Nanostructured functional membranes: perspectives and challenges

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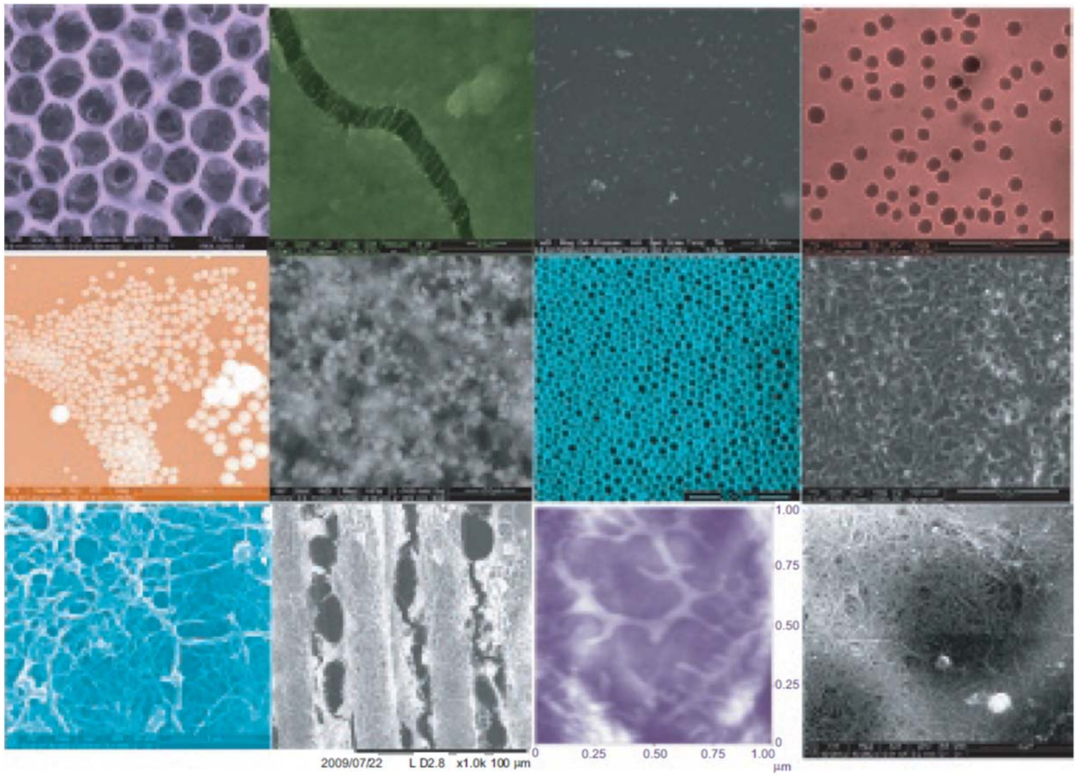
Nanostructured membranes

Nano-scaled features can be into the bulk or throughout the surface.

- Pores with size from 1 to 100 nm are structural elements that allow membranes to be classified as nanostructures;
- The inclusion of nanofillers in polymer matrices also makes the membranes categorized as nanostructures;

- The creation of hierarchically textured membrane surfaces is another requisite for falling into the class of nanostructures.

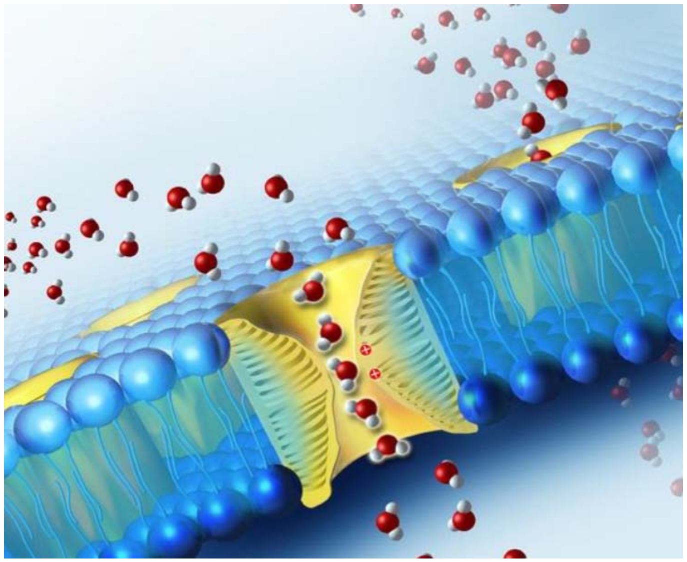
Nanostructured membranes

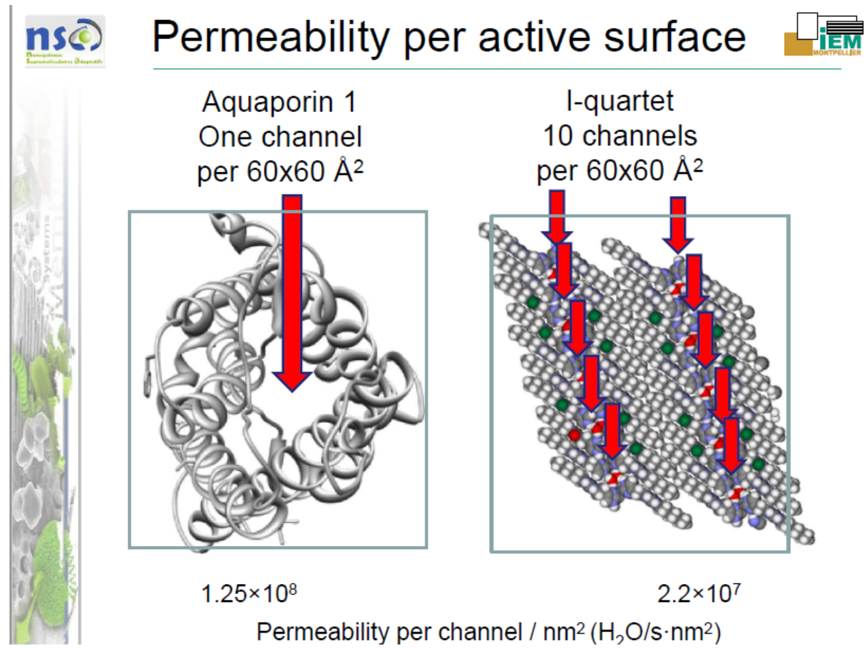


from «Functional Nanostructured Membranes», E. Drioli, L. Giorno, A. Gugliuzza Eds., Pan Stanford Publishing 2019.

Bio-inspired Nanostructured membranes

Water transport through membranes





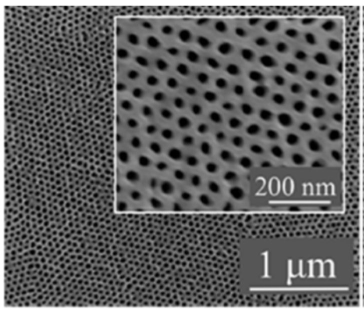
Mihail Barboiou, « From natural to bioassisted and biomimetic artifical water channel systems », Lecture at the XXXIII EMS Summer School, Bertinoro Italy, 2016.

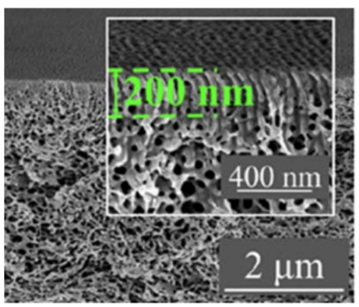
Hybrid Isoporous membranes

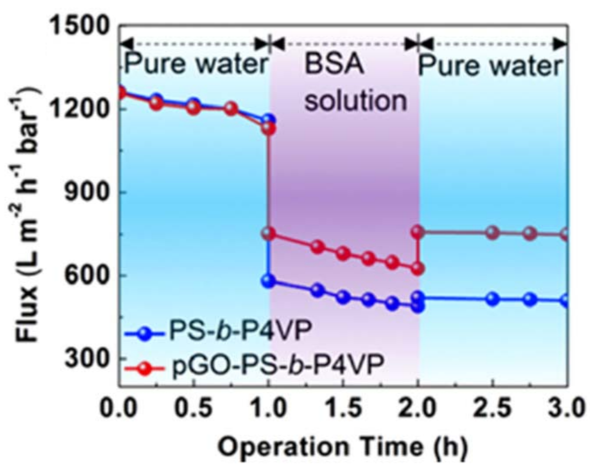
PDMAEMA-grafted GO (pGO) nanosheets
Polystyrene-b-poly(4-vinylpyridine) block copolymer

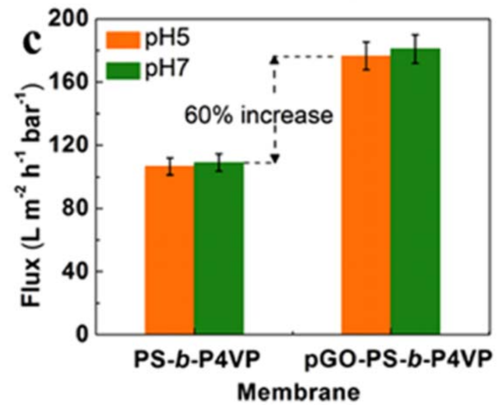
→

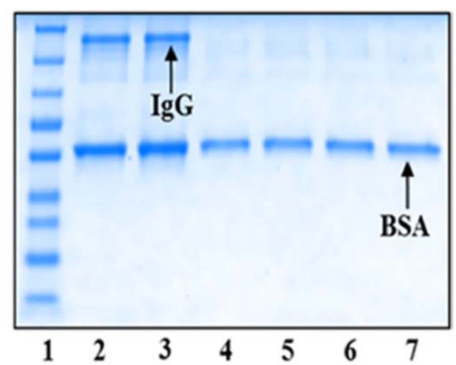
pGO-PS-b-P4VP membranes











R. Shevate *et al.,* ACS Appl. Mater. Interfaces 2019, 11, 8507−8516

Mixed Matrix Membranes Adsorbers (MMMAs) for the removal of water contaminants

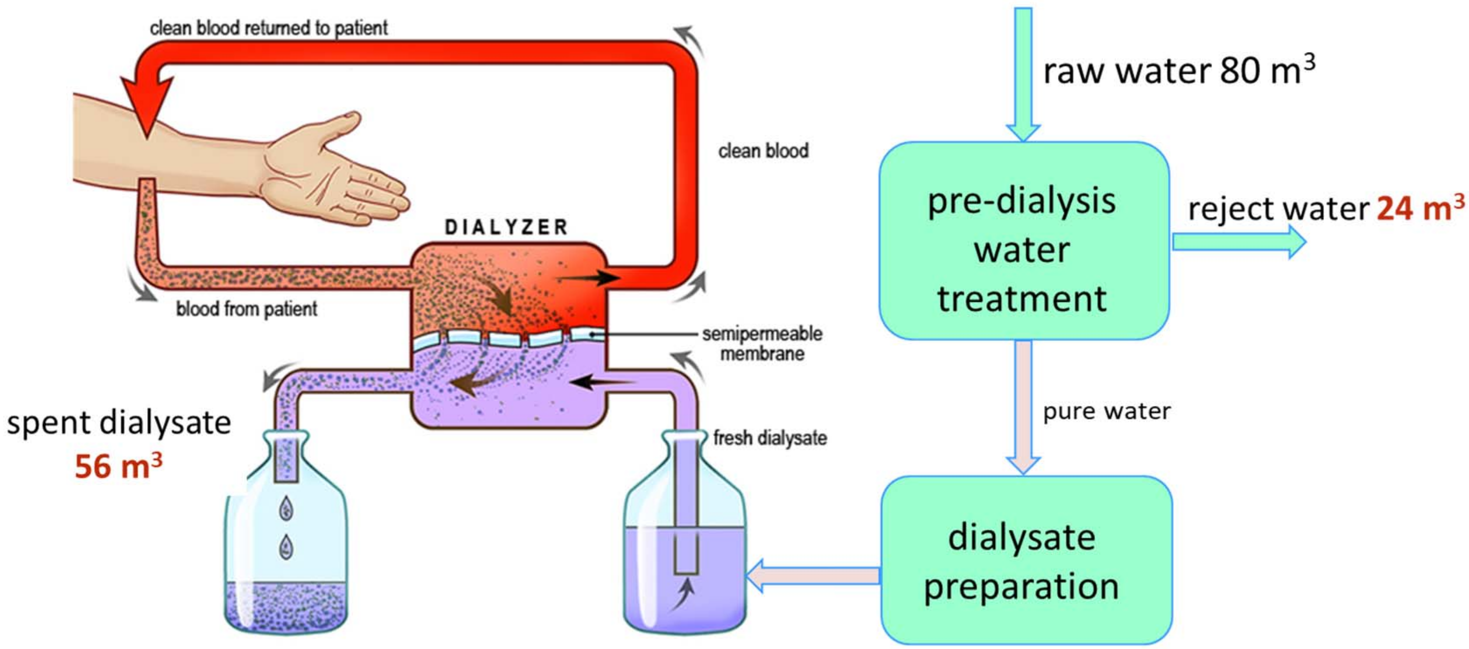
DICAM, Alma Mater Studiorum-Università di Bologna

Matilde De Pascale

Project goal

The aim of the project is to prepare porous Mixed Matrix Membranes Adsorbers (MMMAs) to purify the spent dialysate from uremic toxins. This will allow the recirculation of the stream to the process and the consequent saving of a great amount of water.

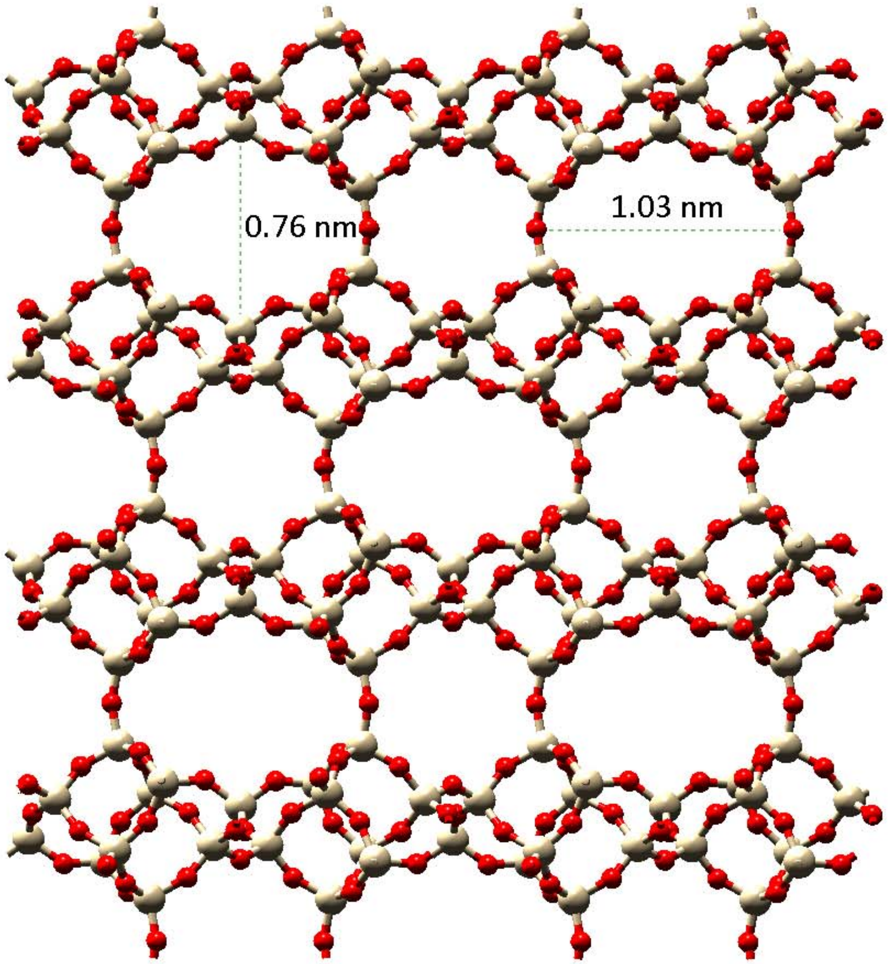
120L water/(patient*treatment) are needed to produce dialysate



Toxins

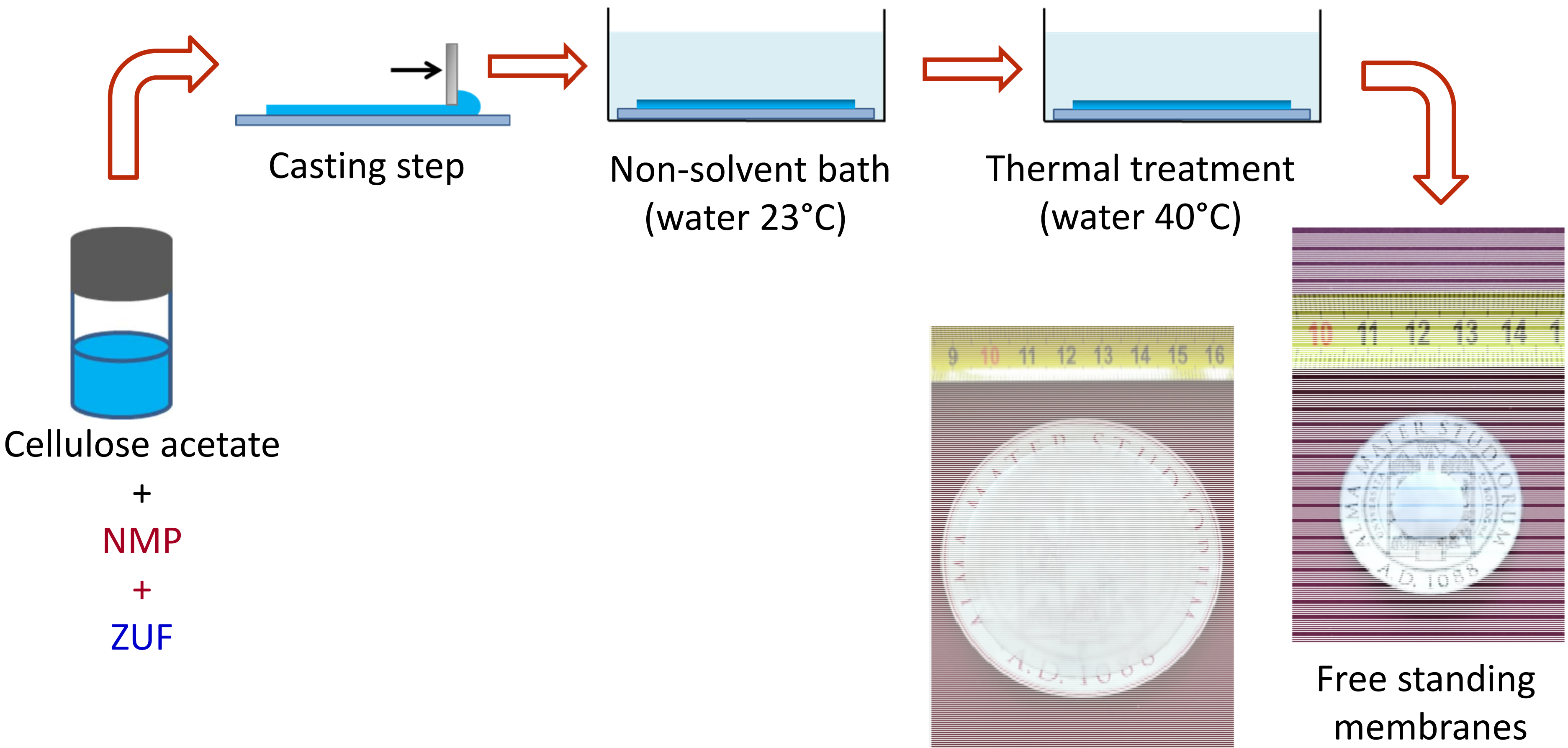
	M_w (g/mol)	c_n (mg/mL)	c_{max} (mg/mL)
Urea	60.00	0.400	4.60
Creatinine	113.12	0.012	0.24
Uric Acid	168.11	0.067	0.15

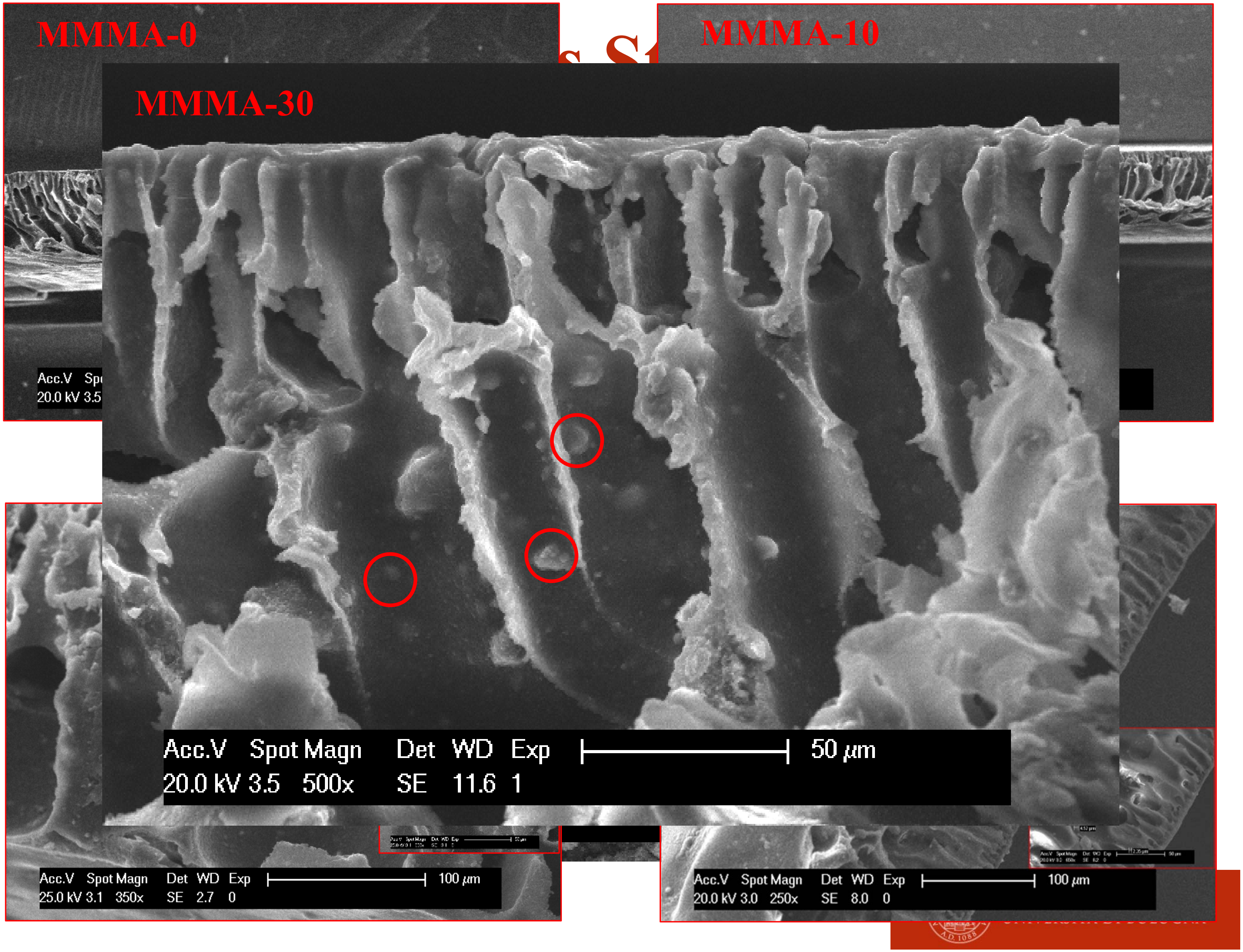
Materials



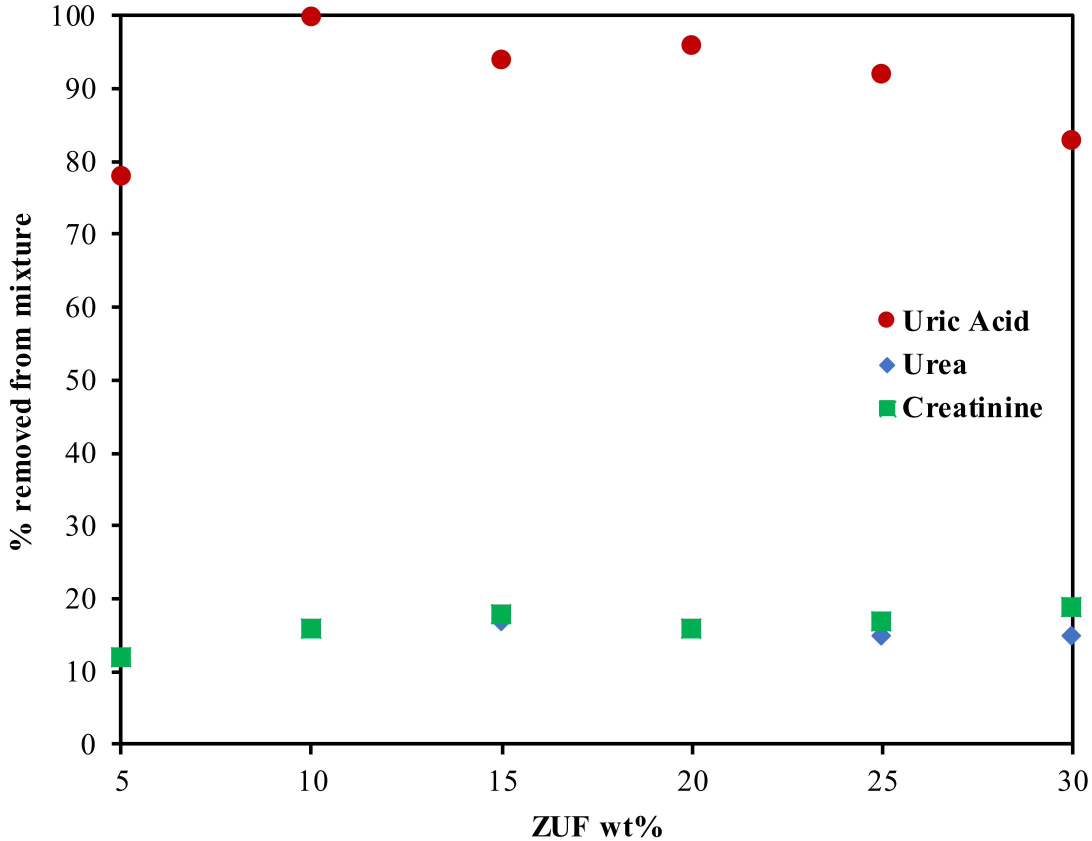
Zeolite structures obtained with the MD software MAPS from Scienomics

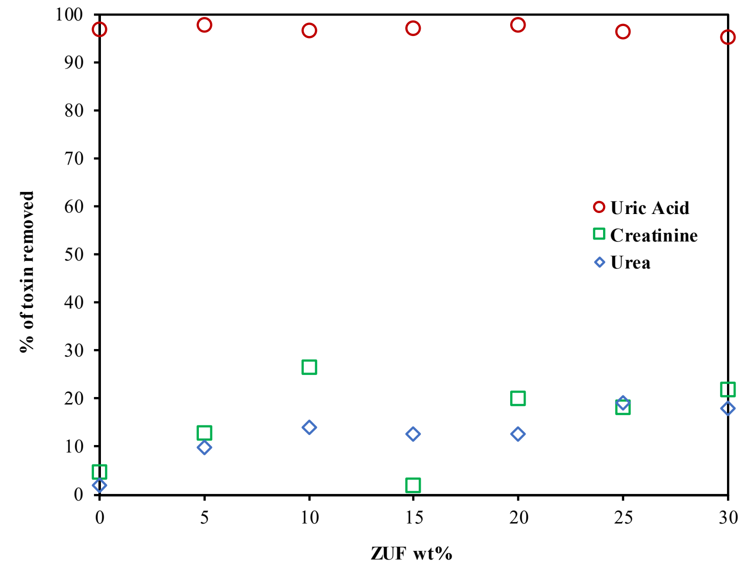
Membrane Preparation




MMMA-0
MMMA-10
MMMA-30
Acc.V Spot Magn Det WD Exp 50 µm
20.0 kV 3.5 500x SE 11.6 1
Acc.V Spot Magn Det WD Exp 100 µm
25.0 kV 3.1 350x SE 2.7 0
Acc.V Spot Magn Det WD Exp 100 µm
20.0 kV 3.0 250x SE 8.0 0

MMMAs batch characterization





Experimental conditions:

2 mL of a mixture of toxins at c_{MAX}

2 membrane discs of 15 mm diameter

Leave under mild agitation for 24 h

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Electrospun nanofiber membranes

Collaboration with prof Maria Letizia Focarete

Chemistry Department "G. Ciamician"

Alma Mater Studiorum-Università di Bologna

Margherita Animini

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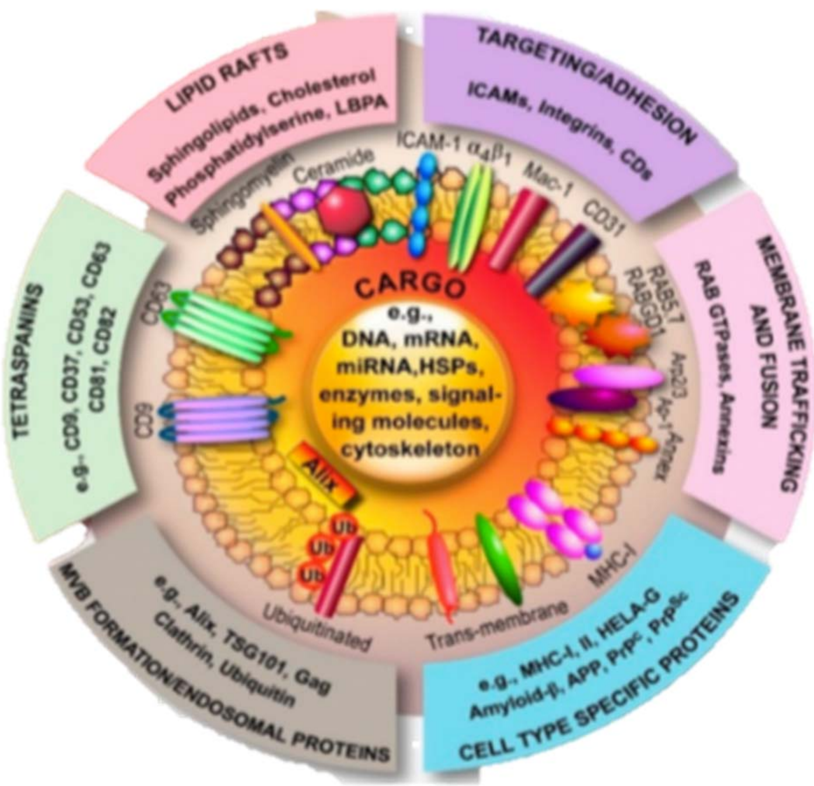
Aim of the research

Production of an affinity membrane for the isolation of **Extracellular Vesicles (EVs)**



EXTRACELLULAR VESICLES

INVOLVED IN INTERCELLULAR

COMMUNICATION

Dimension: 30-150 nm diameter

Biogenesis: inward budding of endosomal membranes

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Affinity Membrane

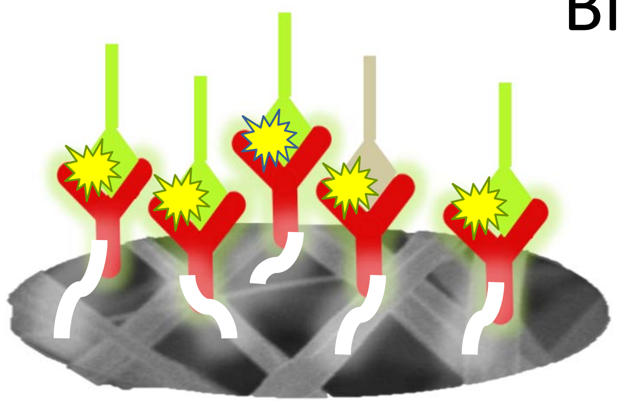
SELECTIVE INTERACTION
LIGAND and TARGET MOLECULE

ELECTROSPINNING

Nano-scaled Fibers

↑ Porosity

↑ Interconnectivity



BIOCONJUGATION

Grafting of a
BIOMOLECULE:
Antibodies,
Enzymes,Peptides

FUNCTIONALIZATION

Introduction of FUNCTIONAL GROUPS and
ACTIVATION of the membrane

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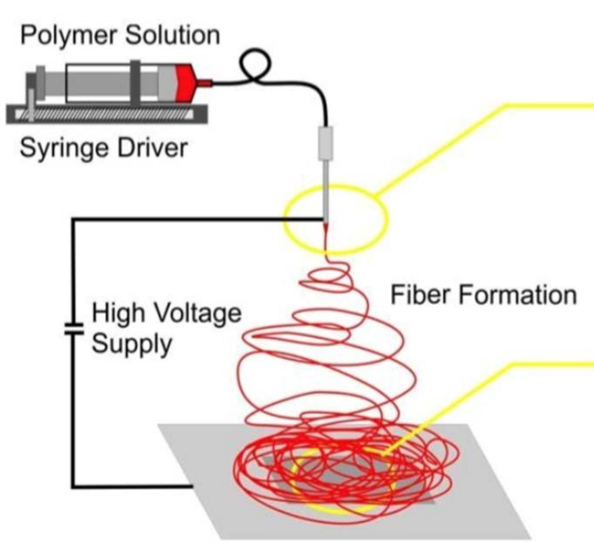
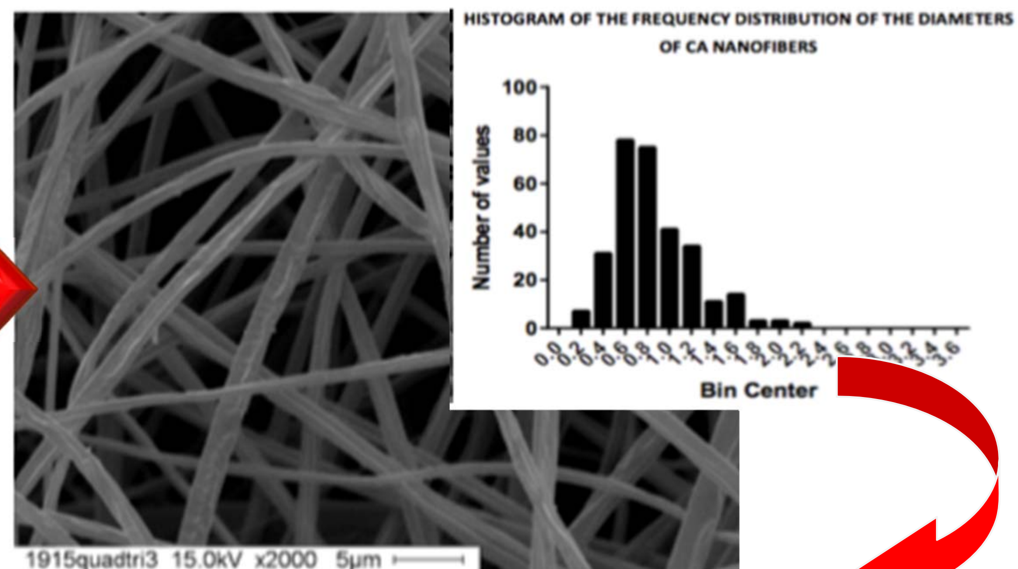
Unpublished work

Cellulose Acetate Nanofibers

CELLULOSE INSOLUBILITY → ELECTROSPINNING of CELLULOSE ACETATE





SUB-MICROMETRIC DIAMETER: 600-800 nm

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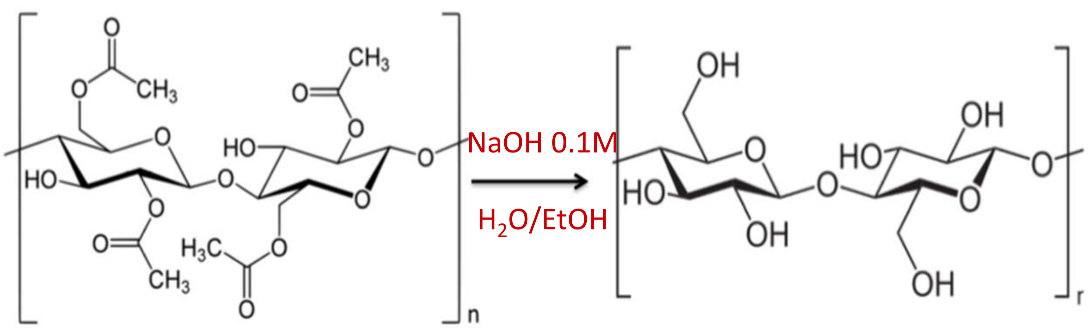
Unpublished work

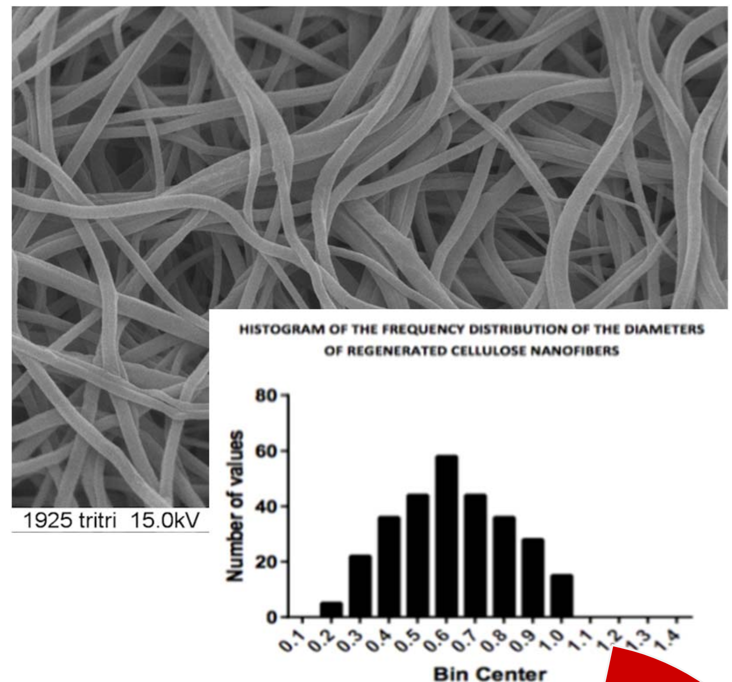
Cellulose Regeneration

HEAT TREATMENT

180°C for **1 h**.

DEACETYLATION





SUB-MICROMETRIC DIAMETER:
400-800nm

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XPS Analysis

Cellulose Acetate

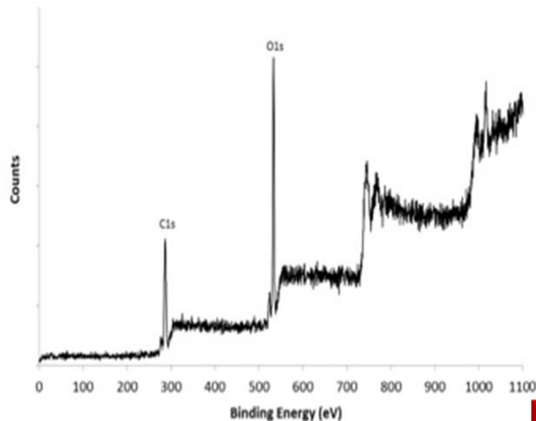
O/C RATIO:

0,69%

COMPOSITION:

O= 40,9%

C= 59,1%



5 CHEMICAL STATES:

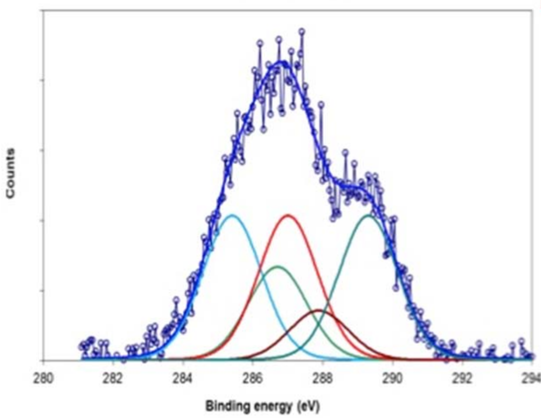
CH3COOH

C-O

C-O-C=O

O-C-O

C=OOH



Theoretical values and area ratio RESPECTED

Regenerated Cellulose

O/C RATIO:

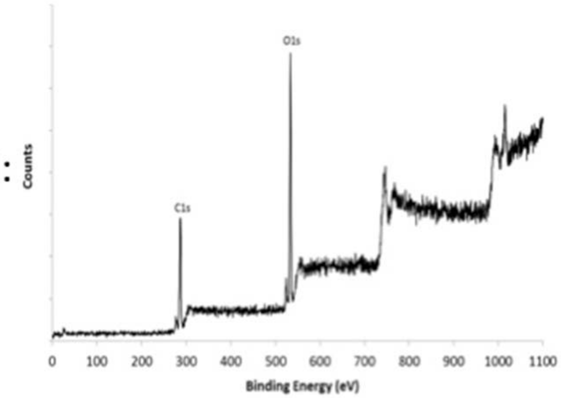
0,85%

COMPOSITION:

O= 45,9%

C= 54,1%

Values RESPECTED

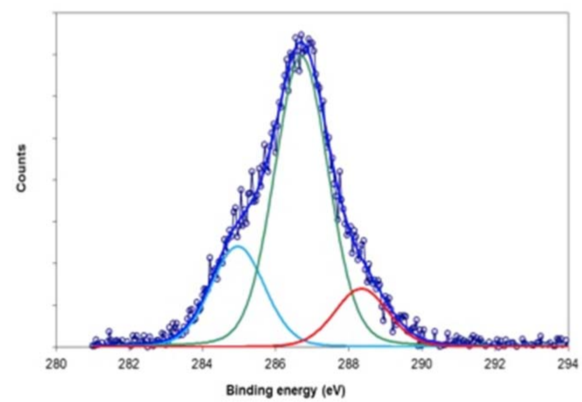


2 CHEMICAL STATES:

C-O

O-C-O

Areas ratio RESPECTED

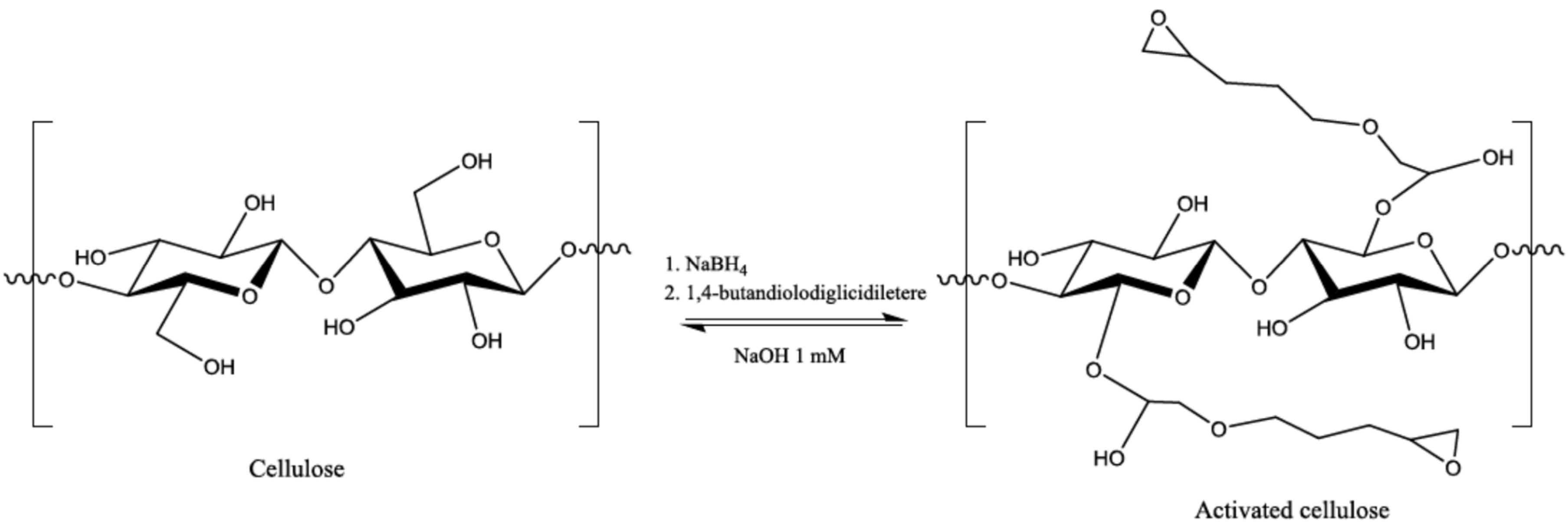


Theoretical values and area ratio RESPECTED

Unpublished work

Membrane activation

EPOXIDIZATION OF REGENERATED CELLULOSE



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XPS Analysis

Regenerated Cellulose

O/C RATIO:

0,85%

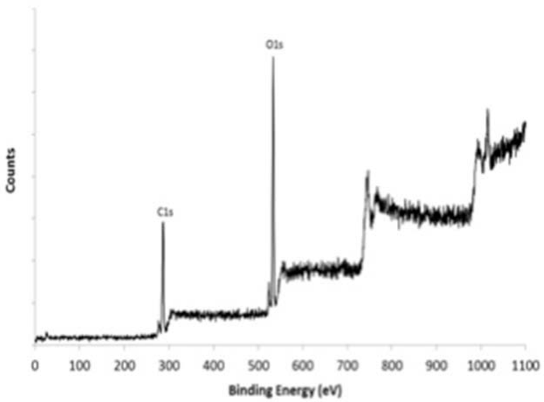
COMPOSITION:

O= 45,9%

C= 54,1%

Values

RESPECTED



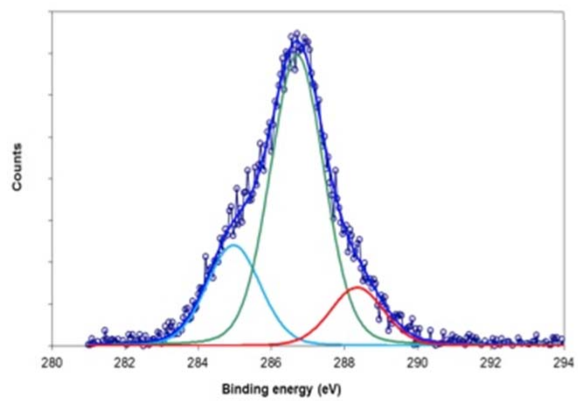
2 CHEMICAL STATES:

C-O

O-C-O

Areas ratio

RESPECTED



Theoretical values and areas ratio RESPECTED

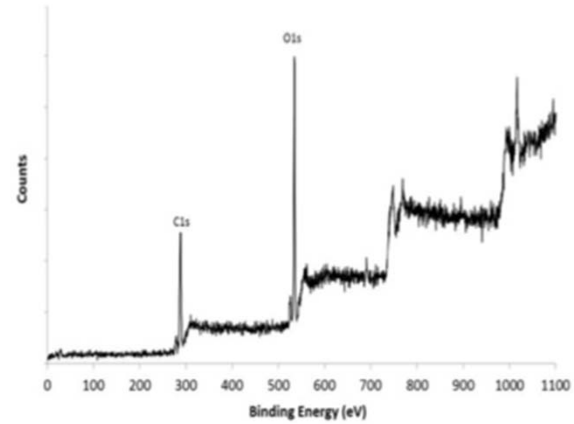
Epoxidized Cellulose

O/C RATIO:

0,59%

Values

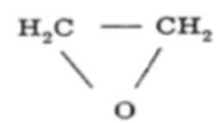
RESPECTED



3 CHEMICAL STATES:

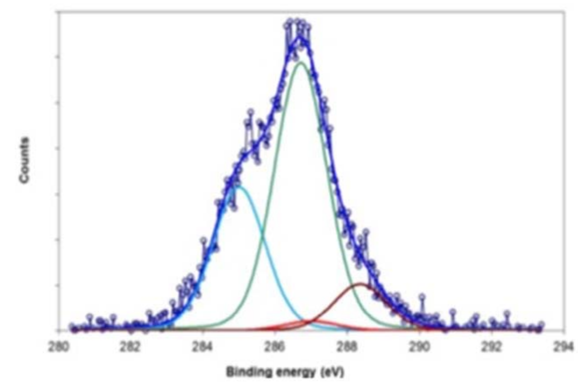
C-O

O-C-O



Areas ratio

RESPECTED

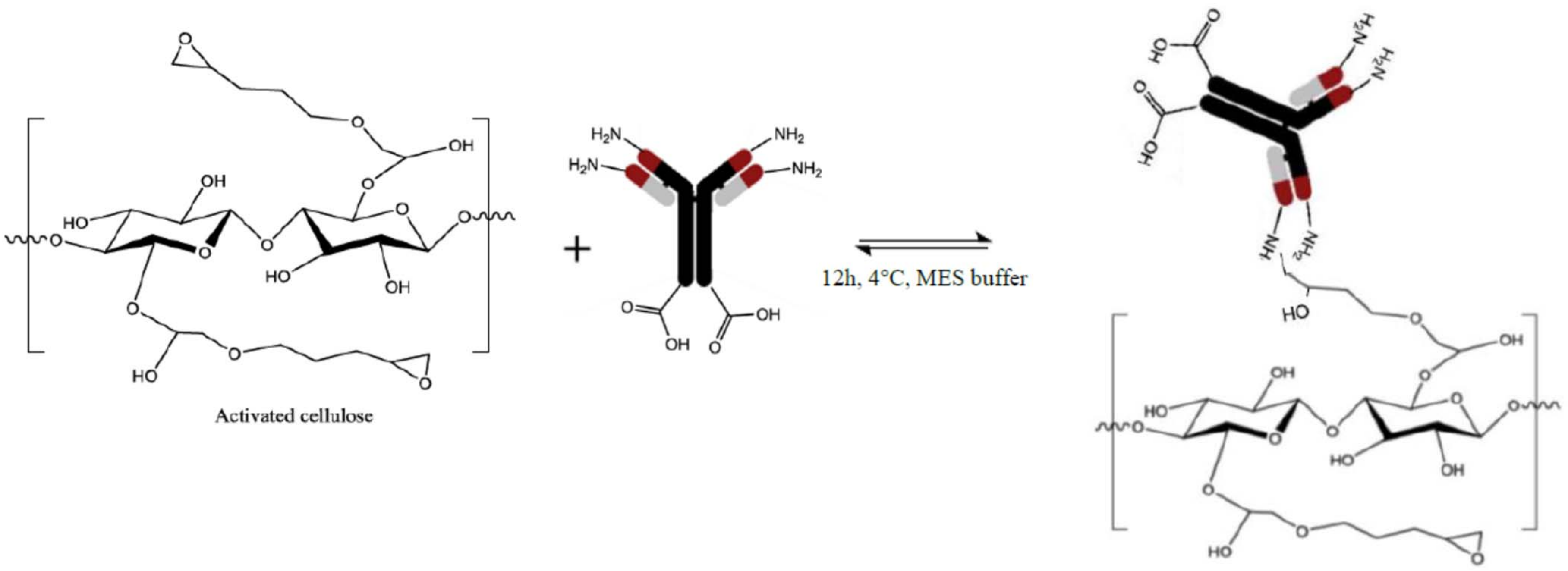


Theoretical values and areas ratio RESPECTED

Unpublished work

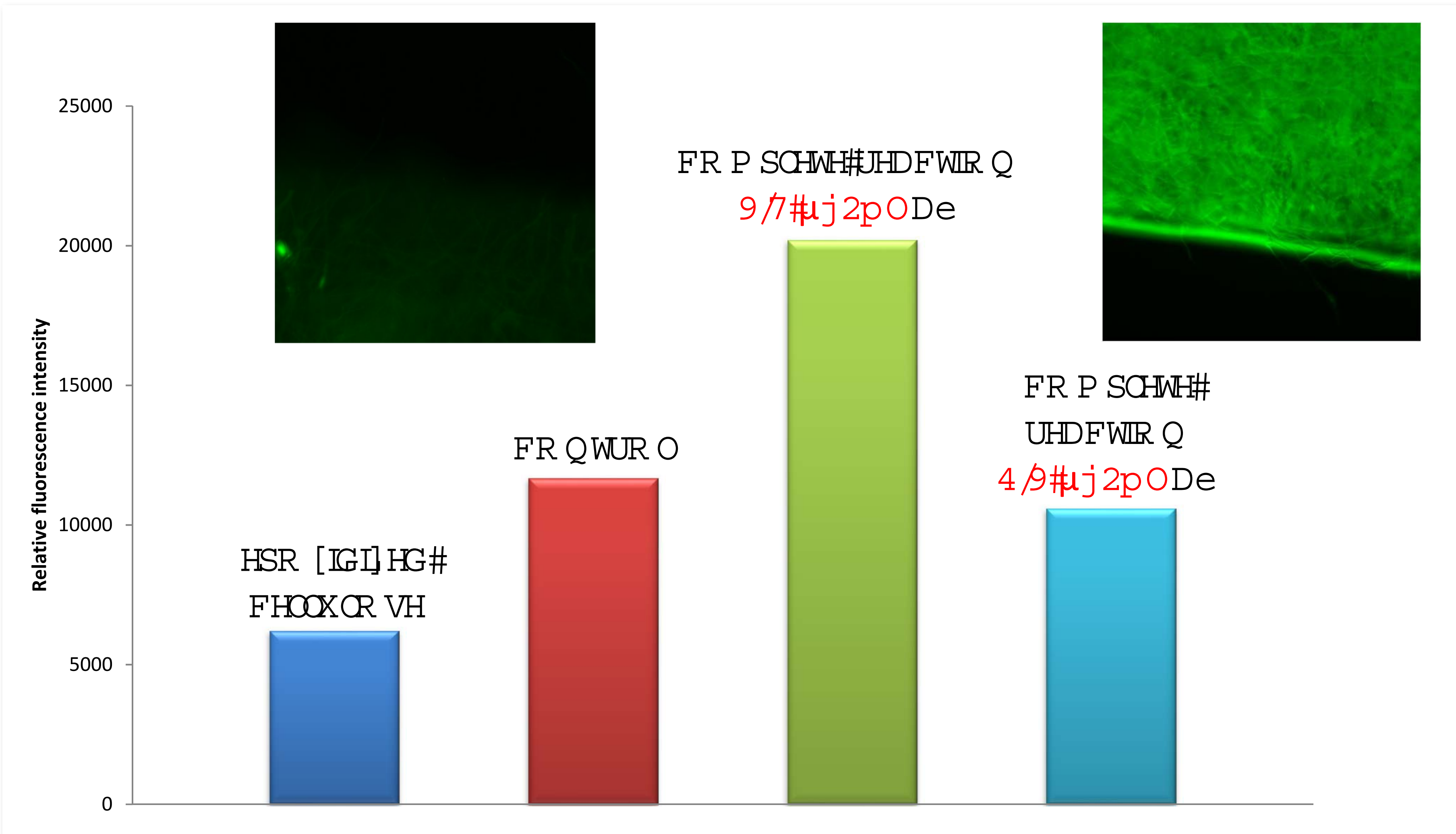
Functionalization

BIOCONJUGATION of Anti-CD63 (FITC) on REGENERATED CELLULOSE



Unpublished work

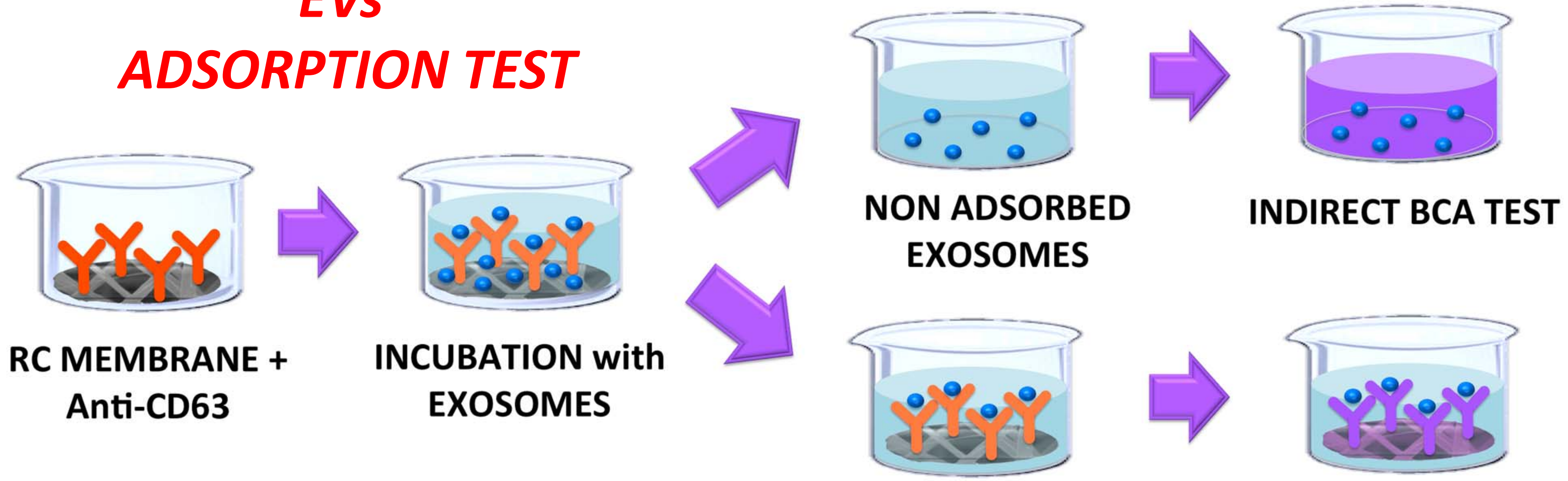
Fluorescence Microscopy



Unpublished work

Adsorption

EVs
ADSORPTION TEST



RESULTS

QUANTIFICATION of ADSORBED EXOSOMES	
DIRECTLY	*INDIRECTLY*
0,0478 mg	0,0508 mg

EVs
CAPTURED

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Unpublished work

CONCLUSIONS

This study led to the preparation of a regenerated cellulose affinity membrane which represents a promising candidate for the capture isolation of extracellular vesicles.

PERSPECTIVES AND CHALLENGES

- ✓ Optimization of the degree of functionalization and bioconjugation
- ✓ Study of the Antigen-Antibody binding kinetic
- ✓ Development of a suitable module to use these membranes in a flow configuration

Unpublished work

Nanostructured Membranes for Gas Separation

Maria Grazia De Angelis, Matteo Minelli, **Marco Giacinti Baschetti**

DICAM, Alma Mater Studiorum-Università di Bologna

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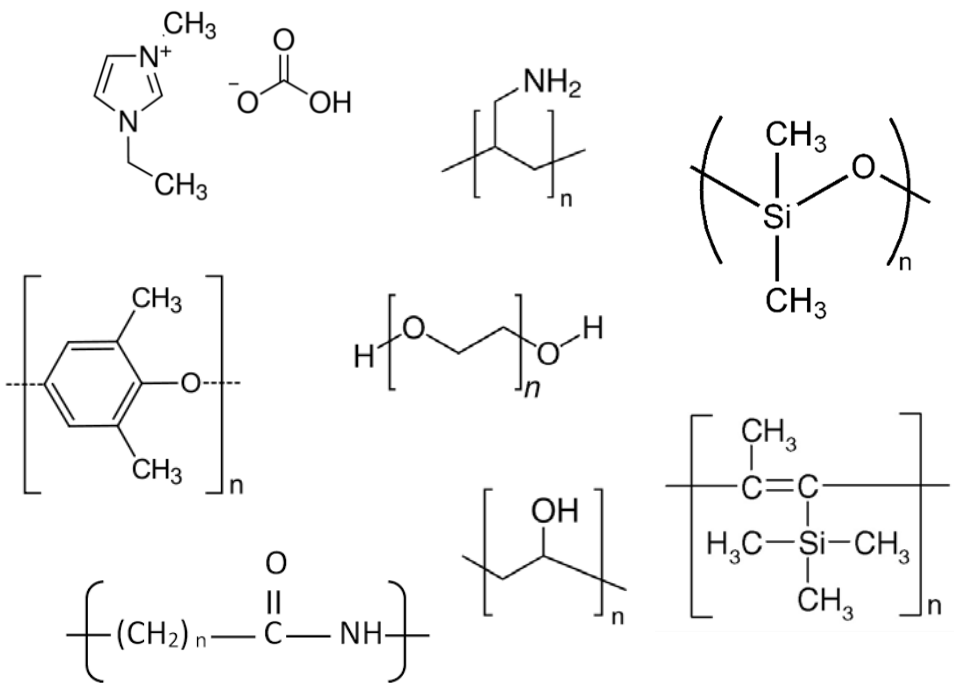
Horizon 2020

Membranes for CO_2 Capture

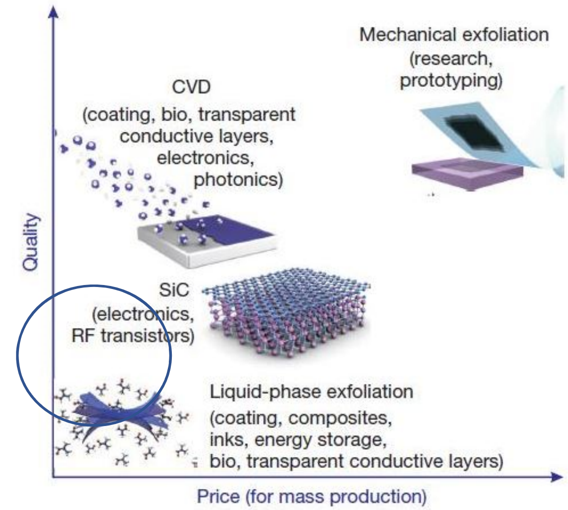
NANOMEMC² is a H2020 funded project focusing on use of nanofiller to boost membrane performances in Carbon capture (CCS) applications.

Polymers

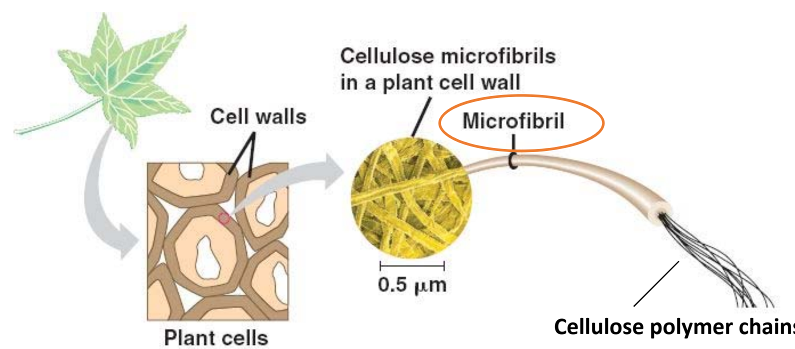


FIllers

Graphene

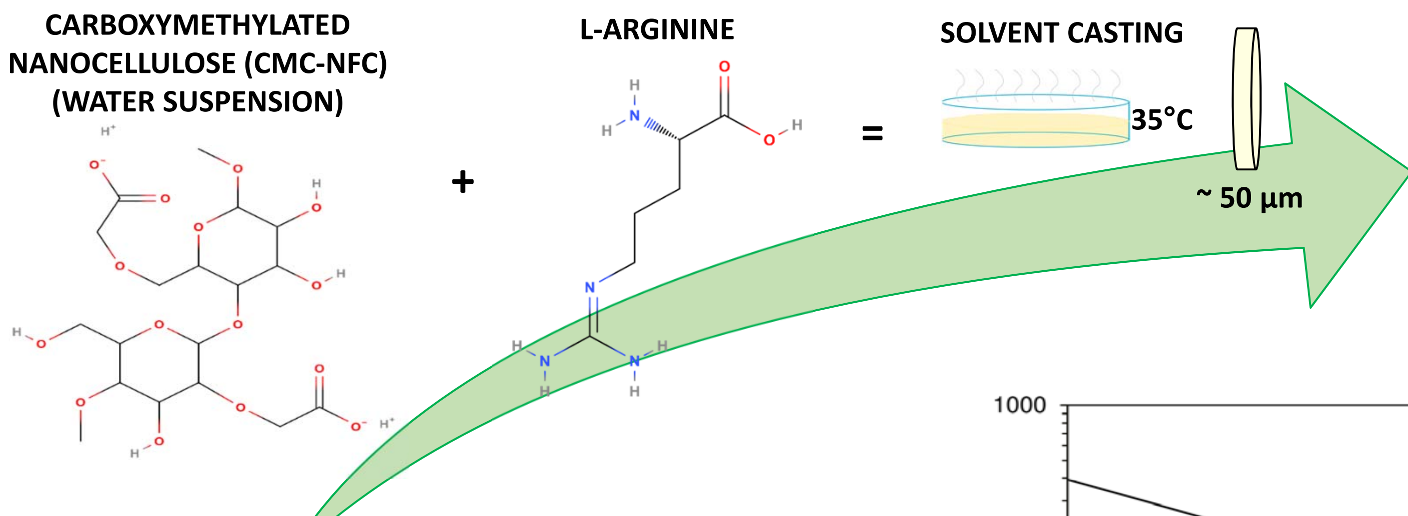


Nanocellulose

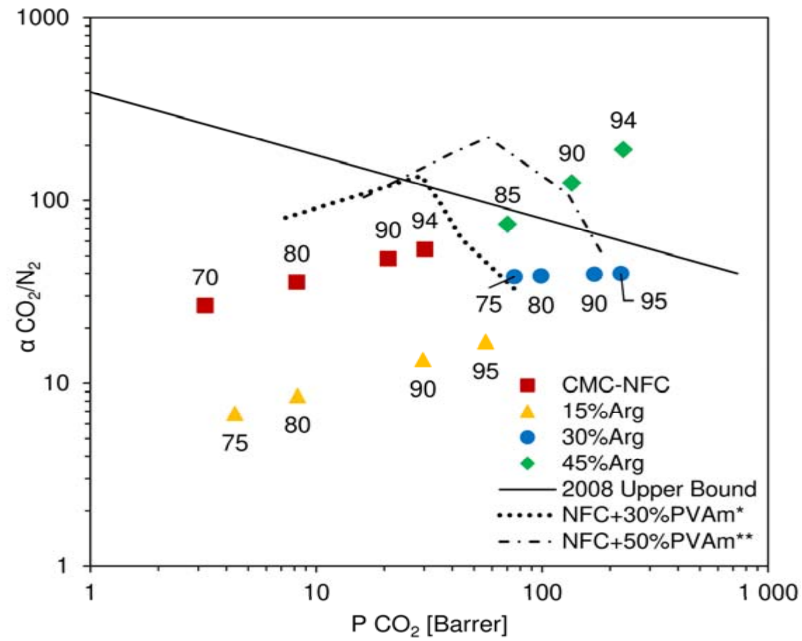


Membranes for CO_2 Capture

Nanocellulose based facilitated transport membranes



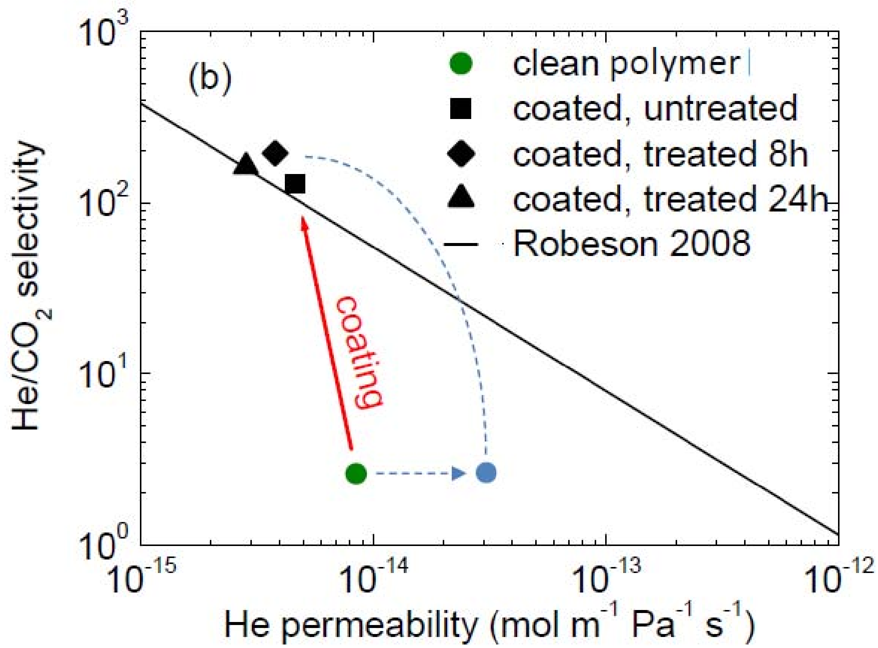
Simple mixing allows to obtain stable membranes with extremely high potential for application in CCS and other CO_2 separation processes

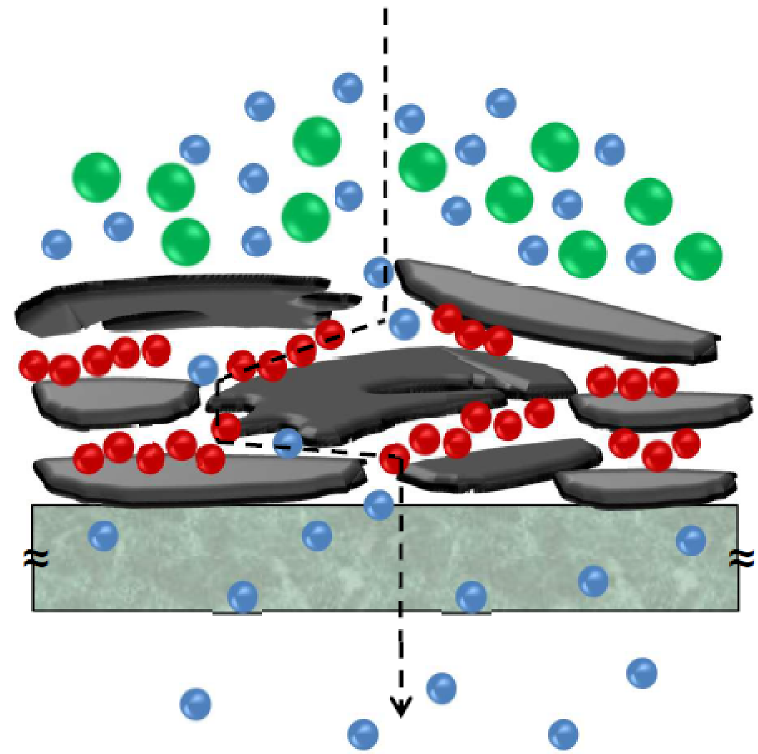


Graphene membranes by LbL deposition

Graphene is deposited via layer by layer (LbL) deposition on the top of a support

The membrane appeared to offer **extremely high He/CO_2 selectivity**





Pierleoni et al - ACS Appl. Mater. Interfaces ***2018****, 10, 11242*

Almost there-what's next?

Membrane technology is well-established in water desalination, wastewater treatment, gas separation, energy power and storage, biomanufacturing, chemical and petrochemical, and agro-food industry.

However, we are still far from the complete exploitation of this technology.

Fouling, aging, membrane lifetime, improved selectivity and transport are among the remaining challenges.

The design of new nanostructured membranes with improved properties is a key issue to these challenges.

membranes

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Special Issue

Membrane Chromatography for Biomolecules Purification

Special Issue Editors:

Prof. Dr. Cristiana Boi
Alma Mater Studiorum-Università di Bologna, Italy
E-mail: cristiana.boi@unibo.it

Submission Deadline: 31 July 2019

This themed issue aims to collect key contributions to the field and give an overview of novel adsorptive membranes with improved properties and functionalities, new applications, and more efficient module design and mathematical modelling, addressing both fundamental aspects and applied research.

Keywords

- Membrane chromatography
- Membrane adsorbers
- Affinity
- Ion exchange
- Hydrophobic interactions
- Biomolecules
- Proteins
- Antibodies
- Surface modification
- Mathematical modelling

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THANK YOU

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