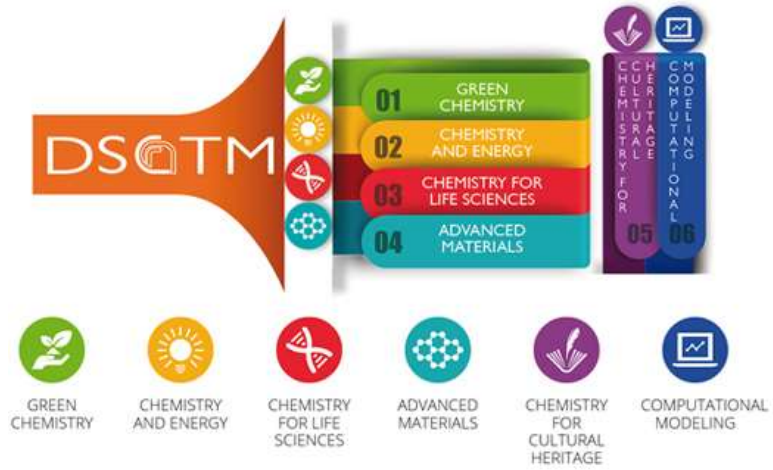

Materials for Biomedical Applications: From Layered Double Hydroxides to Natural Biopolymers

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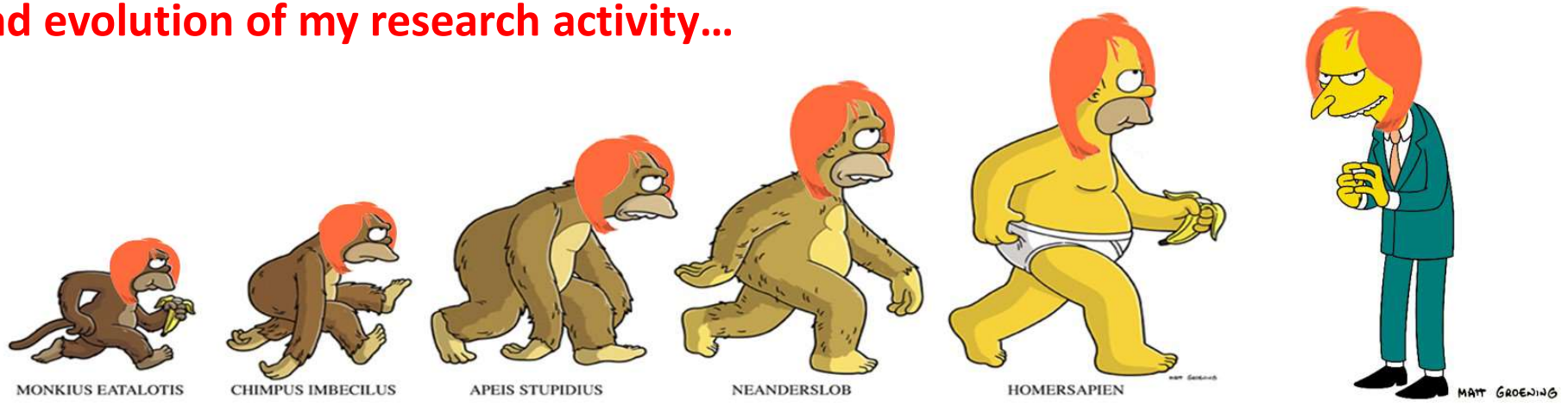
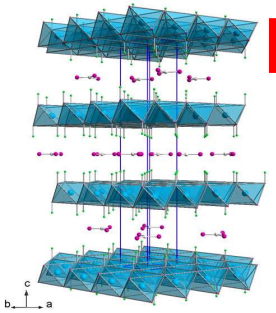
tamara.posati@isof.cnr.it

Conferenza di Dipartimento 2018, Assisi, 24-26 Settembre

History and evolution of my research activity…



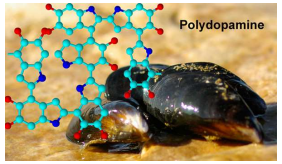
2006 ***2011*** ***2015*** ***Today*** ***Future***



Hydrotalcites (HTlc)

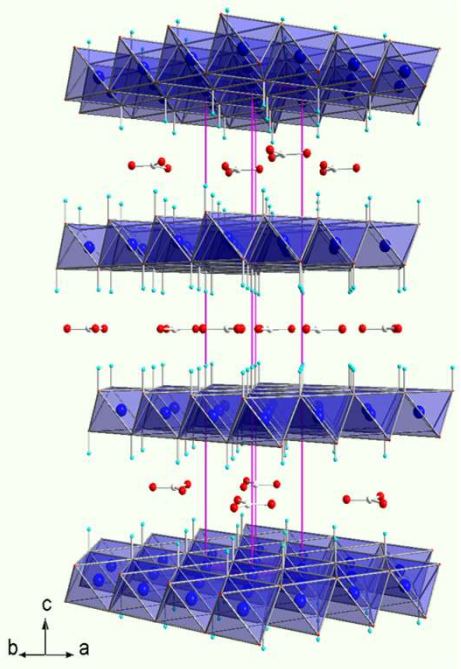
Fibroin

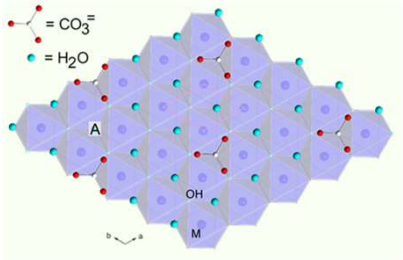
Keratin



Polydopamine

Hydrotalcite-Like Compounds (HTlcs)





$$[M(II)_{1-x}M(III)_x(OH)_2]^{x+}(A^{n-}_{x/n})\cdot mH_2O$$

M(II) = Mg, Zn, Co, Ni, Mn, Cu.
M(III) = Al, Cr, Fe, V, Co, Ga or Ln.
A^{n-} = inorganic or organic anion of charge n.

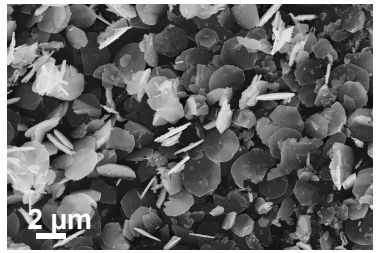
HTlc synthesis

Standard methods :

- Co-precipitation of the metal ions: variable pH (NaOH) or constant pH ($NaHCO_3$–Na_2CO_3)
- Urea method: Hydrolysis of urea at 80 - 100°C

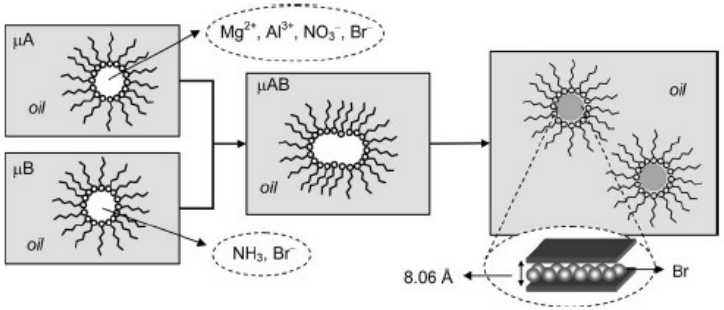
$$CO(NH_2)_2 \rightarrow NH_4CNO$$
$$NH_4CNO + 2H_2O \rightarrow (NH_4)_2CO_3$$

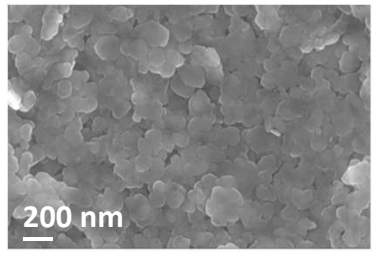
U. Costantino et al. *Eur. J. Inorg. Chem.*, **1998**, 1439.



HTlc microparticles

Double microemulsion technique: w/o microemulsion

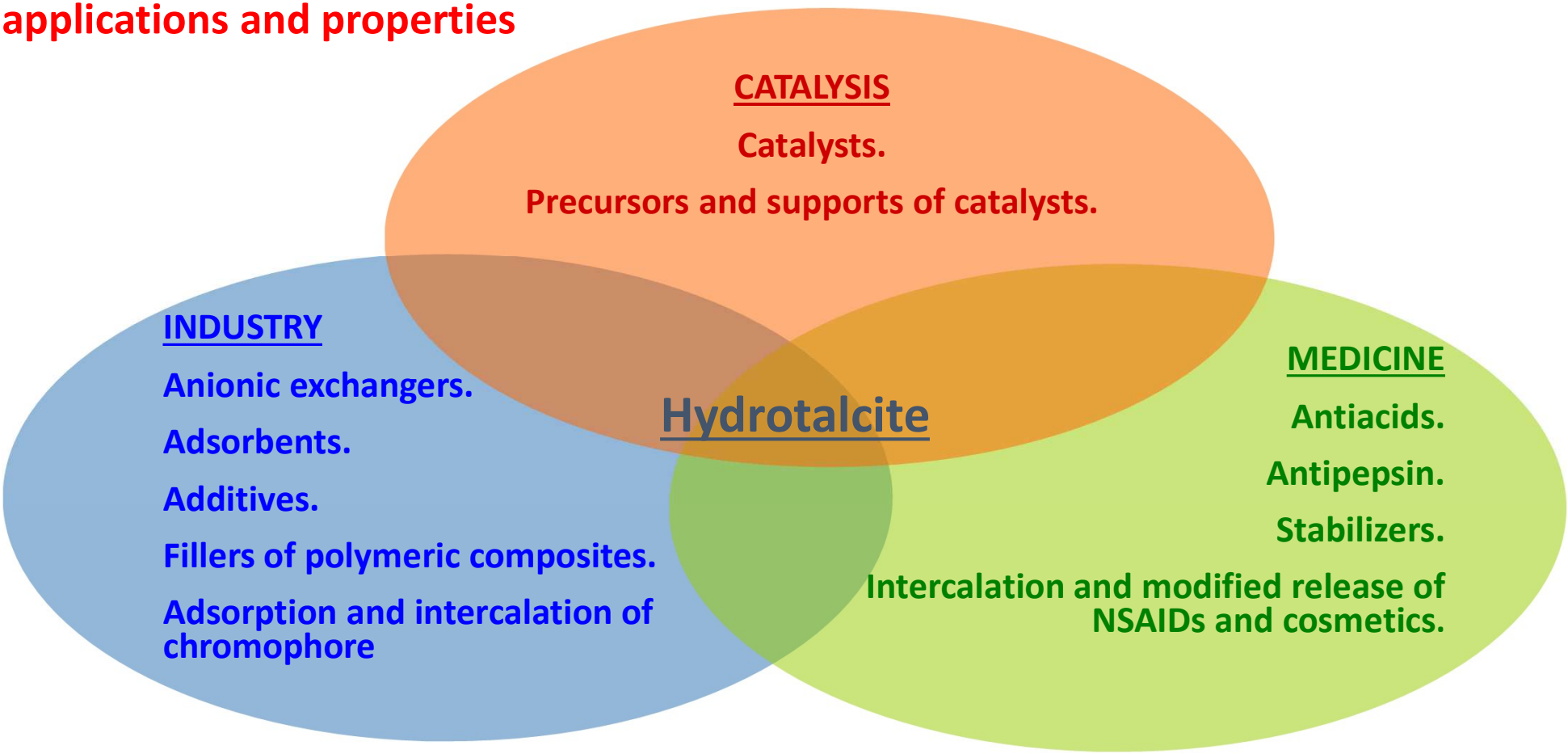




HTlc nanoparticles

F. Bellezza, A. Cipiciani, U. Costantino, M. Nocchetti, T. Posati, *Eur. J. Inorg. Chem.*, **2009**, 2603.

HTlc applications and properties

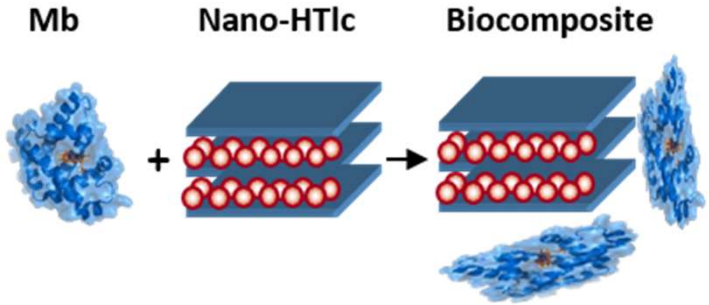


Low toxicity, good biocompatibility, tunable chemical composition and ionic exchange capacity (easy functionalization)

Hydrotalcite before….

1) Interaction with globular enzymes
(Myoglobin, Chymotrypsin and serum proteins)

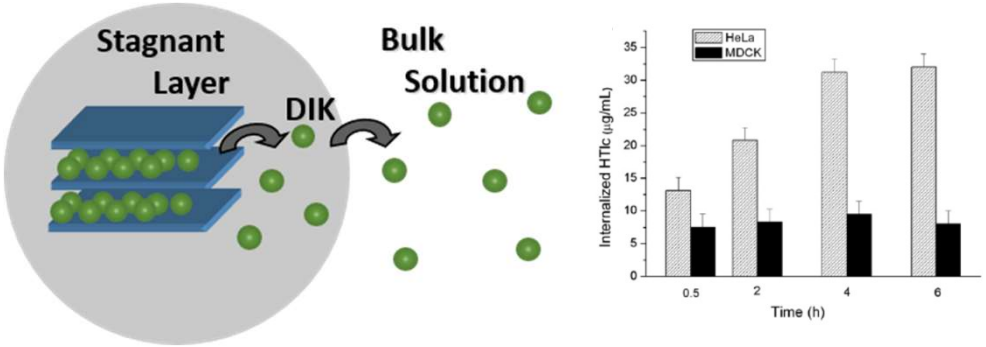
F. Bellezza, T. Posati, A. Cipiciani et al. *Langmuir,* **2009**, 25(18), 10918.



2) Controlled drug release and cellular uptake

L. Perioli, T. Posati, M. Nocchetti et al. *Appl. Clay Sci.,* **2011***, 53*, 374.

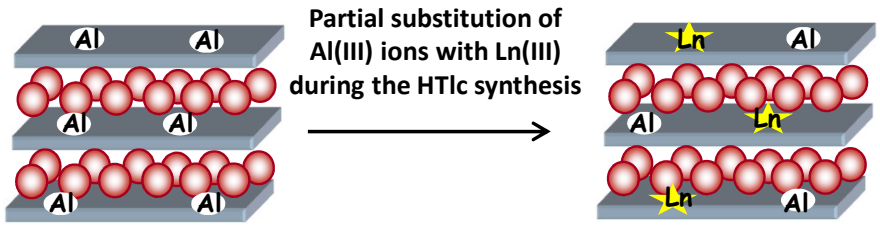
T. Posati, F. Bellezza, A. Cipiciani et al. *Appl. Clay Sci.,* **2012***, 55,* 62.



3) Doping of HTlc nanoparticles with luminescent lanthanide ions (Eu, Tb…)

T. Posati, L. Latterini et al. *Cryst. Grow. Des.*, **2010**, *10*, 2847.

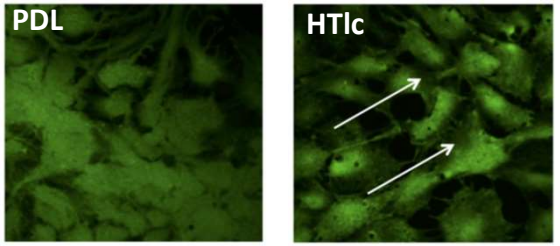
T. Posati, M. Nocchetti et al. *Inorg. Chem.* **2012***,* 51*,* 13229.

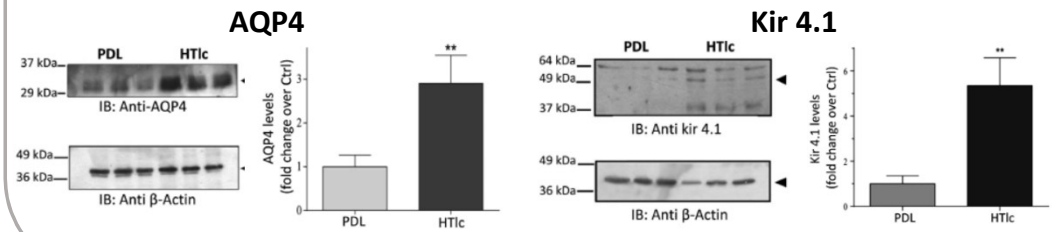


Hydrotalcite at CNR…

Biomedical applications

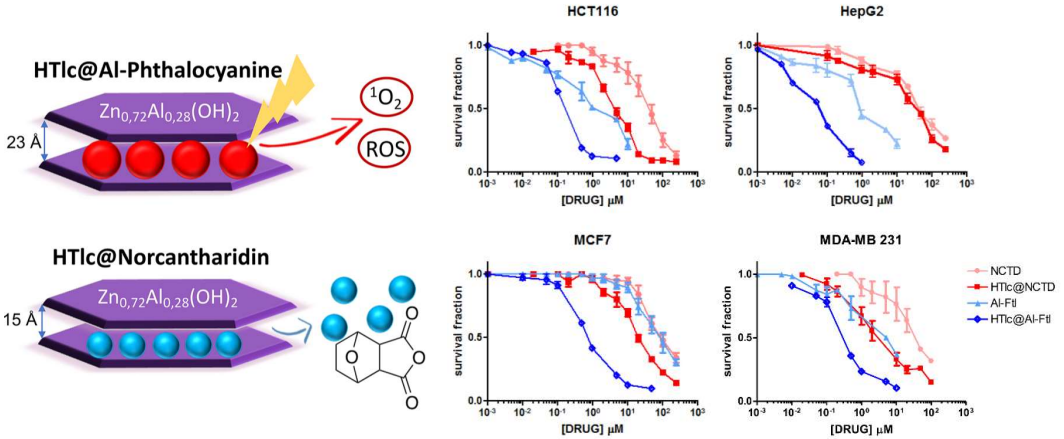
1) HTlc and astrocytes





T. Posati, V. Benfenati, R. Zamboni, M. Muccini et al. *Sci. Rep.,* **2016**, 6, 31226.

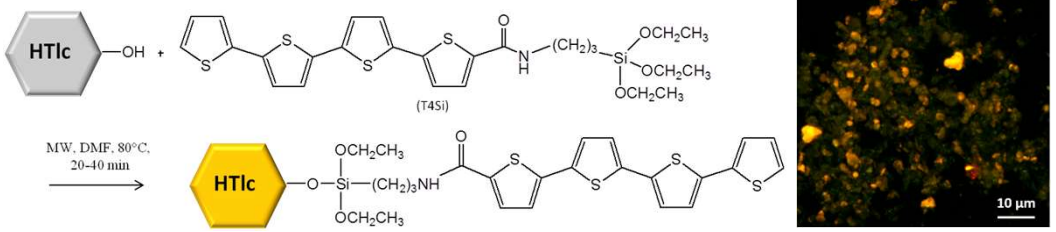
2) HTlc and cancer therapy



C. Martini, C. Ferroni, T. Posati, G. Varchi et al. *submitted*.

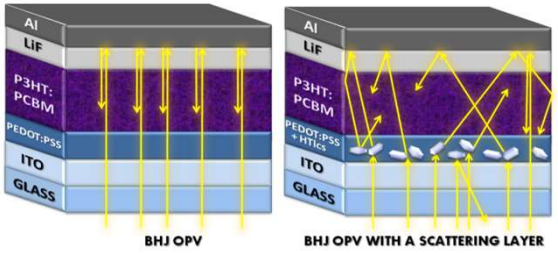
Other applications

3) Chemical functionalization



T. Posati, M. Melucci, V. Benfenati, R. Zamboni et al. *RSC Adv.,* **2014**, 4, 11840.

4) Scattering NPs for organic photovoltaics



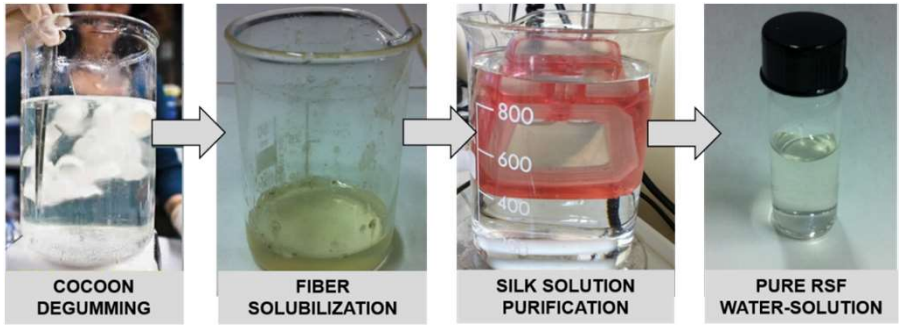
PCE (%)= 2,58 **PCE (%)= 2,98**

T. Posati, M. Bolognesi, M. Seri, et al. *OPP.,* **2013**, 1.

Natural Proteins

Silk Fibroin

Sustainable extraction and purification protocol of «reverse engineering» (water-based)

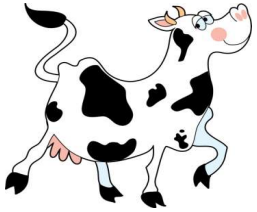


D. L Kaplan et al. *Nature Protocols* **2011,** *6*, 1612.

Keratin

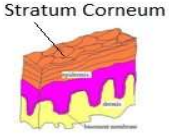
Wool

Feather



Horns & Nails

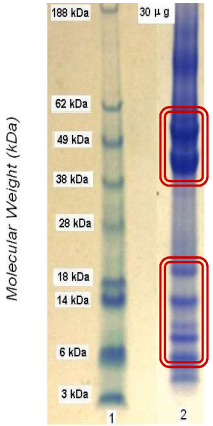
Hair



Skin

Renewable sources at low cost of biopolymers

Keratin Powder

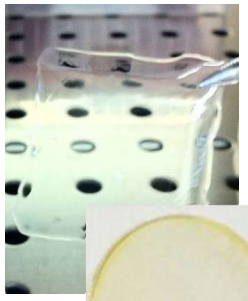


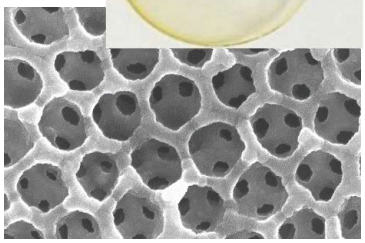
Natural Proteins

PROTEIN SOLUTION

•Easy to process into many material formats

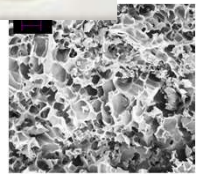
TRANSPARENT, NANOSTRUCTURED AND FLEXIBLE FILM



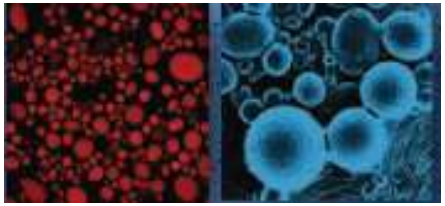


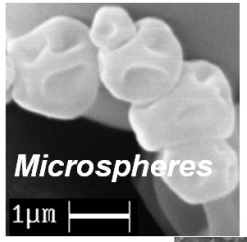
HYDROGELS

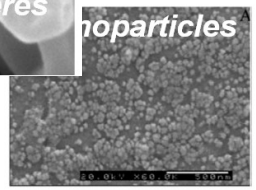
SPONGES



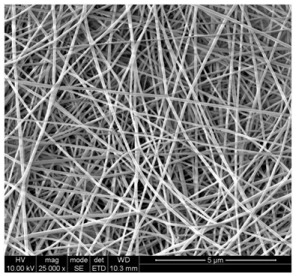
MICROSPHERES AND NANOPARTICLES

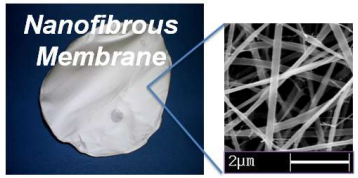






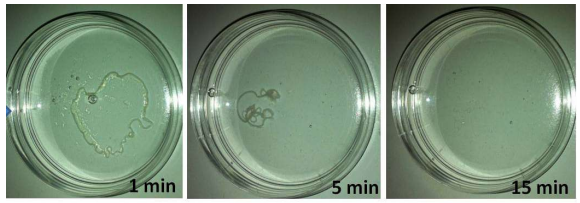
ELECTROSPUN NANOFIBERS





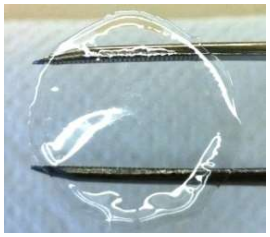
Properties…

Biodegradability

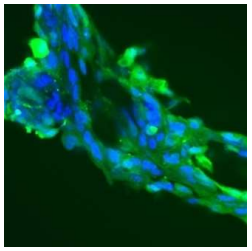


PBS buffer pH 7.4

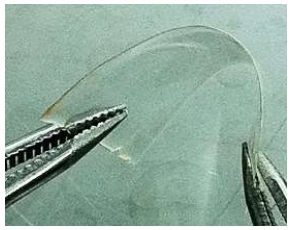
Transparency



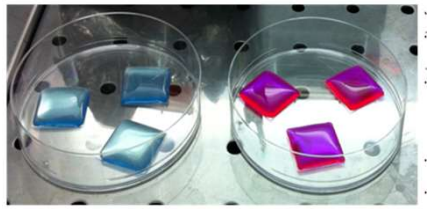
Biocompatibility



Flexibility



Easy functionalization

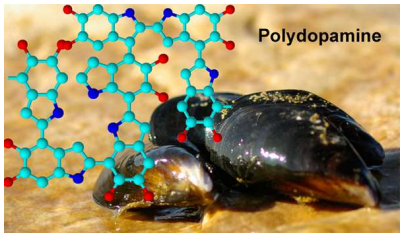


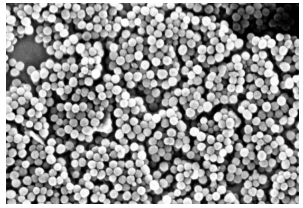
Limits

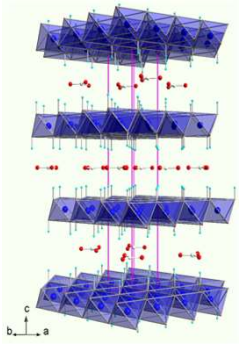
- -Improved mechanical properties
- -Improved biodegradability
- -Microbial growth

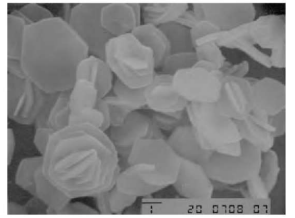
Solutions

Biocomposites
Multifunctional Systems





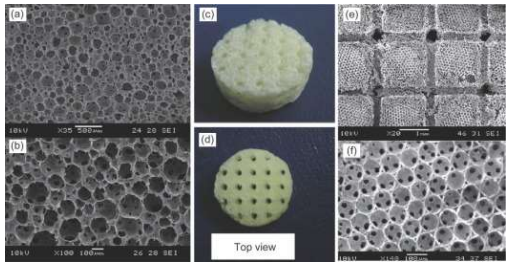


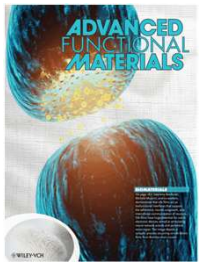


Applications…

Biomedical Field

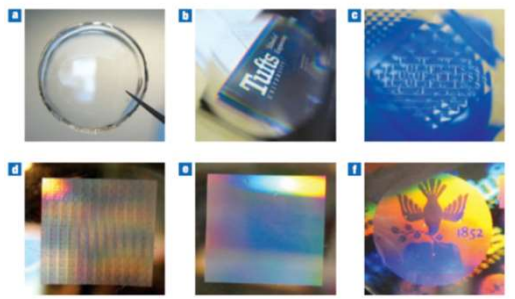
Drug delivery systems
Scaffolds for Tissue Engineering
Regenerative medicine

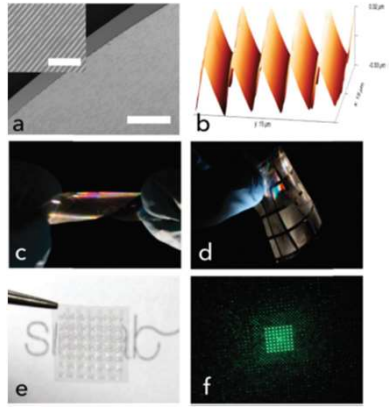




V. Benfenati et al. *Adv. Funct. Mater.* **2012**, *22*, 1871–1884
A. Aluigi, G. Sotgiu et al. *ACS Appl Mater Interfaces*, **2015**, 7, 17416.

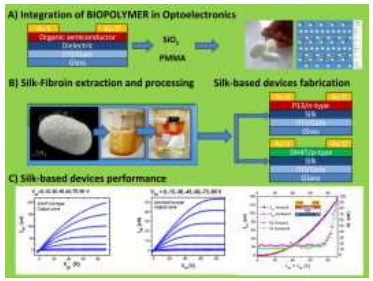
Optical elements

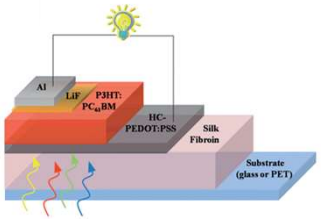




B. Marelli, F. G. Omenetto, *J. Mater. Chem. C,* **2015**, *3,* 2783.
S. Toffanin, M. Muccini, R. Zamboni et al. *Appl. Phys. Lett*., **2012**, *101*, 091110.

Electronic and optoelectronic devices

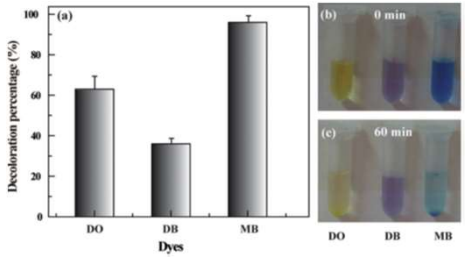


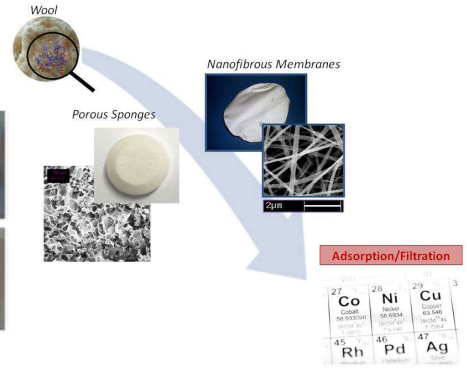


R. Capelli, R. Zamboni et al. *Organic Electronics* **2011,** *12*, 1146.
M. Seri et al. *RSC Adv.* **2014,** *4*, 44815.

Depuration Systems

Water Treatment
Air Cleaning

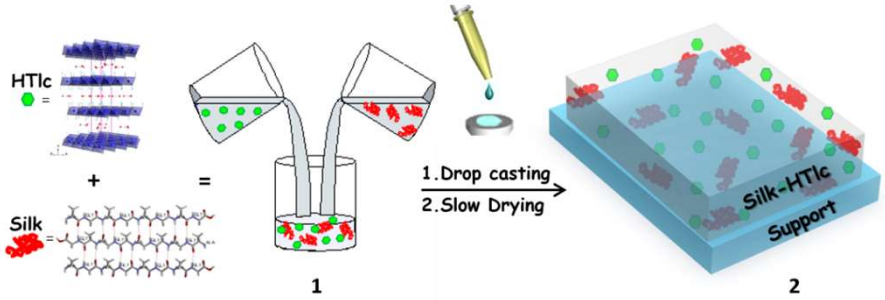


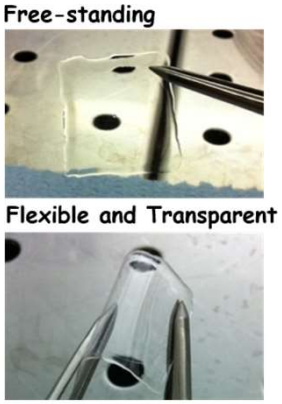


S. Xiao et al. *Advanced Powder Technology,* **2014***,* 25, 574–581
A. Aluigi et al. *Eur. Polym. J.,* **2011***,* 47, 1756.

Silk Fibroin and Hydrotalcite biocomposite films

(1) Blending of SF solution and HTlc nanoparticles (NPs)
(2) Drop casting and slow drying



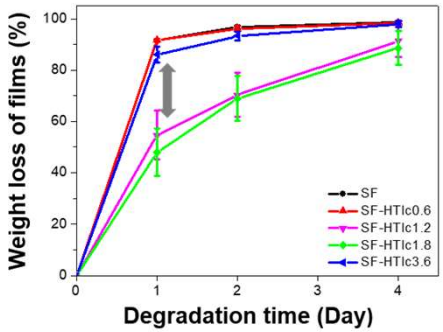


were…

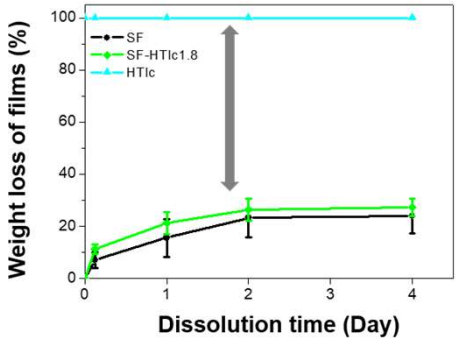
… STRONGER and TOUGHER than PRISTINE SF

filler wt %	E/MPa	stress at break/Nmm^{-2}	elongation at break/%	modulus of toughness/MPa
SF	2278 ± 17.42	44.4 ± 0,5	2.07 ± 0.08	45.7 ± 2.6
SF-HTlc0.6	2415 ± 9.7	65.3 ± 8.6	3.02 ± 0.36	86.1 ± 6.8
SF-HTlc1.2	2557 ± 4.15	75.9 ± 9.4	3.42 ± 0.32	105.9 ± 9.9
SF-HTlc1.8	2812 ± 58.2	56.16 ± 8.8	1.79 ± 0.39	64.9 ± 4.6
SF-HTlc3.6	2575 ± 112.76	21.65 ± 7.2	0.87 ± 0.10	8.9 ± 1.9

…MORE RESISTENT TO PROTEASE



and PROTECTIVE for HTlc-NPs towards ACID ENVIRONMENT

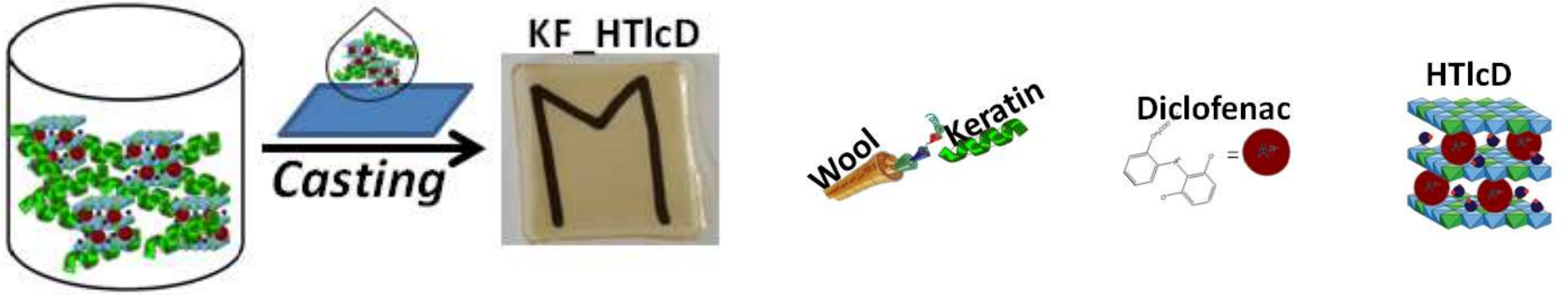


Mutual benefit on the stability of the two components after their combination

T. Posati, V. Benfenati, M. Muccini, R. Zamboni et al. *Biomacromolecules,* **2014,** *15*, 158.

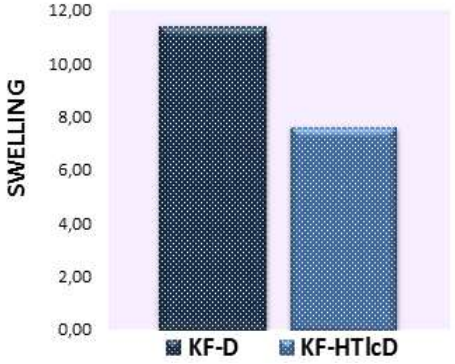
Keratin and Hydrotalcite biocomposite films

(1) Blending of Keratin solution and HTlc nanoparticles with intercalated diclofenac (D) anions
(2) Drop casting and slow drying

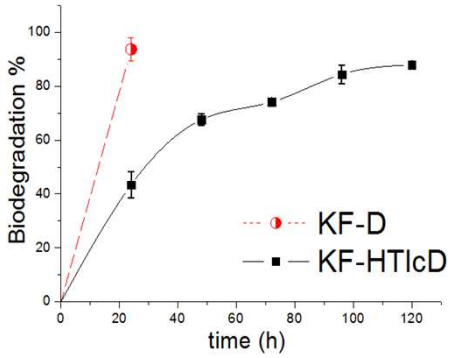


showed…

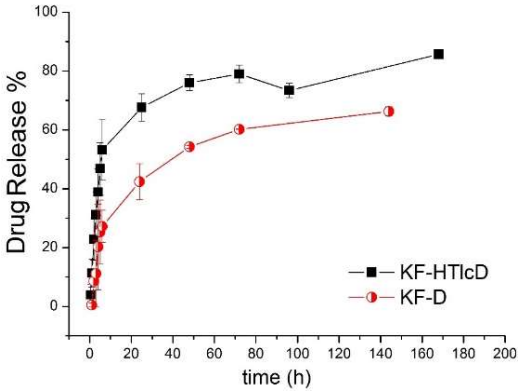
…Minor SWELLING



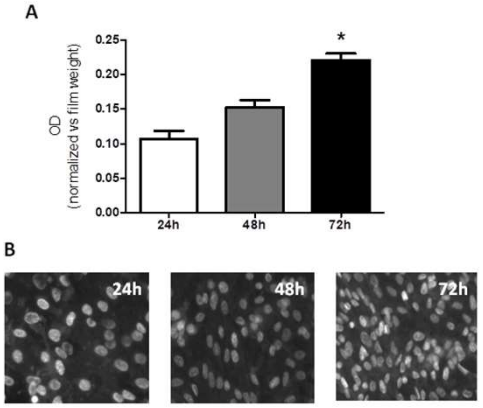
…Reduced In-vitro BIODEGRADATION



…Greater DRUG RELEASE



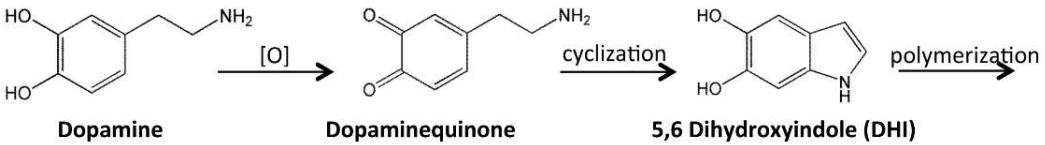
…Good BIOCOMPATIBILITY (human fibroblast)

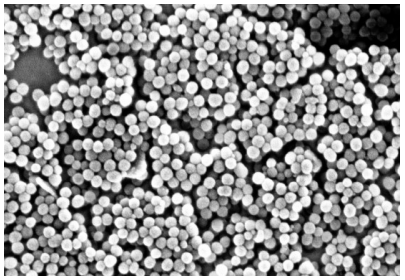


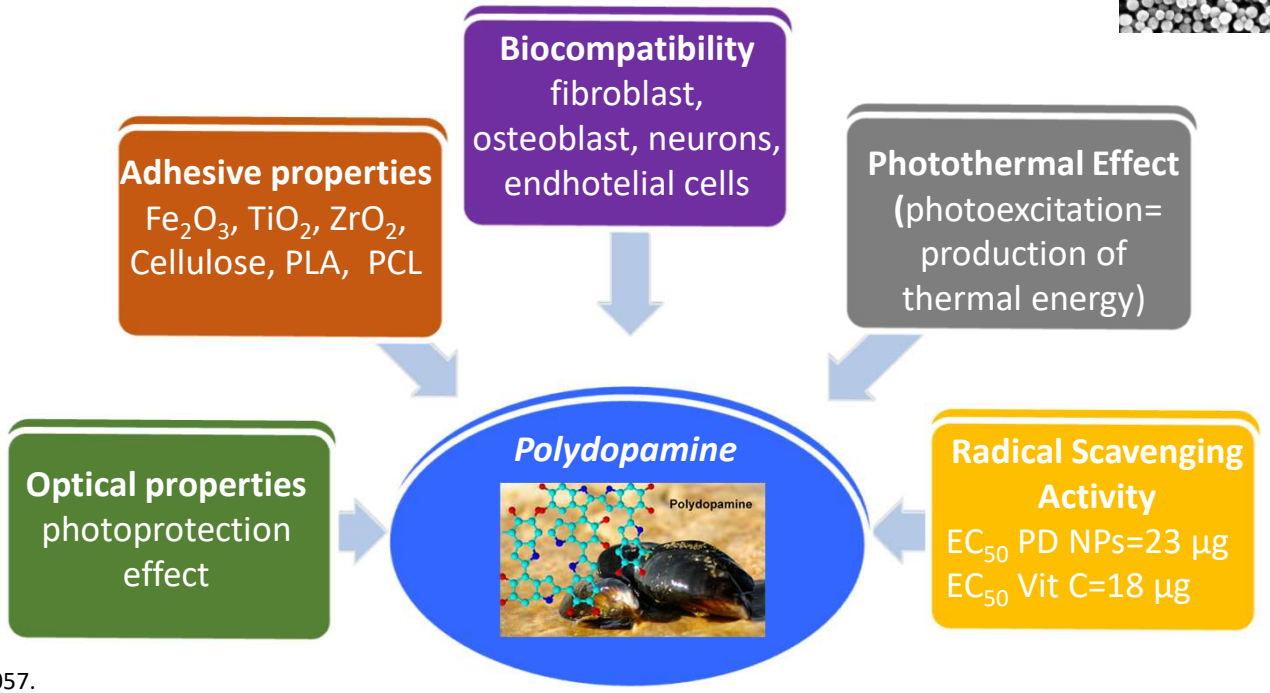
T. Posati, A. Aluigi et al. *Eur. Polym. J.* **2018**, 105, 177.

Polydopamine nanoparticles (PD-NPs)

Demand for surfaces highly biocompatible, rich in functional groups
Simple and efficient approach applicable to any surface



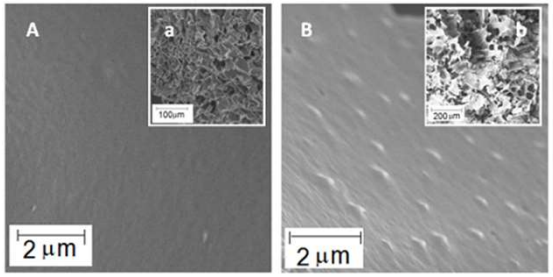


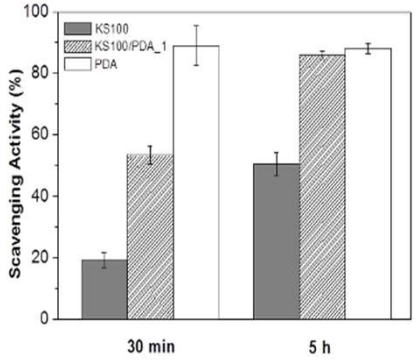


H. Lee et al. *Science* **2007**, 318, 426.
Y. Liu et al. *Chem. Rev.*, **2014,** 114, 5057.

PD-NPs and keratin sponges

- Good dispersion degree of PD into keratin sponges
- No effect on pore shape and the size distribution
- Time-dependent antioxidant activity

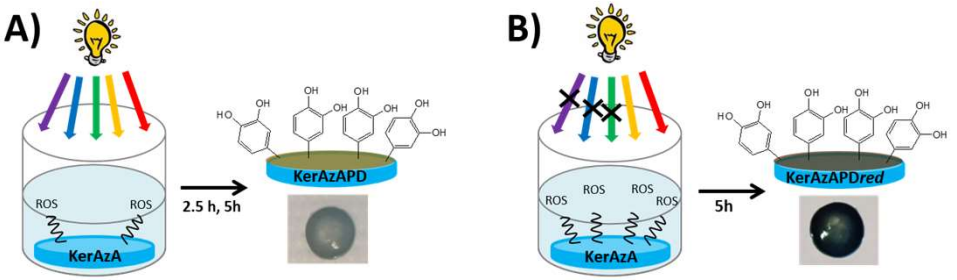




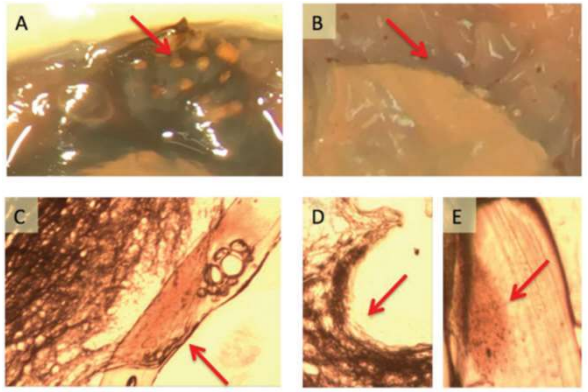
T. Posati, A. Aluigi et al. *Materials and Design* **2016,** *110*, 475.

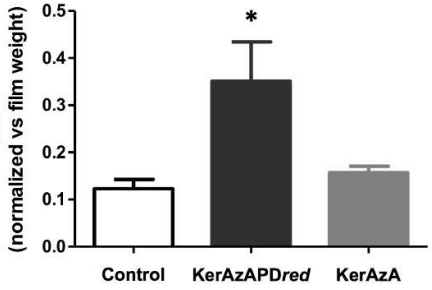
PD coating on keratin/AzA films

Polydopamine deposition by reactive oxygen species (ROS) generated by keratin films doped with a photosensitizer



- Photothermal effect of PD = welding of the keratin film to connective tissue
- Human fibroblasts adhere and grow better on PD coated films





T. Posati, A. Aluigi, G. Sotgiu et al. *Macromol. Mater. Eng.* **2018**, 1700653

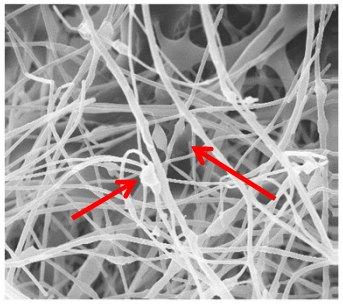
Conclusions

- We developed **Hydrotalcites** and innovative **Keratin** and **Fibroin-based 2D and 3D-scaffolds** of potential interest in Tissue Engineering, Wound Healing, Regenerative Medicine and Drug Delivery fields

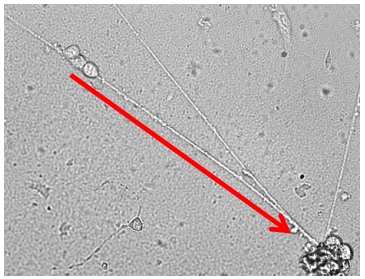
Future Perspectives

- **Keratin/Hydrotalcites** sponges and **polysulfone** powder or membranes, coated with **polydopamine** for water depuration

- **Keratin/Hydrotalcites electrospun nanofibers** for biomedical applications



- **Keratin/Fibroin blend** for biomedical applications and water depuration



- Detailed study on the interaction between **hydrotalcite based materials** and **neural cells.**

COCOON Project

Lending Institution

EUROPEAN CENTRAL BANK

Partners

National Research Council of Italy

DSCTM

ISOF CNR — **Institute of Organic Synthesis and Photoreactivity**

ICCOI CNR Istituto di Cristallografia — **Institute of Crystallography**

IBB — **Institute of Biostructures and Bioimaging**

BANCA D'ITALIA — **Banca d'Italia**

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CARIAGGI FINE YARNS COLLECTION

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MIST E-R

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«La ricerca scientifica, benché quasi costantemente guidata dal ragionamento, è pur sempre un'avventura»

Louis-Victor Pierre Raymond de Broglie

You for your attention!!