

Nano-tecnologie: dalle Scienze Fisiche a campi interdisciplinari

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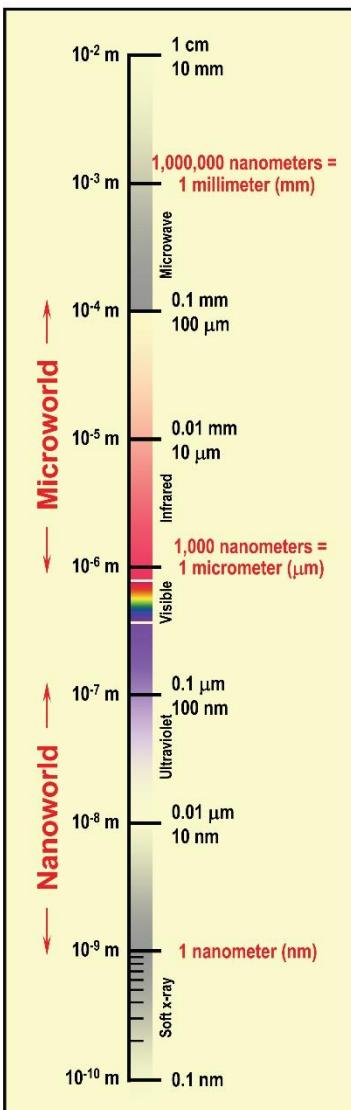
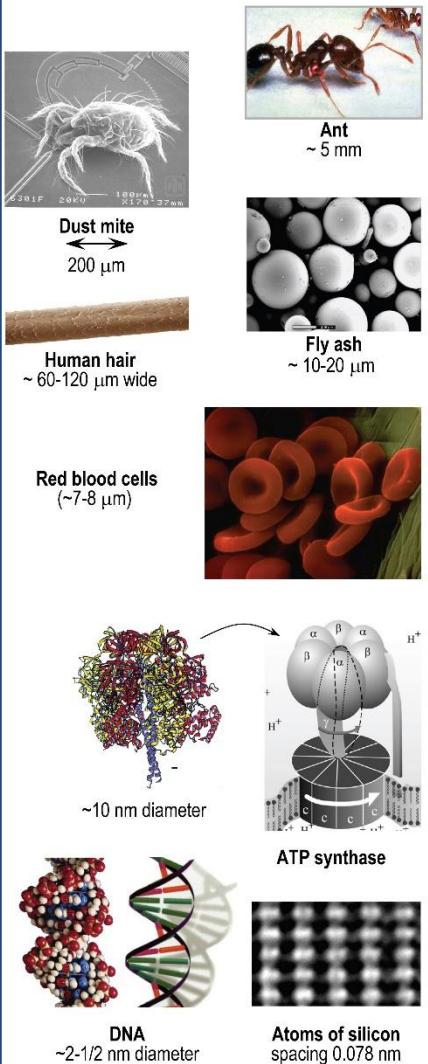


Pisa 12.12.2018

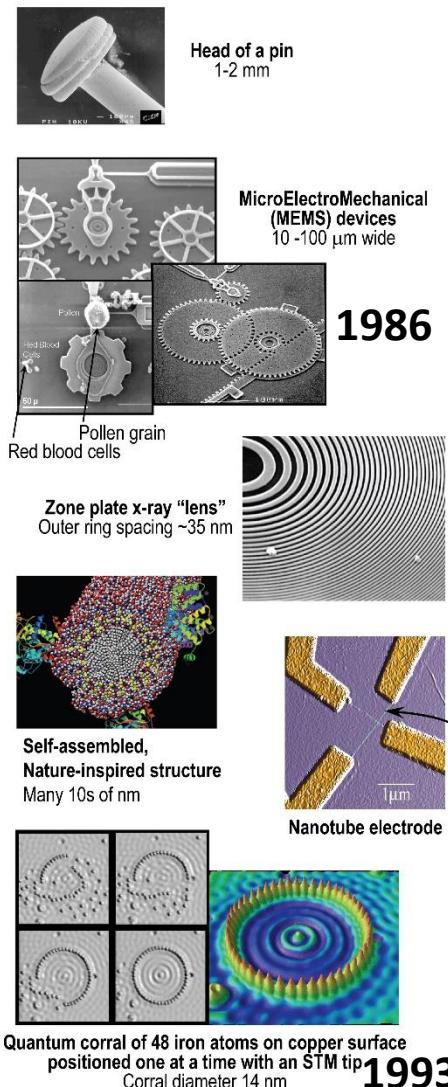


The Scale of Things – Nanometers and More

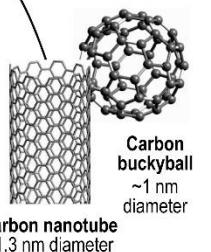
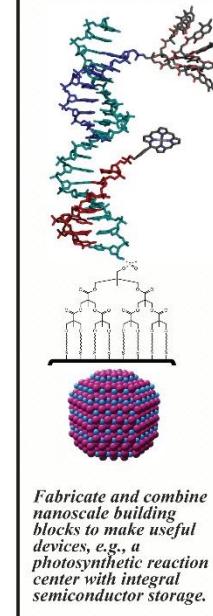
Things Natural



Things Manmade



The Challenge



Rivoluzione
industriale

200 anni

Atterraggio
sulla Luna
1969

22 anni

World Wide
Web
1991

12 anni

Genoma
umano
2003

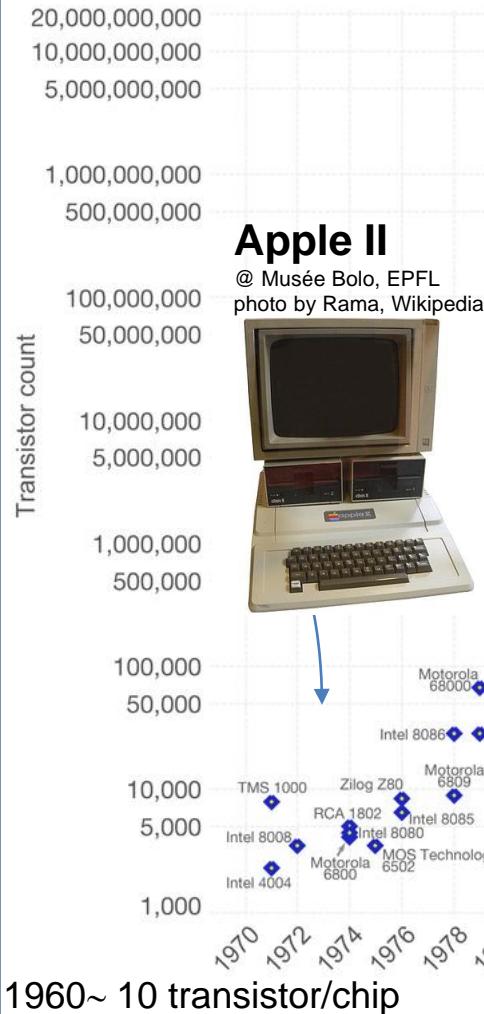
Office of Basic Energy Sciences
Office of Science, U.S. DOE
Version 05-26-05, jmd

La miniaturizzazione ha cambiato il modo di vivere, giocare, lavorare: l'esempio dei microprocessori

Moore's Law – The number of transistors on integrated circuit chips (1971-2016)

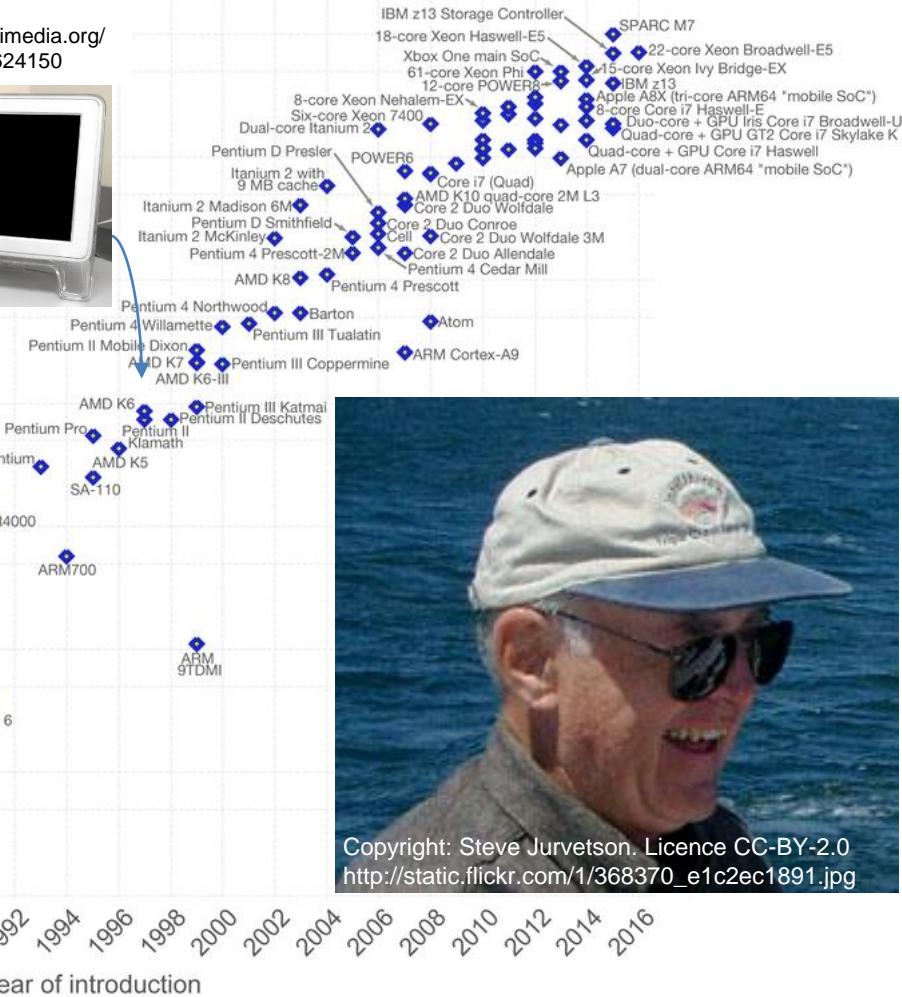
Our World
in Data

Moore's law describes the empirical regularity that the number of transistors on integrated circuits doubles approximately every two years. This advancement is important as other aspects of technological progress – such as processing speed or the price of electronic products – are strongly linked to Moore's law.



Power Mac G4

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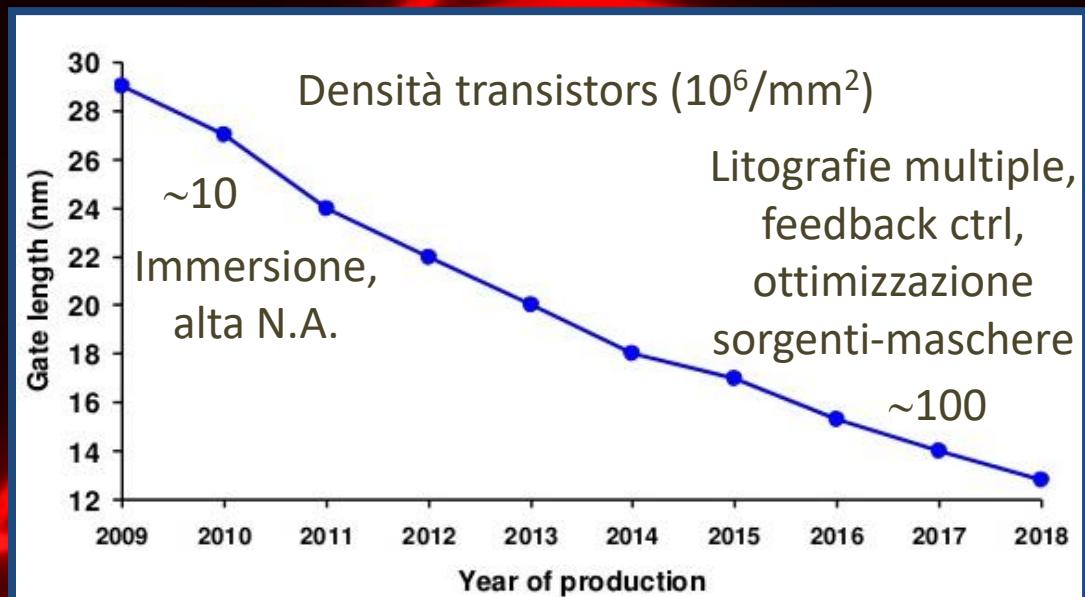
Data source: Wikipedia (https://en.wikipedia.org/wiki/Transistor_count)

The data visualization is available at OurWorldinData.org. There you find more visualizations and research on this topic.

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La miniaturizzazione: l'esempio dei microprocessori

La ‘vera’ legge di Moore:
diminuzione delle
dimensioni dei gate dei
transistors

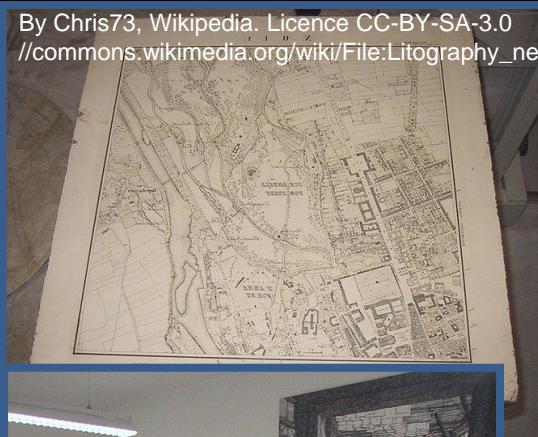


International Technology Roadmap for Semiconductors, 2011

Litografia, microlitografia, nanolitografia

By Chris73, Wikipedia. Licence CC-BY-SA-3.0

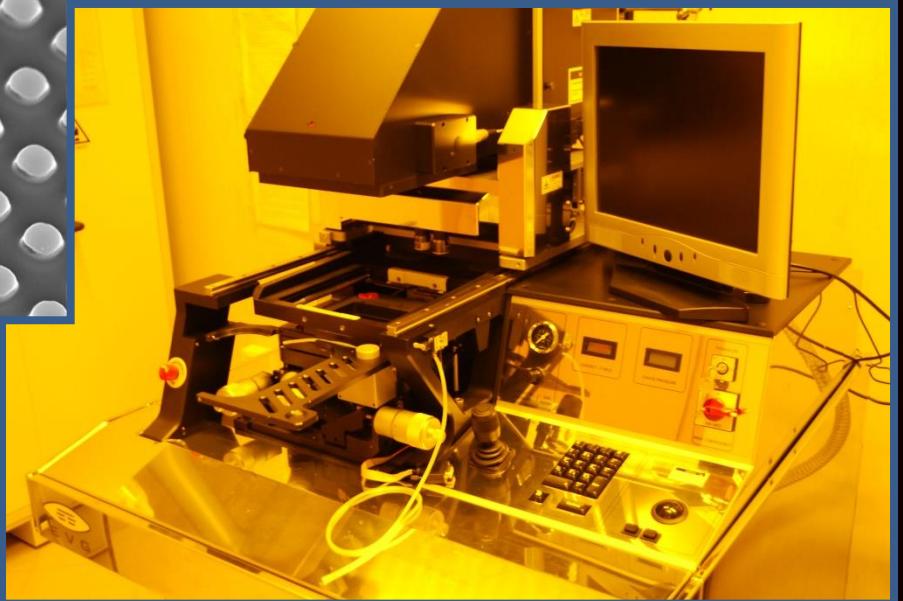
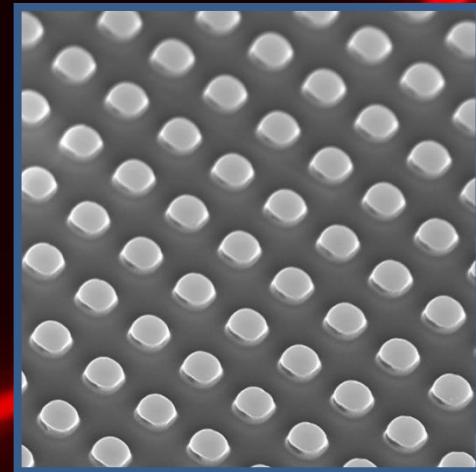
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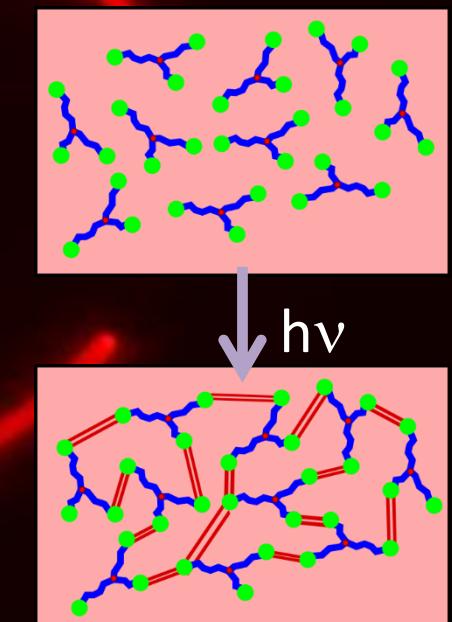
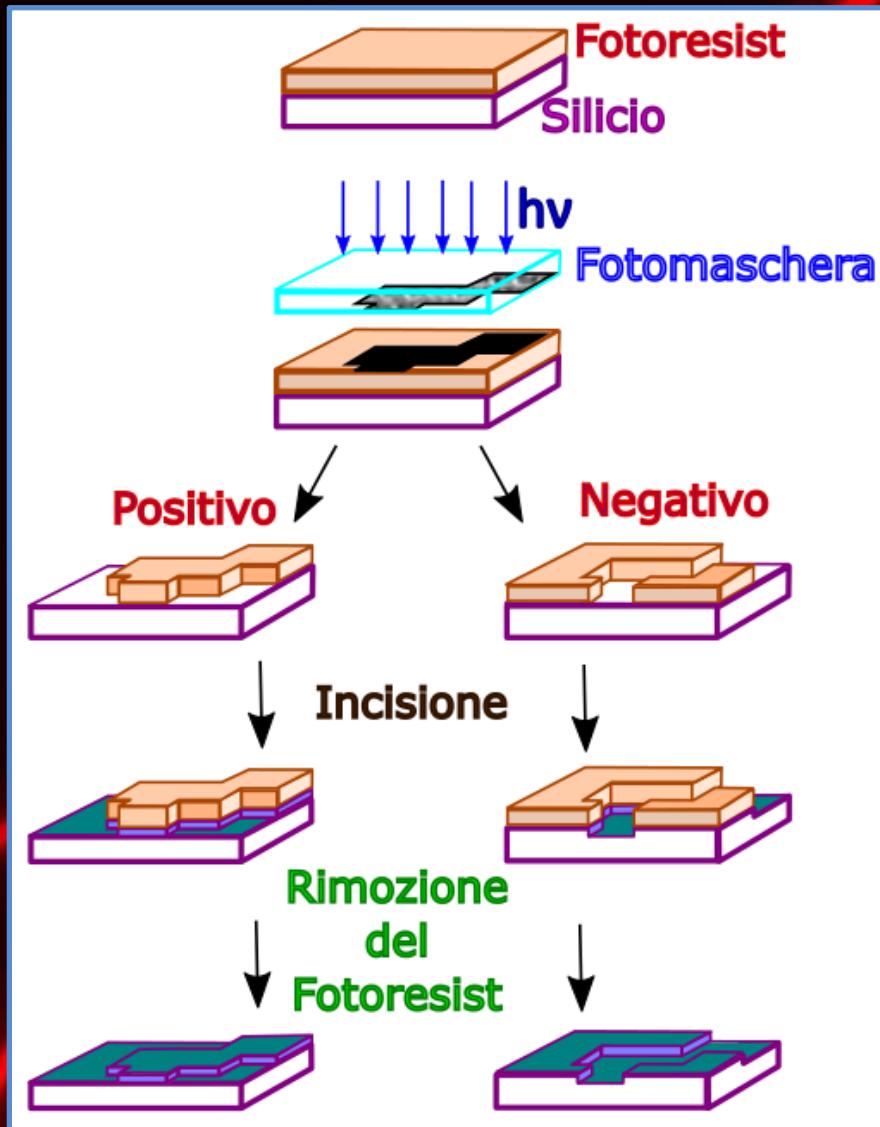
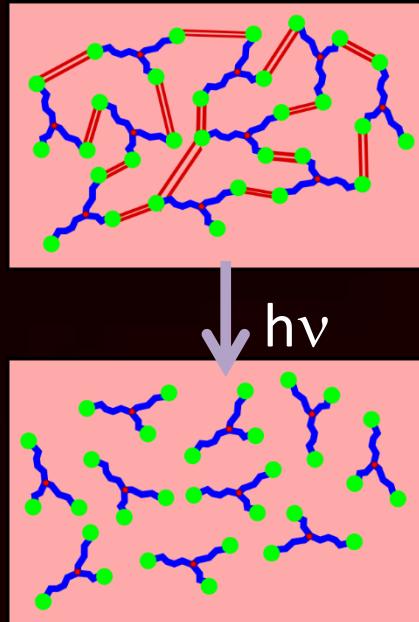
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//commons.wikimedia.org/wiki/File:Lithograph_press_with_map_of_Moosburg_02.jpg



L'esempio della fotolitografia: interazione tra fotoni e molecole organiche



Vantaggi e svantaggi: necessità di micro- e nano-tecnologie ‘soft’

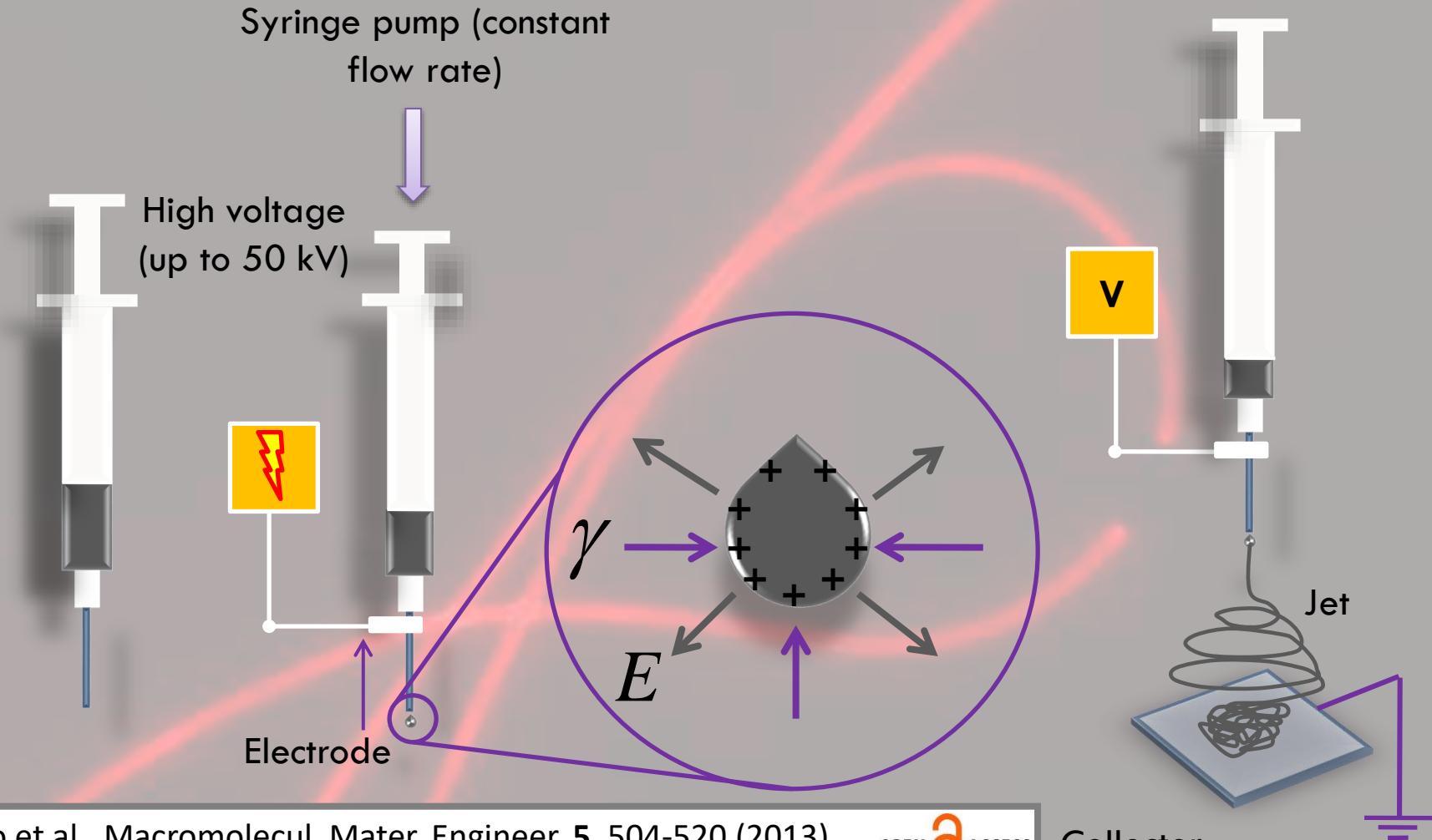
Vantaggi:

- Tecnologie ben ottimizzate, parallele, veloci (< 1h)
- Tecnologie che operano su larga area

Svantaggi:

- Limite fisico alla risoluzione: $R = k\lambda / N.A$ (Rayleigh).
- Necessità di geometrie 2D e planari
 - assenza di versatilità architetturale
- Alta energia del fascio incidente (UV, EUV, e^- ecc.)
 - assenza di versatilità chimica

Electrospinning



L. Persano et al., Macromol. Mater. Engineer. **5**, 504-520 (2013)

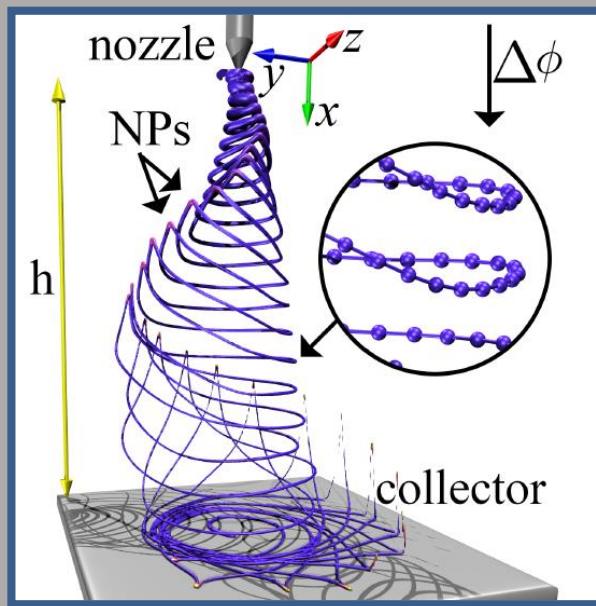
OPEN ACCESS

A. Camposeo et al., Macromol. Mater. Engineer. **5**, 487-503 (2013)

D. Pisignano, Polymer Nanofibers, RSC Publishing (2013)

L. Persano et al., Prog. Polym. Sci. **43**, 48-95 (2015)

Electrospinning: come si forma una nanostruttura

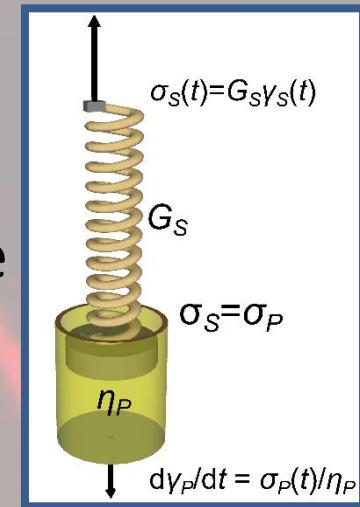


M. Lauricella, et al., EPL **119**, 44001 (2017)

N beads

Interazione Coulombiana

Interazione viscoelastica tra le *beads* (Maxwell, σ : richiamo di i verso le particelle adiacenti)



Tensione superficiale

$$m \frac{d^2 \mathbf{r}_i}{dt^2} = \sum_{\substack{j=1, \dots, N \\ j \neq i}} \frac{e^2}{R_{ij}^3} (\mathbf{r}_i - \mathbf{r}_j) - \frac{e \Delta \phi}{h} \hat{\mathbf{x}} + \frac{\pi a_{ui}^2 \sigma_{ui}}{l_{ui}} (\mathbf{r}_{i+1} - \mathbf{r}_i) - \frac{\pi a_{di}^2 \sigma_{di}}{l_{di}} (\mathbf{r}_i - \mathbf{r}_{i-1})$$

a_{ui} : raggio del getto nella sezione tra le particella $i+1$ ed i

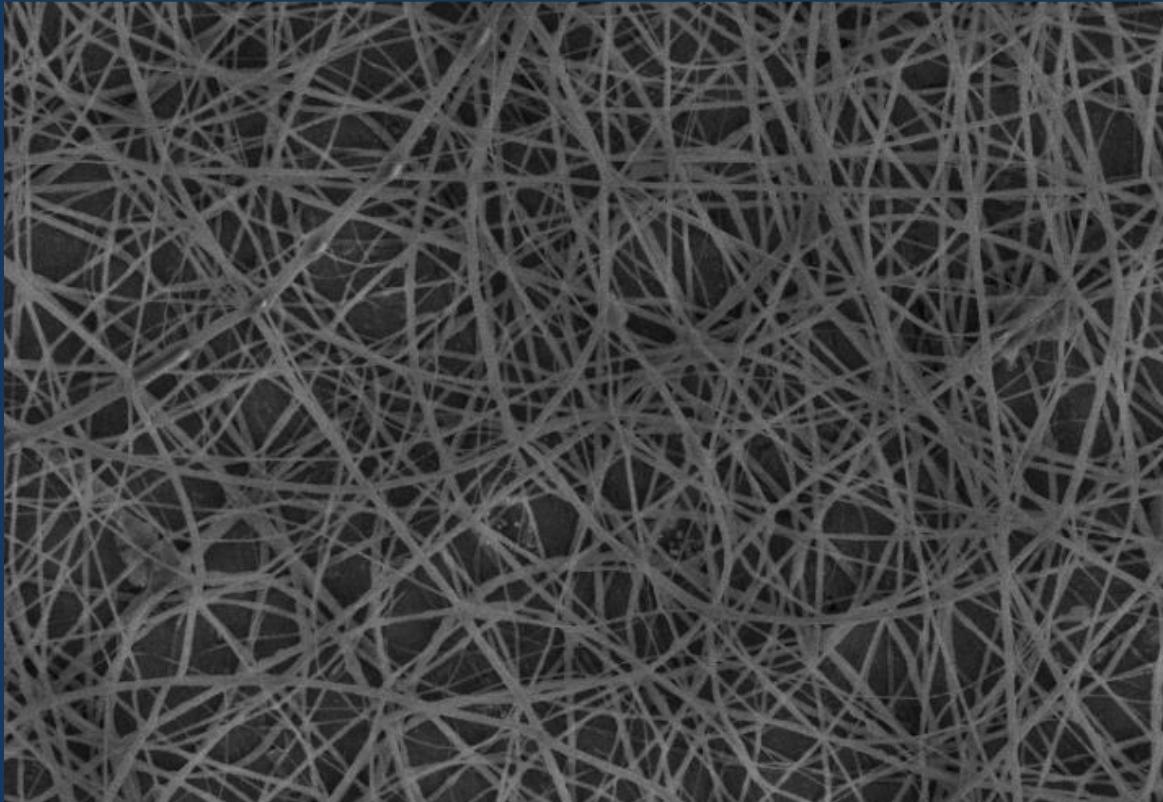
Coefficiente
di tensione
superficiale

$$-\frac{\alpha \pi a^2 k_i}{\sqrt{y_i^2 + z_i^2}} (\hat{\mathbf{y}}|y_i| \text{sign} y_i + \hat{\mathbf{z}}|z_i| \text{sign} z_i)$$

Raggio di curvatura⁻¹ @ particella i -esima

distanza tra le particella $i+1$ ed i

D. Reneker, et al., J.
Appl. Phys. **87**, 4531-47
(2000)



Risoluzione (ϕ delle fibre: 2 nm – 100 μ m)

Alta produttività

Dimensionalità scalabile: 1D, 2D, 3D

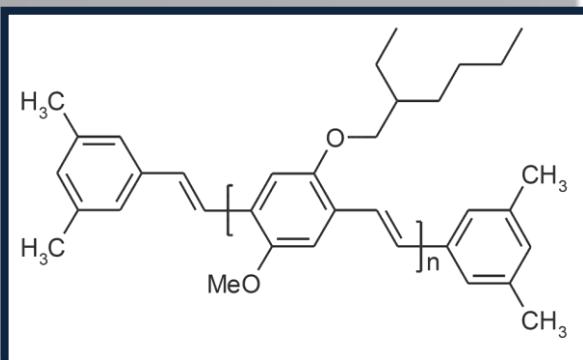
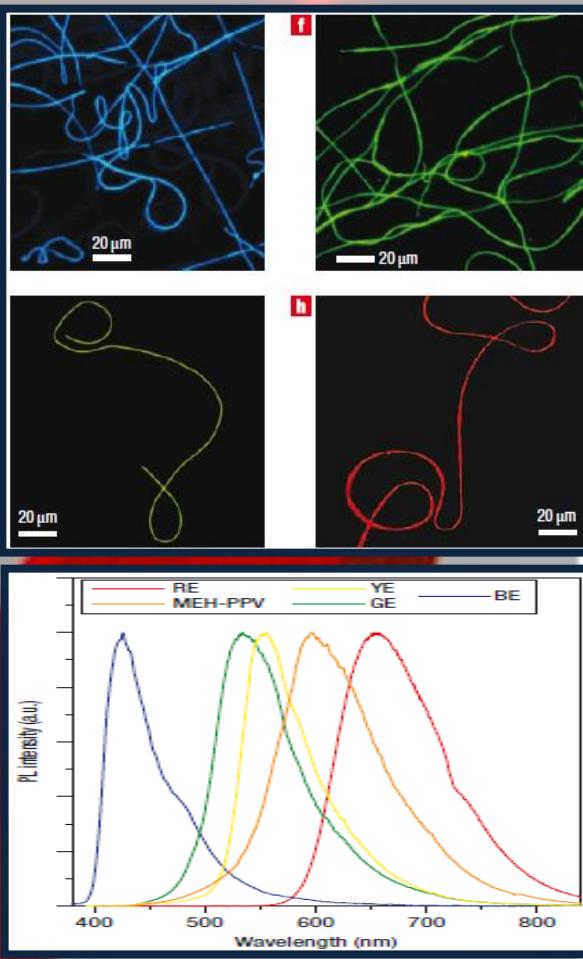
Flessibilità in termini di molecole impiegabili

Nano-tecnologie + ‘soft matter’ =

\Rightarrow versatilità scientifica

(esempi: Nanofotonica, Energia, Biomedicale)

1. Nanofotonica: semiconduttori organici

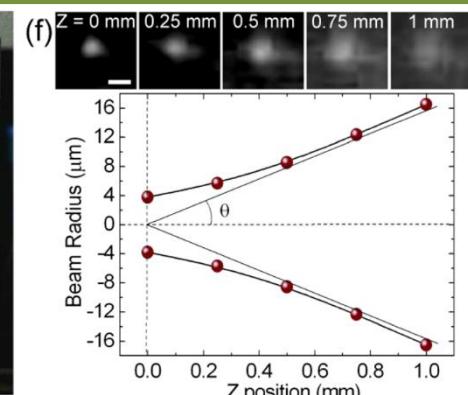
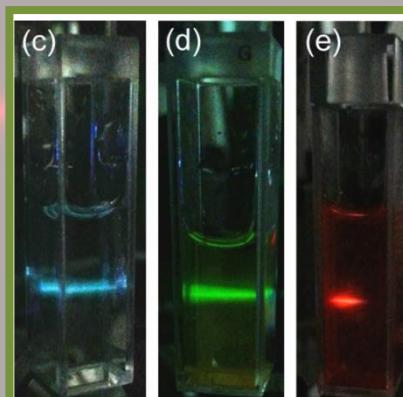
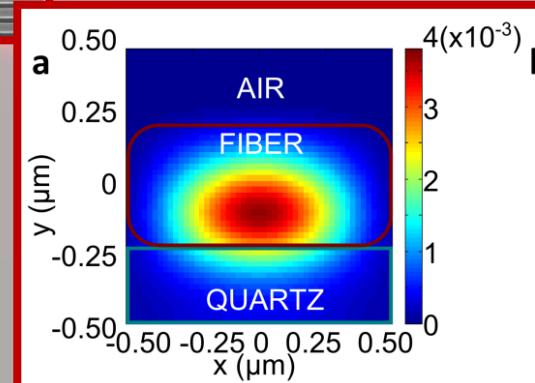
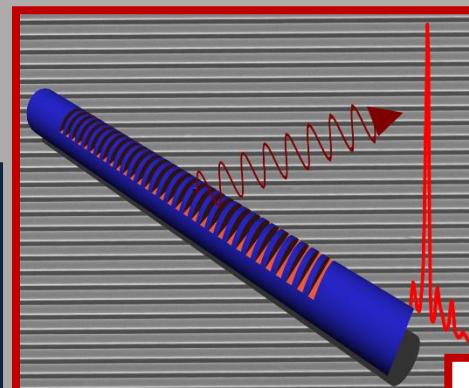
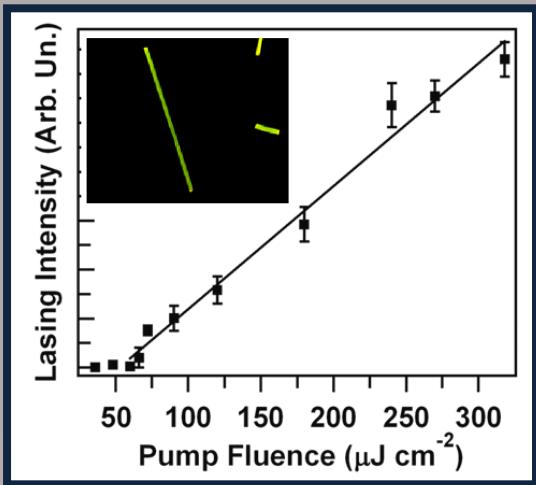
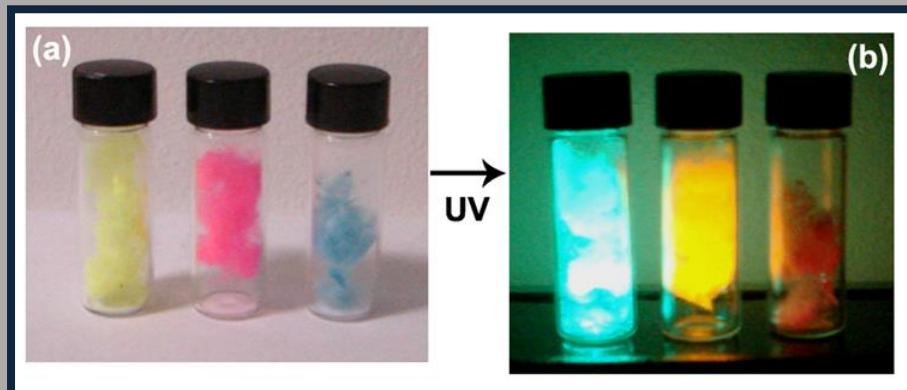


F. Di Benedetto, et al., Nature Nanotechnol. **3**, 614 (2008)

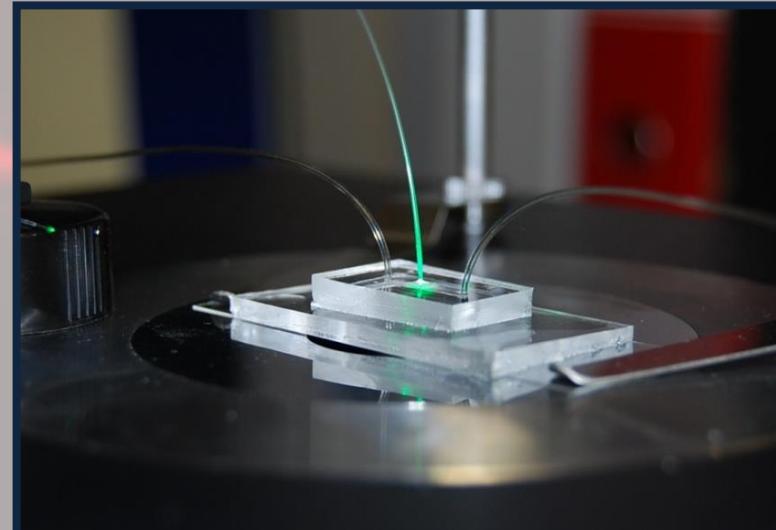
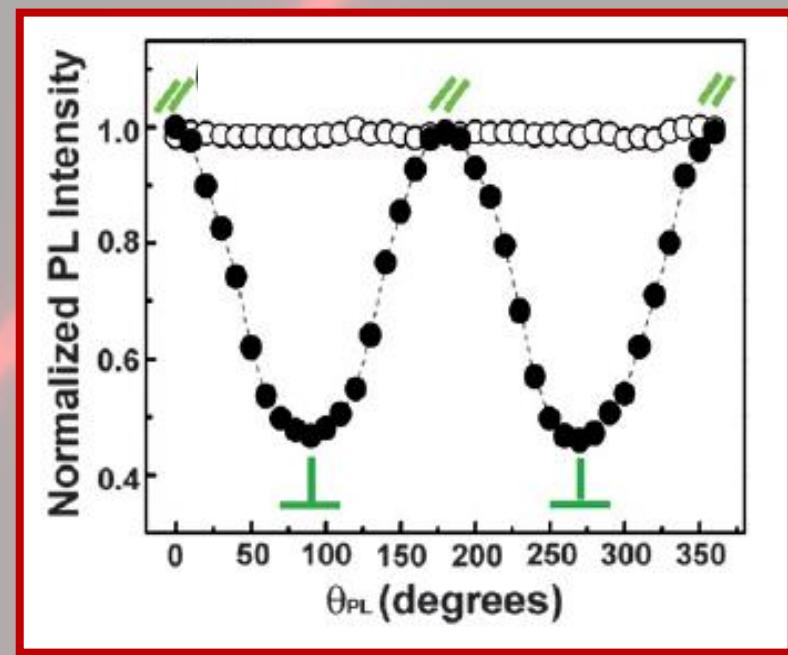
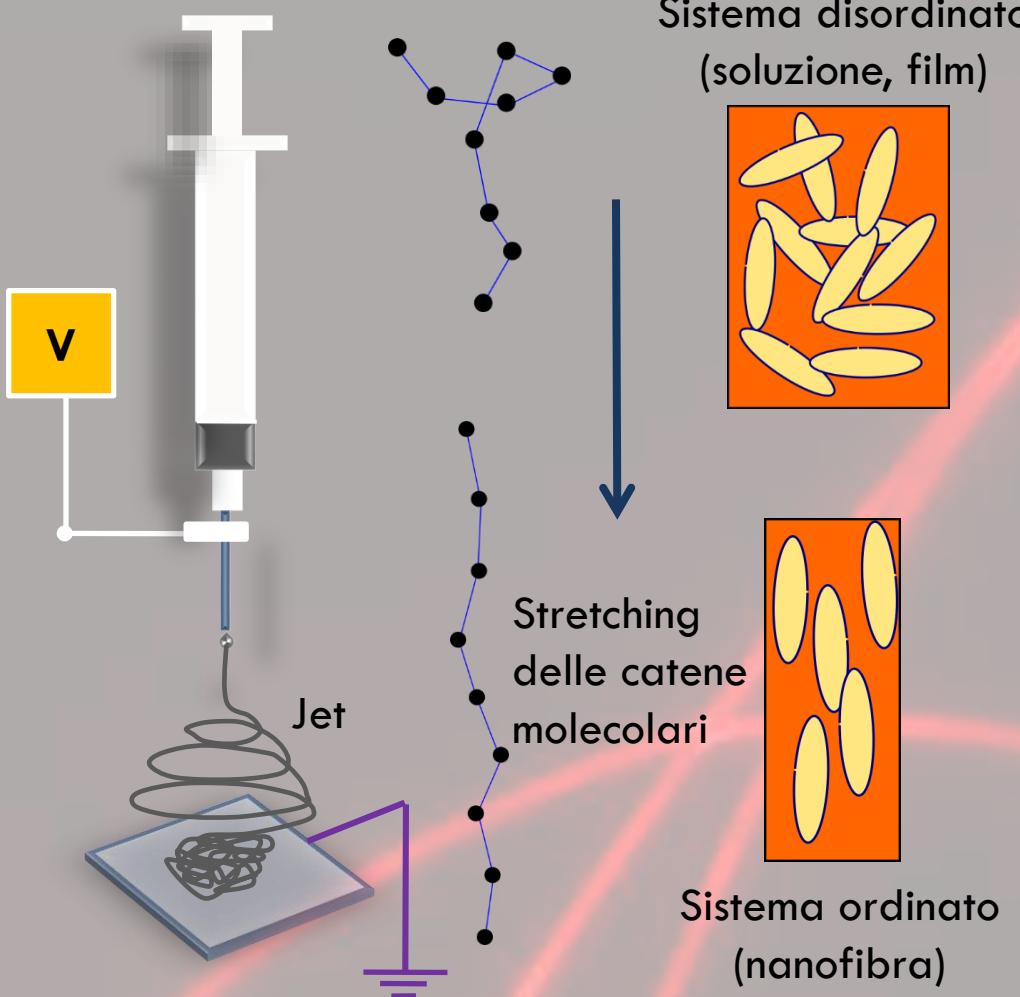
A. Camposeo et al., Nano Lett. **13**, 5056-5062 (2013)

A. Camposeo et al., Macromolecules **47**, 4704-4710 (2014) OPEN ACCESS

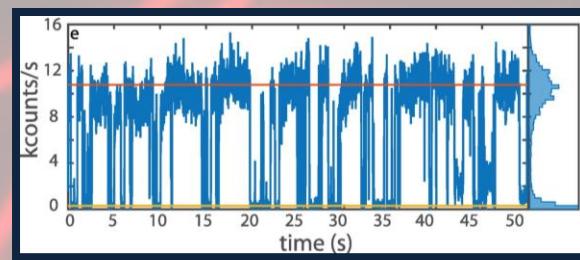
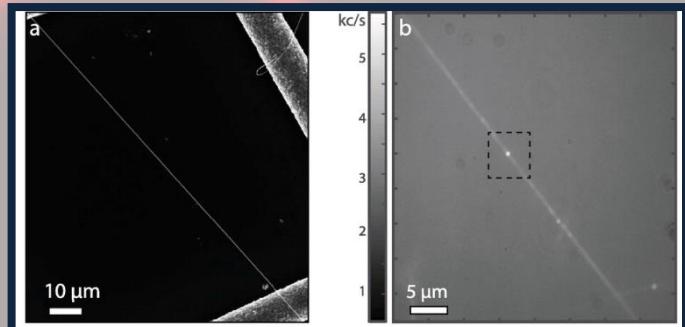
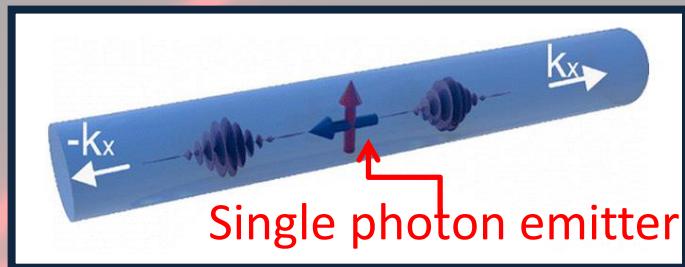
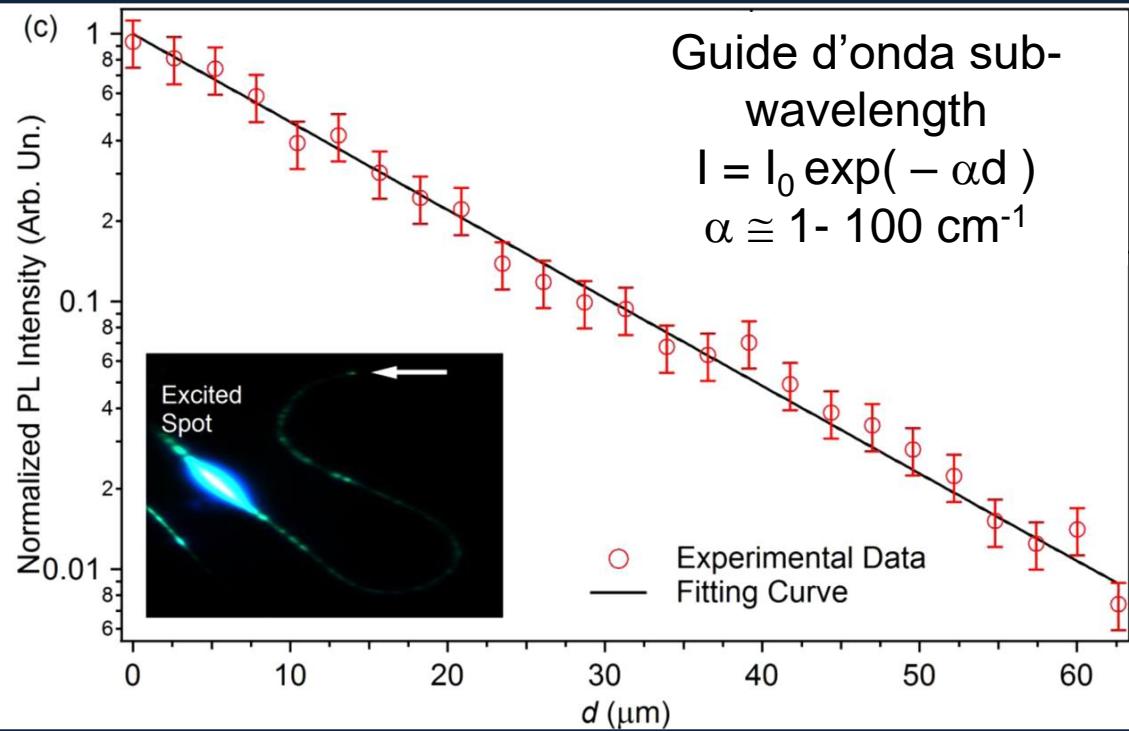
1. Nanofotonica: laser



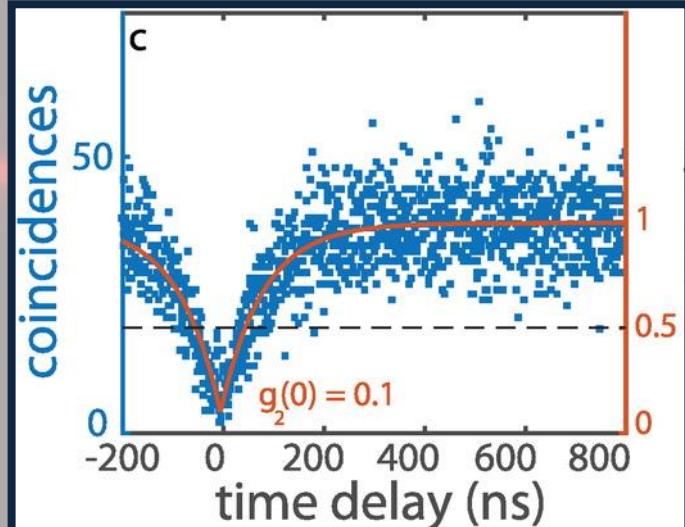
1. Nanofotonica: emissione polarizzata



1. Nanofotonica: tecnologie quantistiche



n : numero di fotoni rilevati
SPS: $g_2(0) = 0$



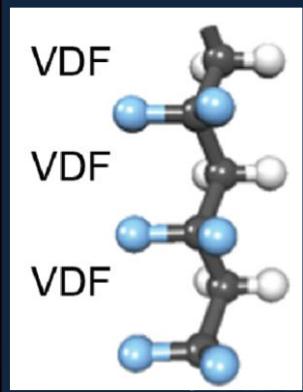
V. Fasano, et al., Macromolecules **46**, 5935-5942 (2013)

M. Gaio, et al., ACS Nano **10**, 6125-6130 (2016).

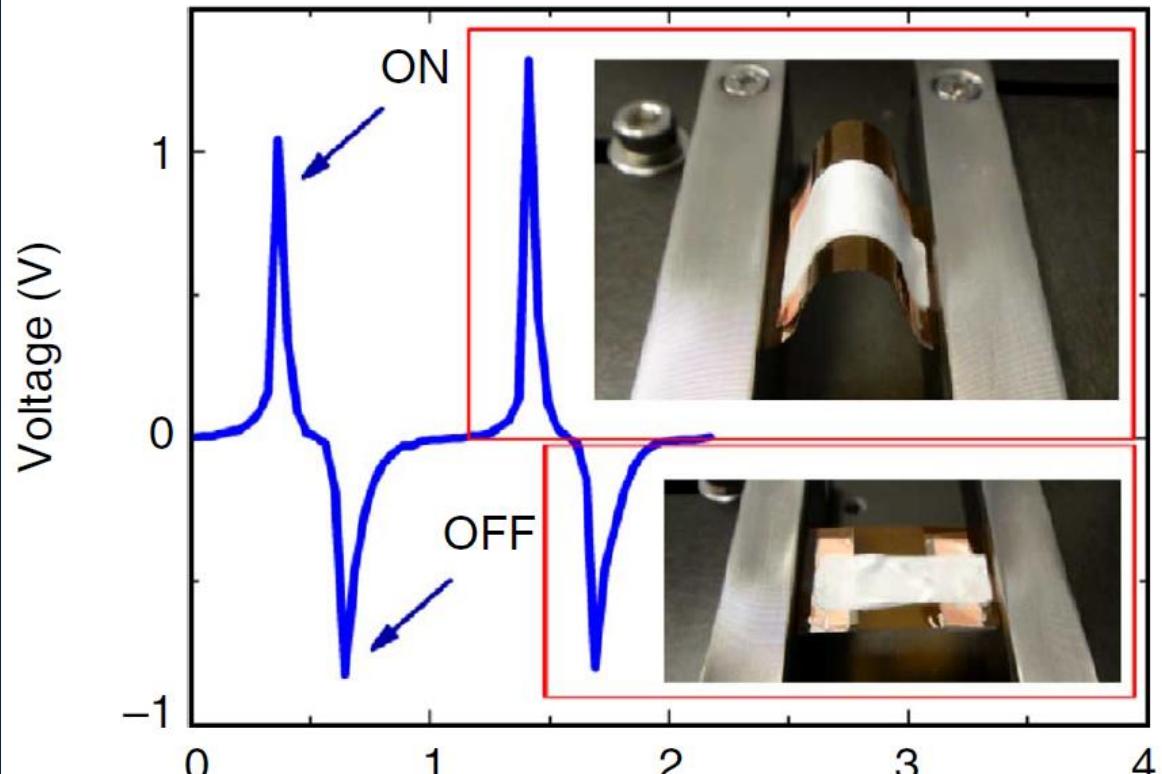
In collaboration with R. Sapienza now @ Imperial College, London

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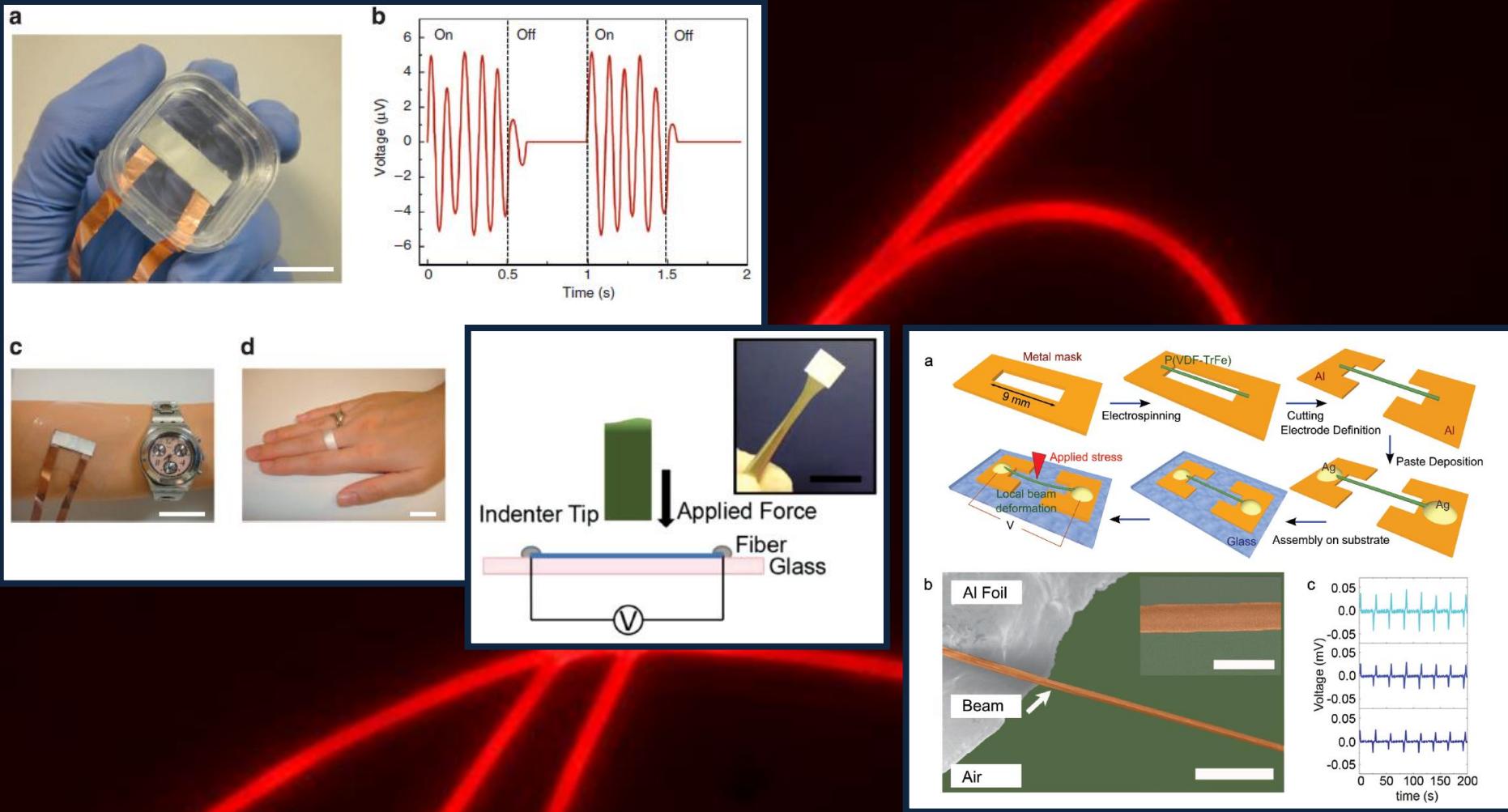
2. Nanoelettronica: ‘energy harvesting’



$$d_{ij} = (\partial D_i / \partial \sigma_j)_E$$



2. Nanoelettronica: ‘energy harvesting’



L. Persano et al., Nature Communications **4**, 1633 (2013)

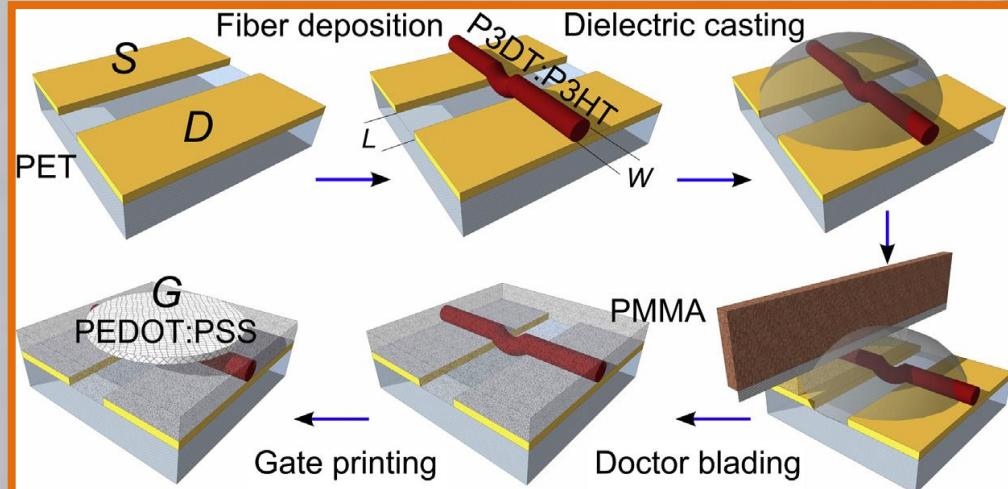
L. Persano et al., Adv. Mater. **26**, 7574-7580 (2015)

L. Persano et al., Adv. Mater. **28**, 7633-7639 (2016)

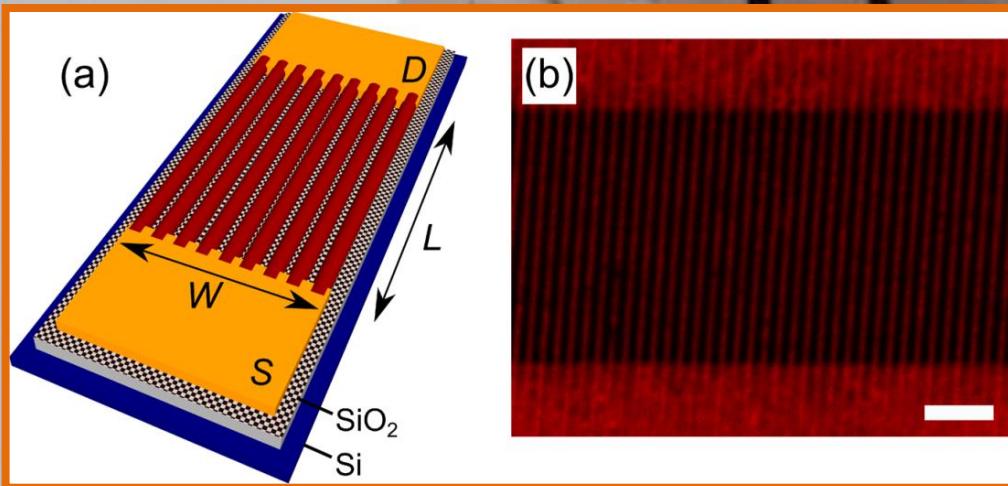
OPEN ACCESS

In collaborazione con J. A. Rogers now @ Northwestern, and L. De Lorenzis @ Braunschweig

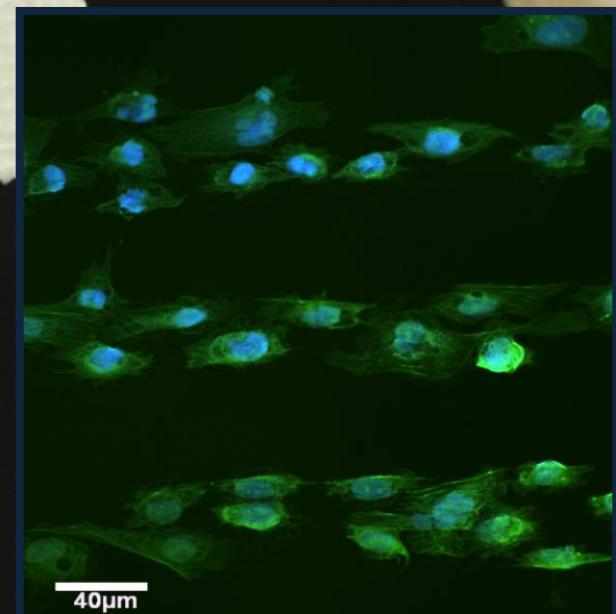
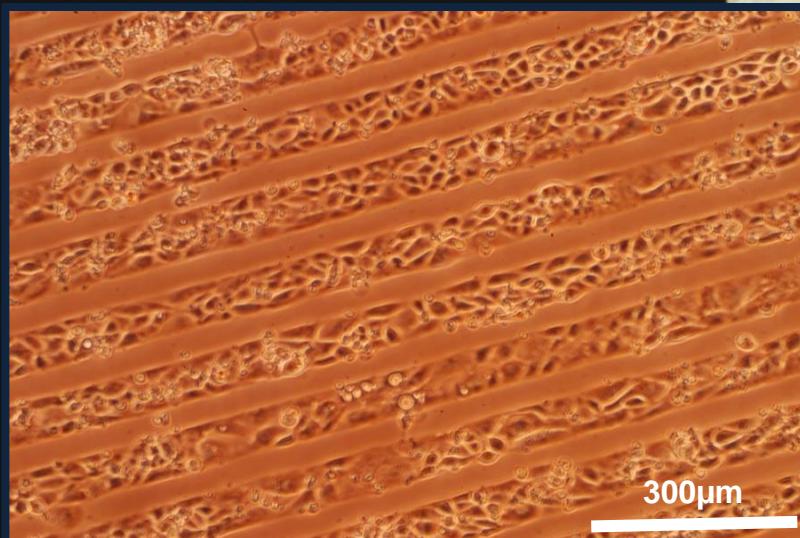
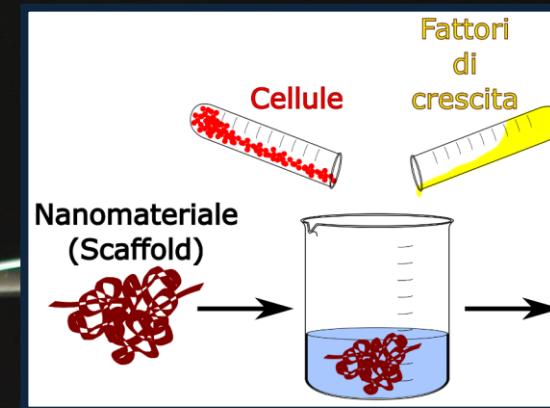
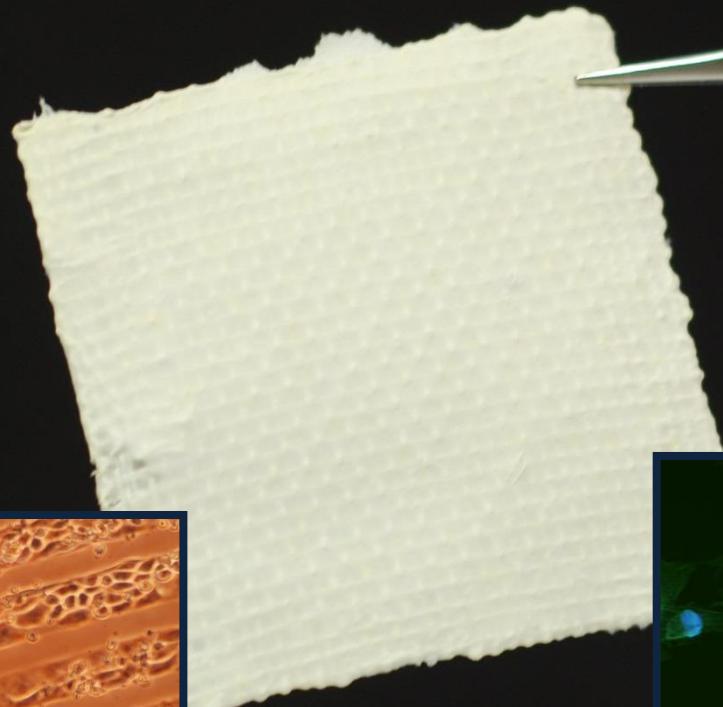
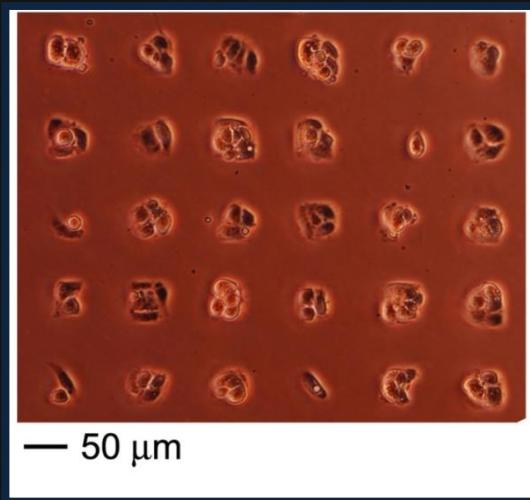
2. Nanoelettronica: transistor flessibili



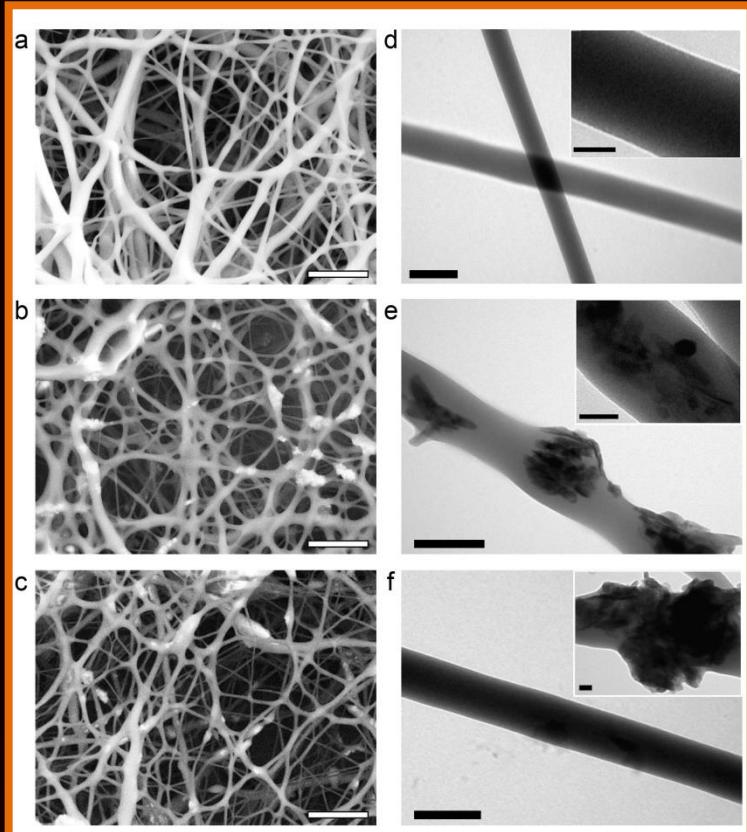
Nanofibre di carbonio



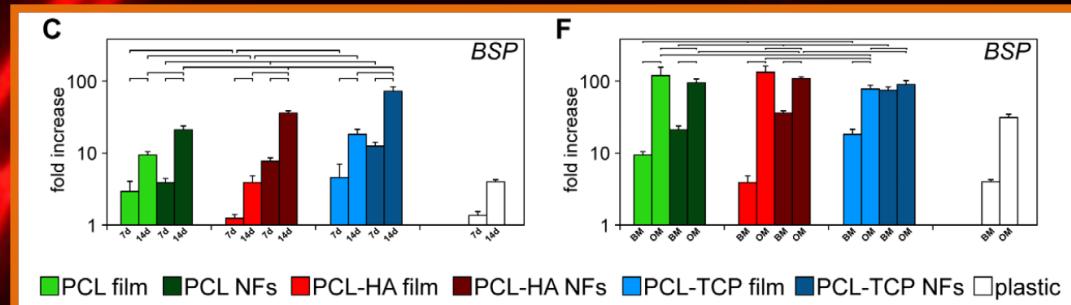
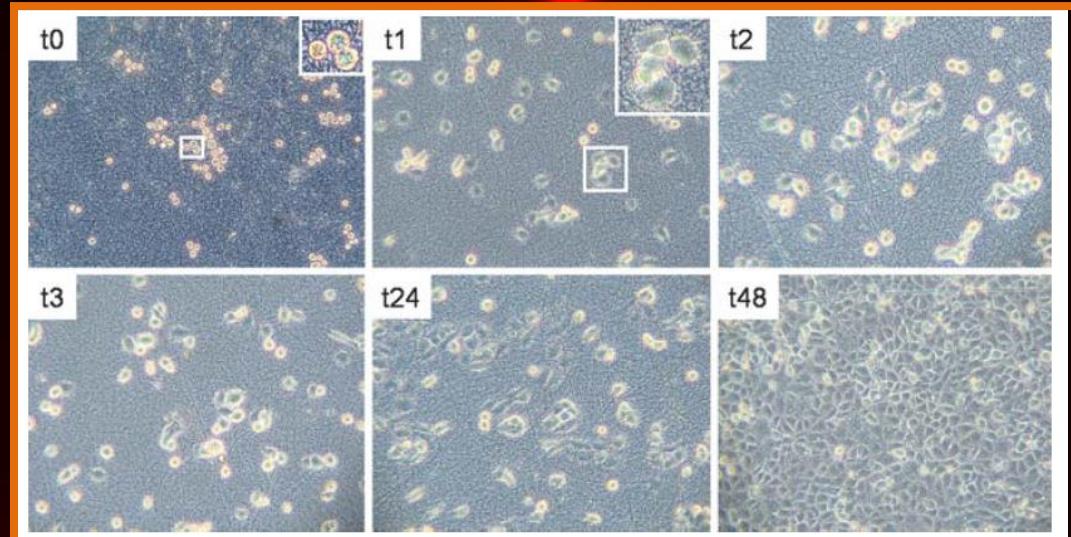
3. Biomedicale: ingegneria tissutale e nanomedicina rigenerativa



3. Biomedicale: ingegneria tissutale e nanomedicina rigenerativa

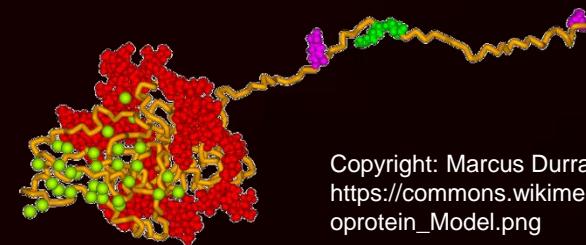


+ hMSCs



Mezzo basale

Mezzo osteogenico



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https://commons.wikimedia.org/wiki/File:Bone_Sialoprotein_Model.png

- A. Polini et al., Soft Matter **6**, 1668 (2010); PLoS ONE **6**, e26211 (2011).
M. Moffa et al., Soft Matter **9**, 5529 (2013)
A. Sciancalepore et al., Biomater. **94**, 57 (2016)

What's next:

- Sistemi microscopici adattativi, intelligenti
- Materiali auto-riparanti
- Riprogrammazione cellulare, fisica del cancro

