Chimiche e Farmaceutiche

Conclusioni

- I nanomateriali, i materiali nanostrutturati e le nanotecnologie hanno portato ad una rivoluzione scientifica e culturale negli ultimi 60 anni.
- Questi materiali hanno applicazioni in moltissimi campi: dall'elettronica alla medicina, dall'arte alla fisica, dalla biologia all'ingegneria, dall'energia all'ambiente, ma le potenzialità vanno molto oltre.
- Una attenta valutazione dell'impatto che hanno sulla salute e sull'ambiente deve essere condotta in modo mirato e specifico. Generalizzare non è possibile.
- "Pensare "nano" in realtà vuol dire soprattutto pensare "in grande", andare oltre gli schemi convenzionali e immaginare strade completamente nuove per fare le cose che vorremmo." (G. Pacchioni in "Quanto è piccolo il mondo"; Zanichelli 2008")

grazie a tutti voi per l'attenzione

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