POLITECNICO
MILANO 1863

Synthesis and functionalization of macromolecules

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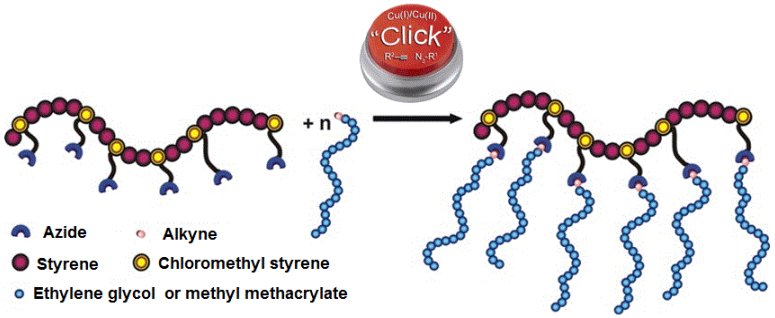
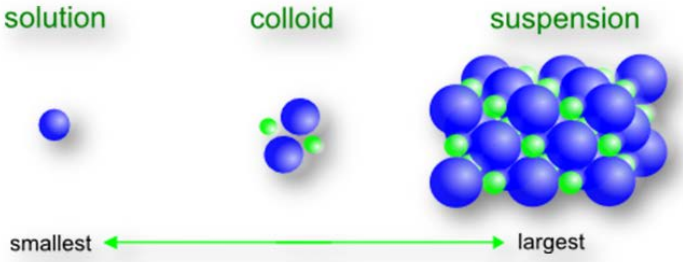
Research topics

- polymer synthesis and functionalization



- colloids (hydrophobic and hydrophilic)

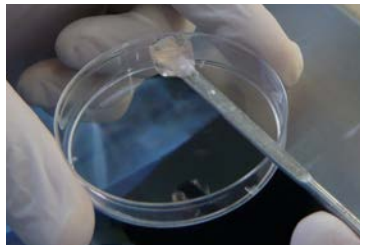


- mathematical modelling

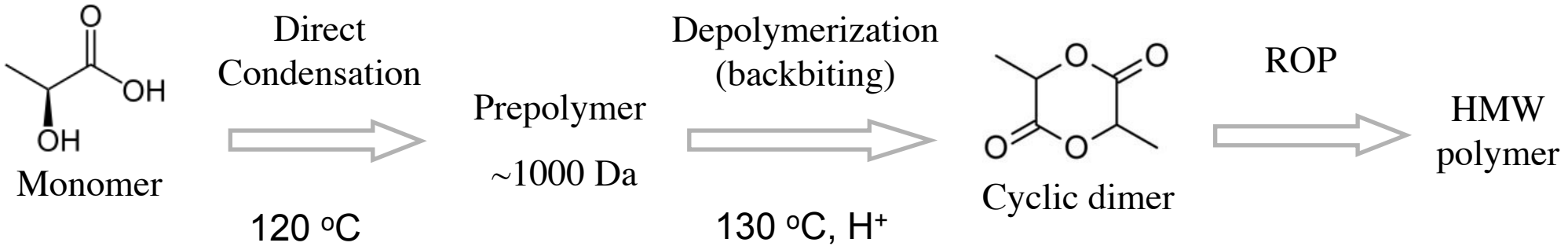
$$\frac{\partial \rho}{\partial t} + \frac{\partial \rho v_j}{\partial x_j} = 0$$

$$\frac{\partial \rho v_i}{\partial t} + \frac{\partial \rho v_i v_j}{\partial x_j} = -\frac{\partial p}{\partial x_i} + \frac{\partial \tau_{ij}}{\partial x_j} + \rho g_i$$

- polymer-based formulations



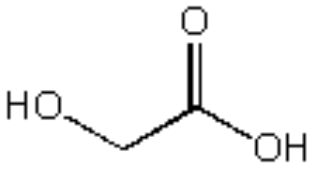
Biodegradable polyesters



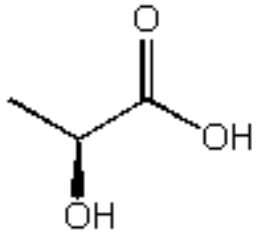
- Process design requires proper understanding of all the synthetic steps involved:
  - Direct polycondensation
  - De-Polymerization
  - Ring Opening Polymerization

- Through these chemical pathways, useful materials with different properties can be produced

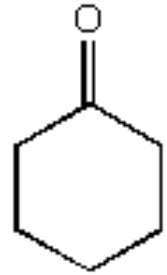
Biodegradable polyesters



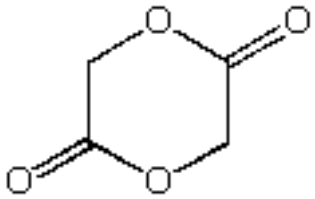
Glycolic Acid



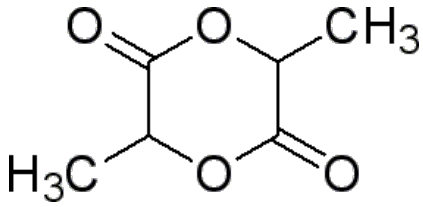
Lactic Acid



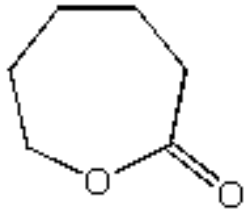
Cyclohexanone



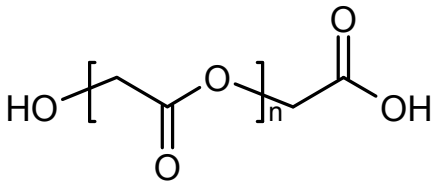
Glycolide



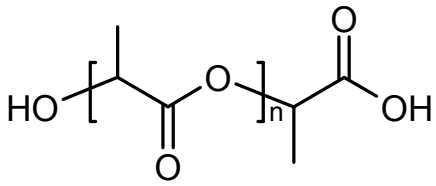
Lactide



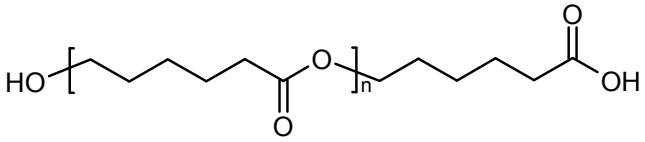
ε-Caprolactone



Poly Glycolic Acid (PGA)

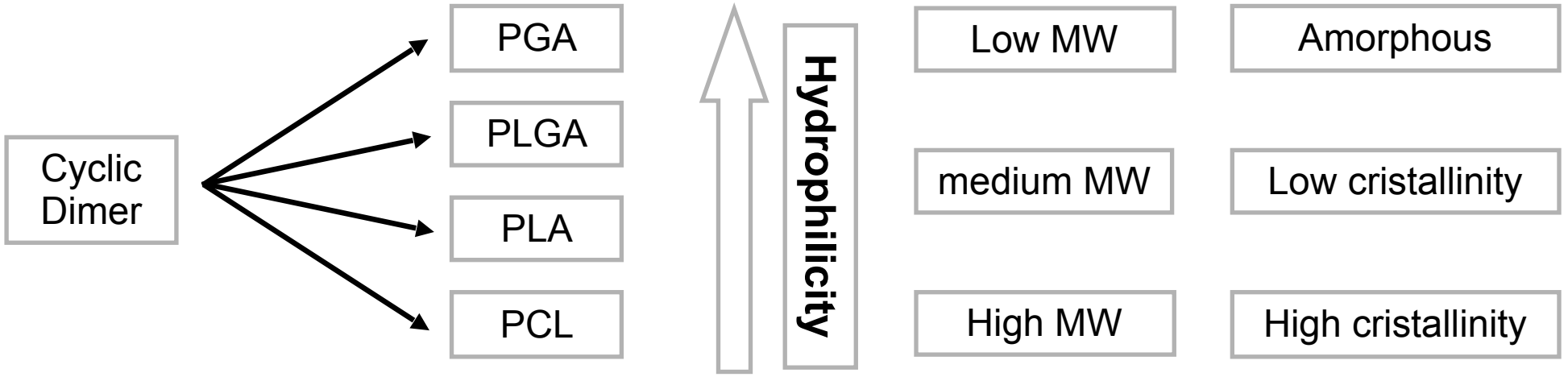


Poly Lactic Acid (PLA)



Poly Caprolactone (PCL)

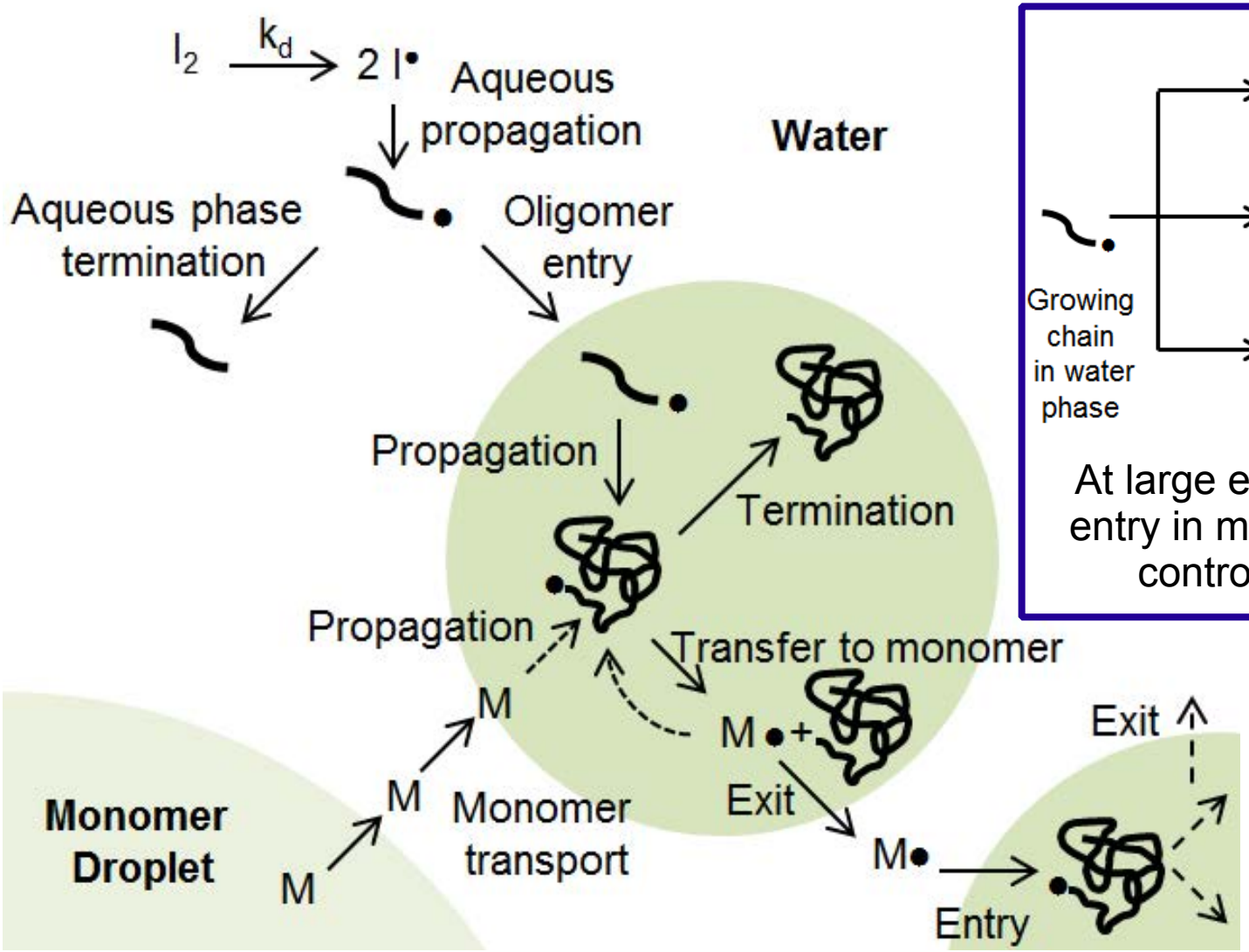
Biodegradable polyesters

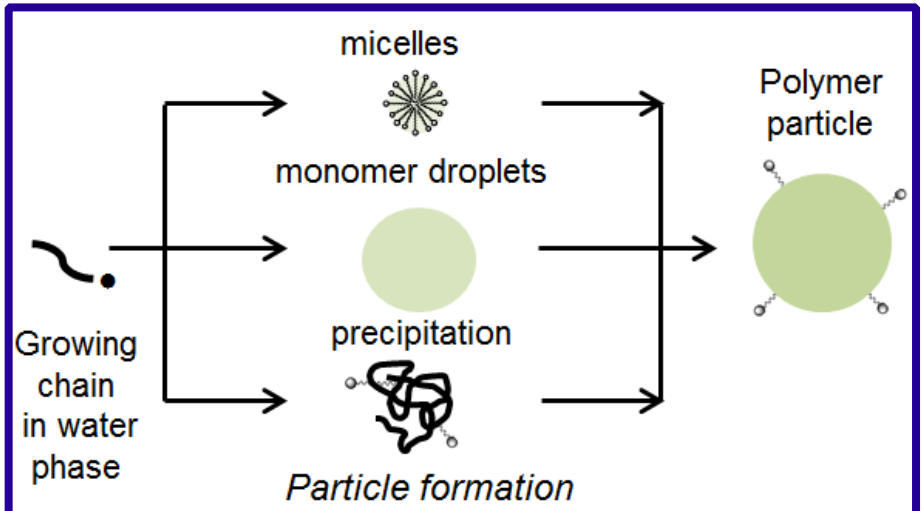


- Proper selection of characteristics above allows:
  - Decreasing materials cost
  - Increasing materials performances
  - Tuning materials features

- Degradation behavior is of primary importance:
  - Guides the material applications

Emulsion polymerization

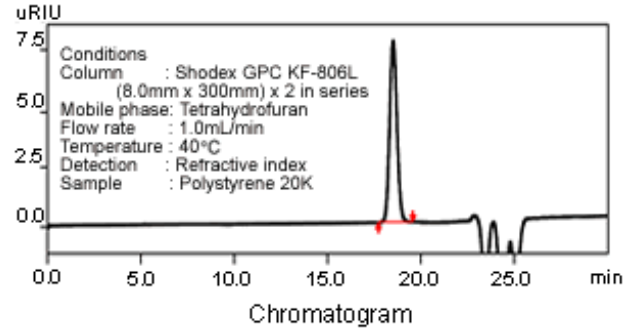




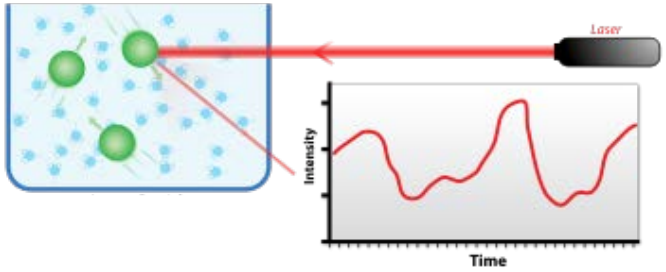
At large emulsifier concentrations, the entry in micelles dominates allowing to control the final number of NPs

Polymer characterization

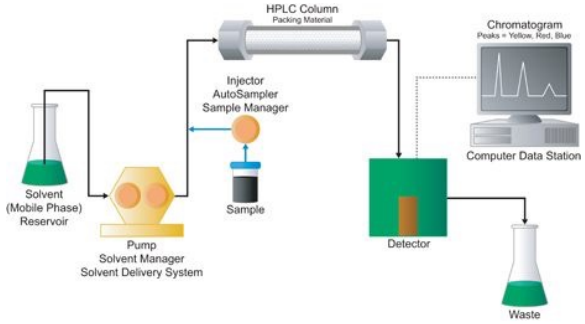
- Gel permeation chromatography



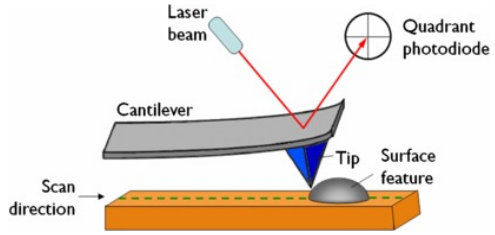
- Dynamic Light Scattering



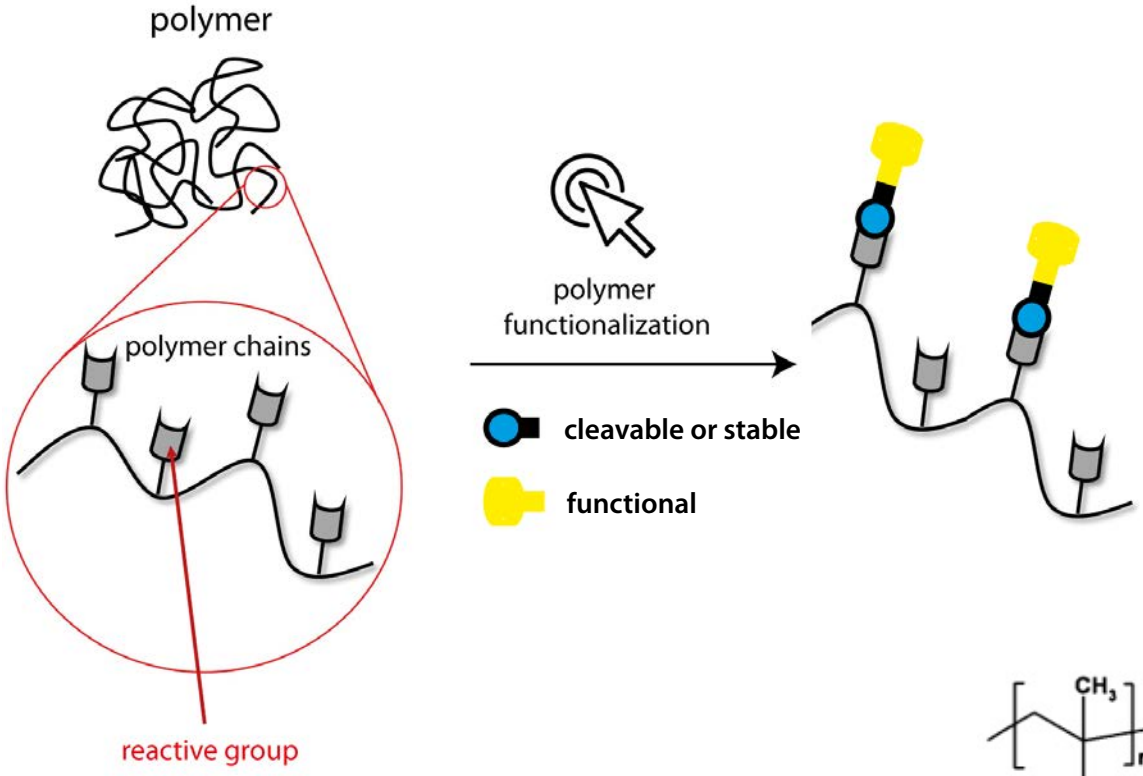
- High Pressure Liquid Chromatography



- Atomic Force Microscopy

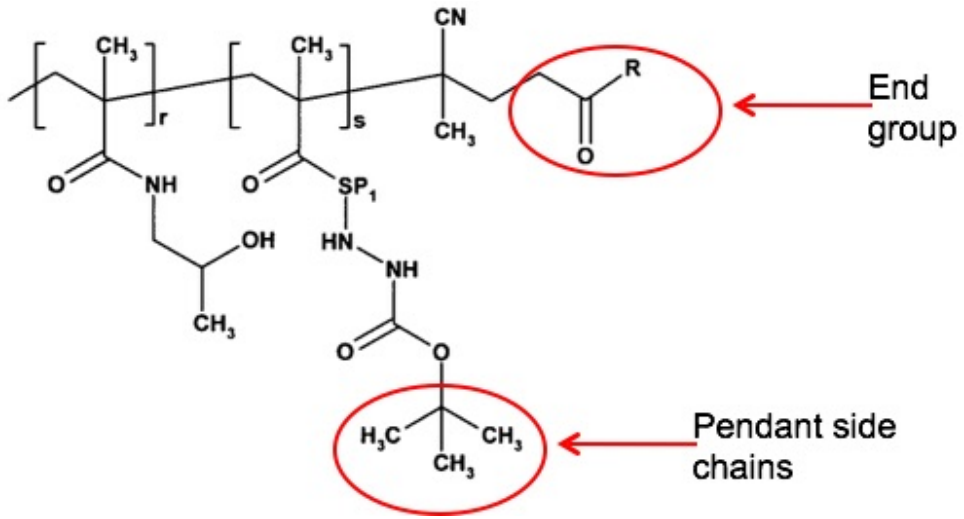


Post-polymer functionalization

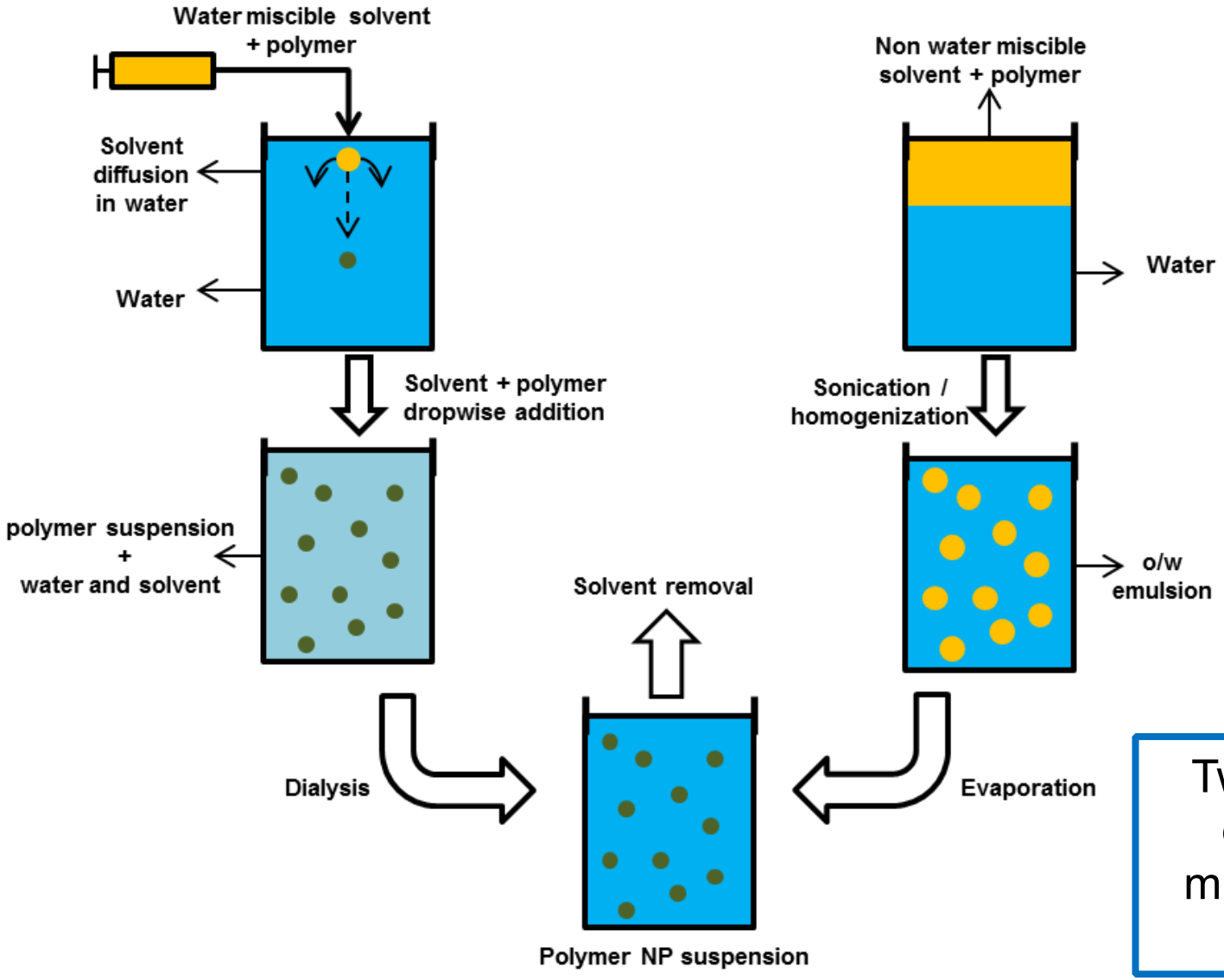


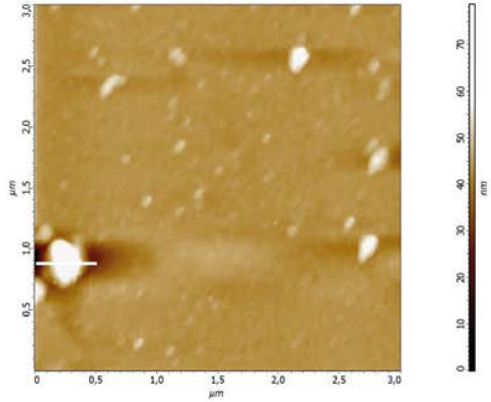
- Post-polymerization in bulk or during material processing (extrusion etc…);

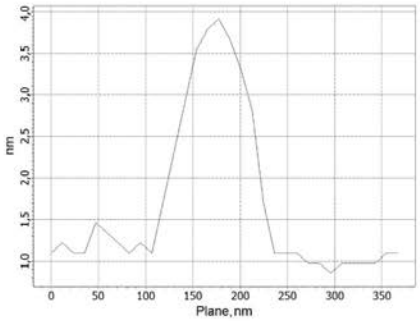
- Improve materials performances for industrial applications.



Polymeric colloids: physical processes

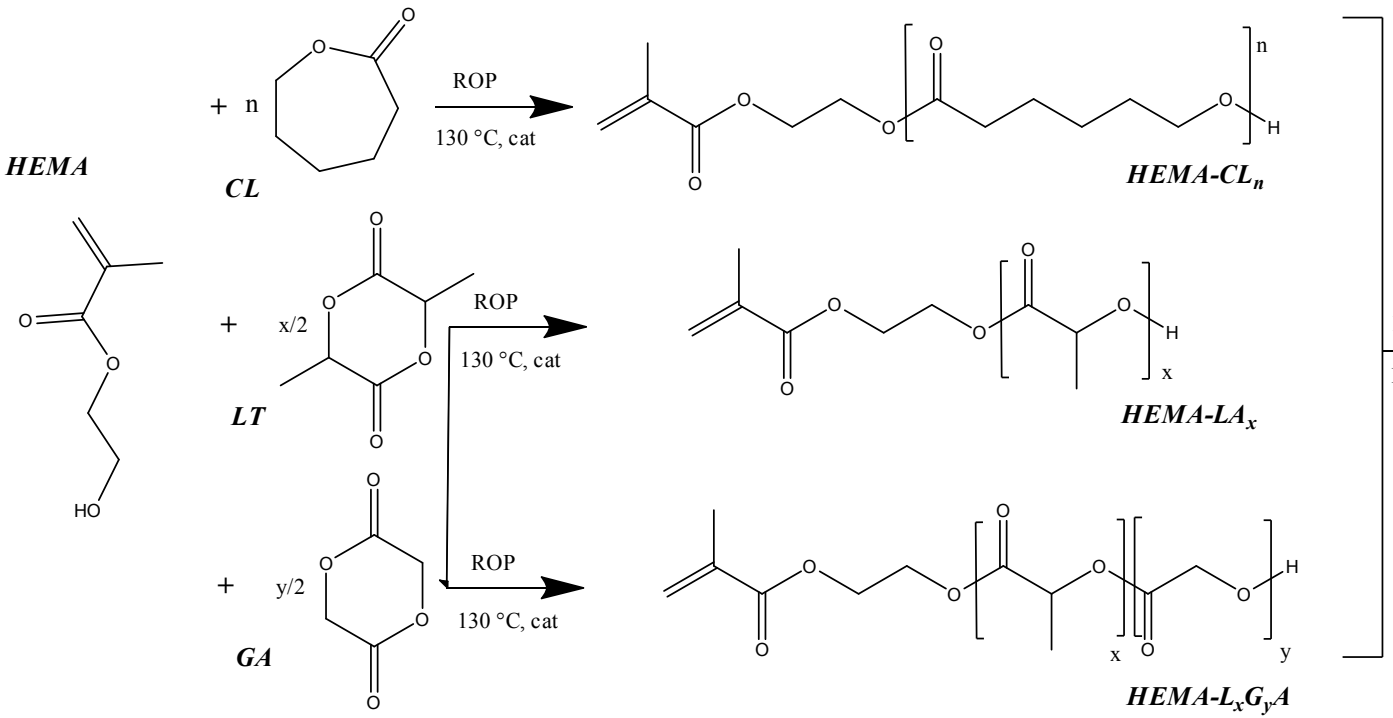


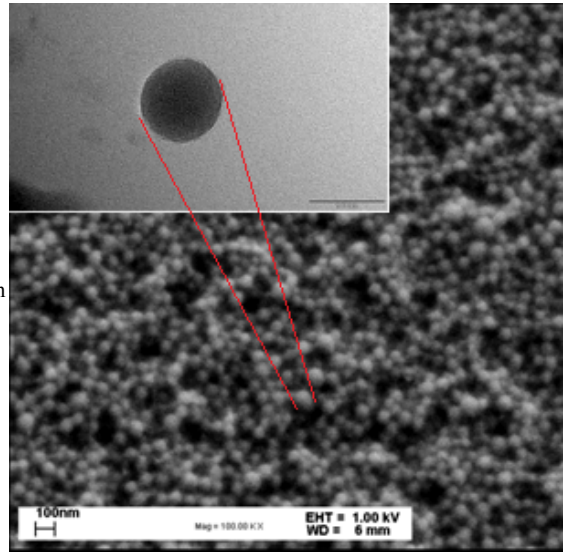




Two available methods depending upon the miscibility of the solvent with water

Polymeric colloids: chemical processes

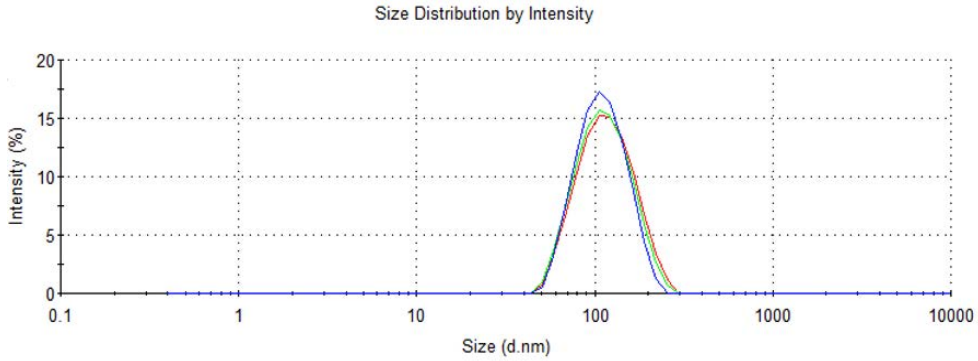




Monomer

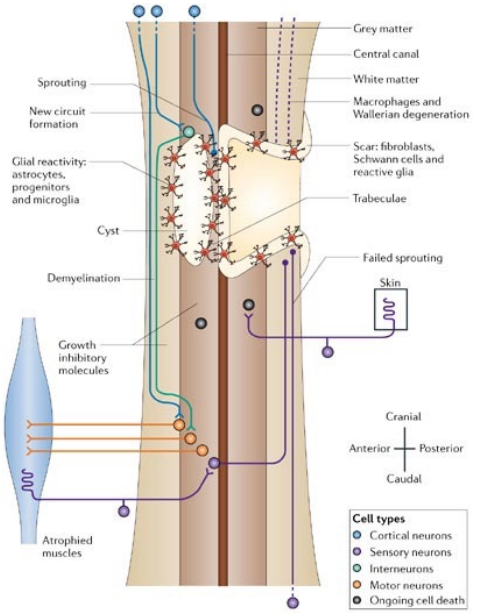
Macromonomer

Polymer NP suspension



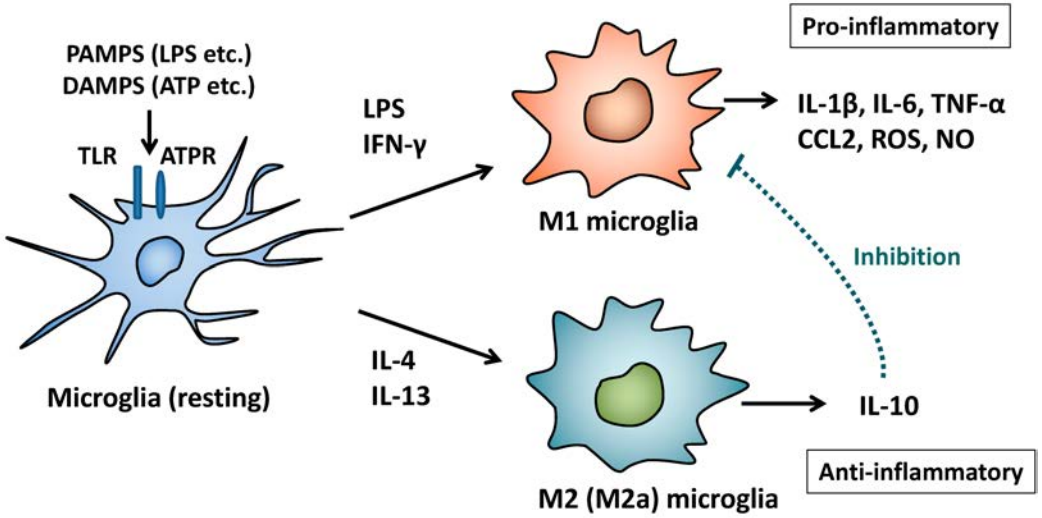
High tunability;
High control of NPs diameter;

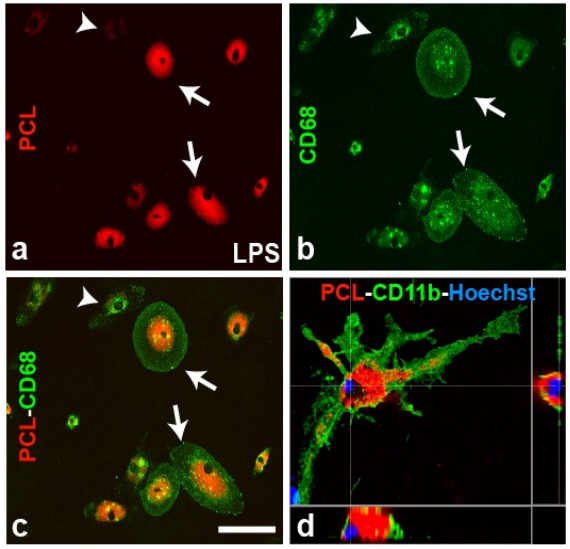
Application: spinal cord injury

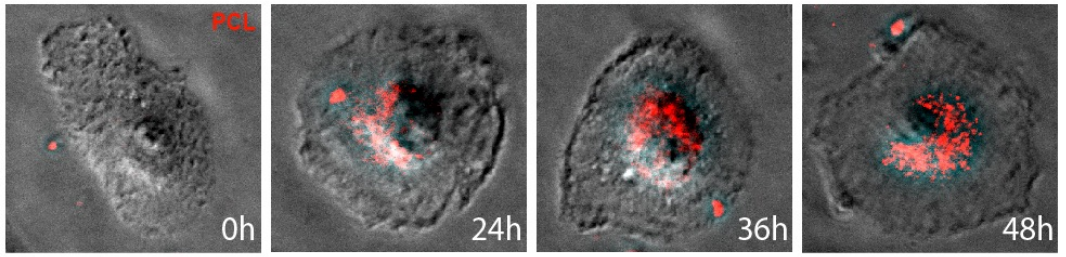


In **E.U.** every year 10.000 pz out of 400 M population suffer from Spinal Cord Injuries

99.5% of injuries leave permanent neurological consequences.

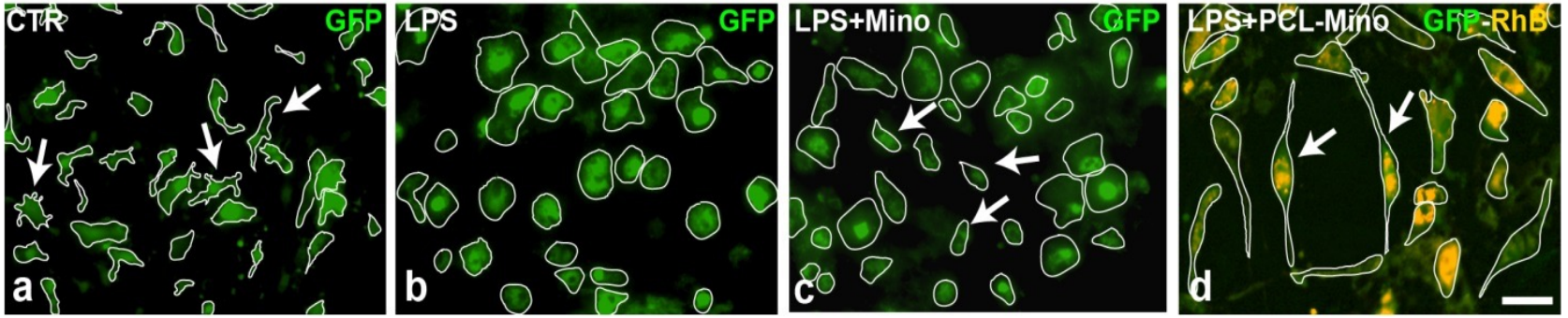


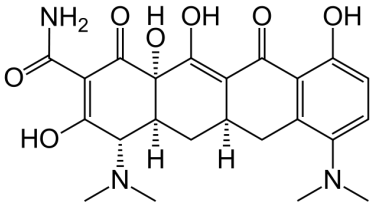




Selective treatment

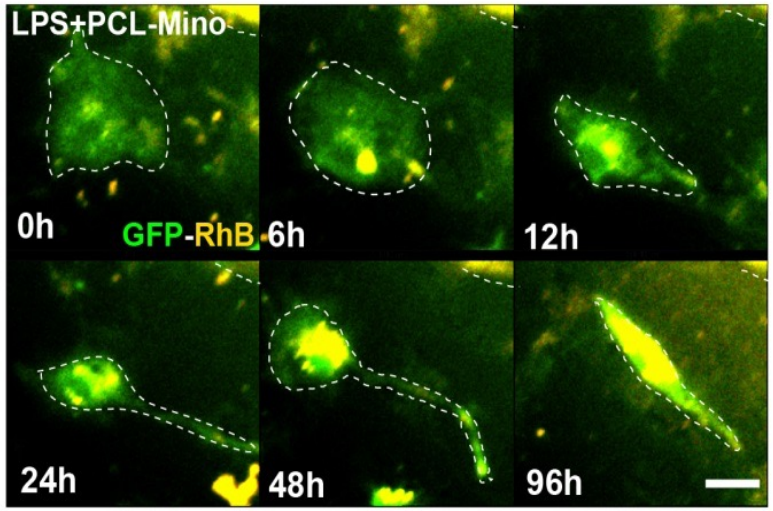
microglia | activated microglia | partially deactivated microglia | deactivated microglia

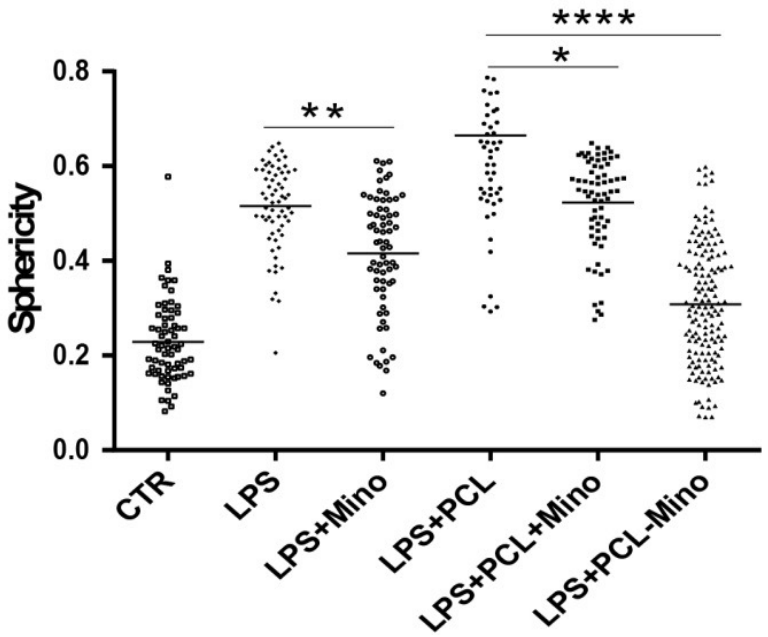




minocycline

anti-inflammatory drug





Minocycline selective treatment can reduce the inflammation of microglia cells

Mathematical modeling

Main results:

- complete control over formulation and process;
- complete control over transport phenomena having a robust and reliable modelling tool ;
- simple but based only on fundamental laws!

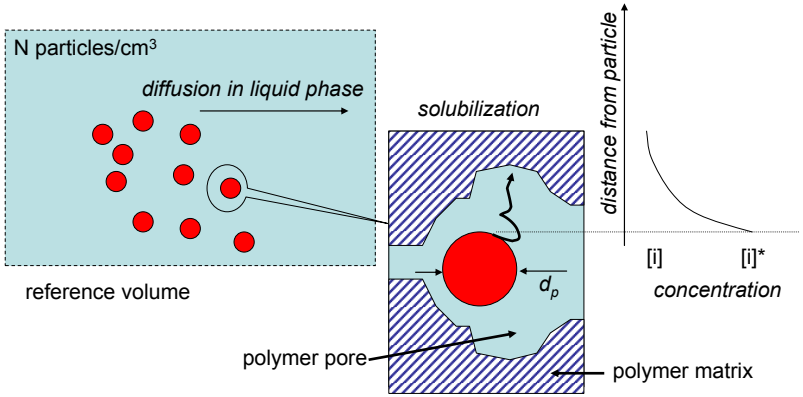
-> A SMART INDUSTRIAL USE !

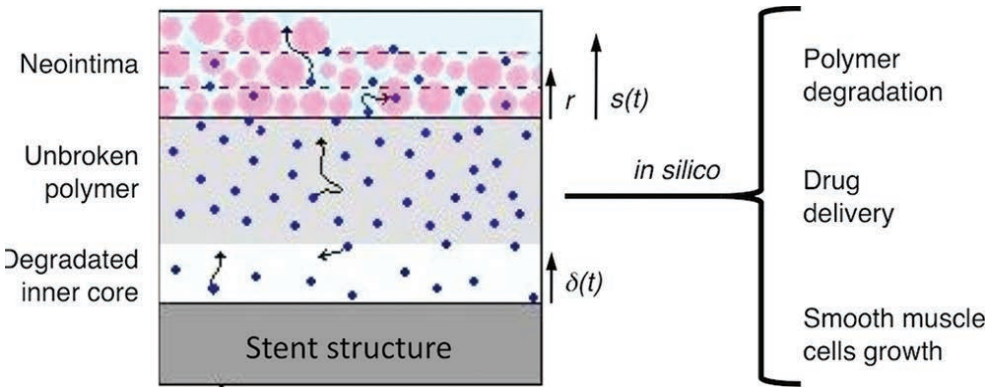
-> **<u>faster engineering of new devices !</u>**

$$\frac{dC_M}{dt} = k_{C,M}\frac{S_{EXT}}{V_M}(C_M^0 - C_M) - 2k_P C_M \mu_0 + \frac{k_P}{K_{EQ}} C_W(\mu_0 - C_M)$$

$$\frac{dC_W}{dt} = k_{C,W}\frac{S_{EXT}}{V_R}(C_W^0 - C_W) + k_P \mu_0^{\,2} - \frac{k_P}{K_{EQ}} C_W(\mu_1 - \mu_0)$$

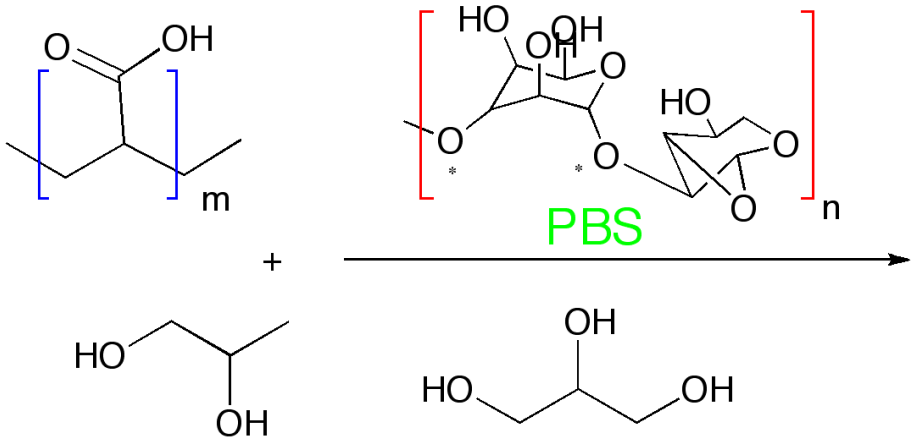
$$\frac{d\mu_0}{dt} = k_{C,M}\frac{S_{EXT}}{V_M}(C_M^0 - C_M) - k_P \mu_0^{\,2} + \frac{k_P}{K_{EQ}} C_W(\mu_1 - \mu_0)$$

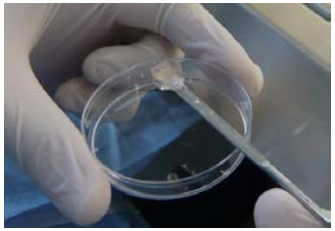




Polymeric hydrogels

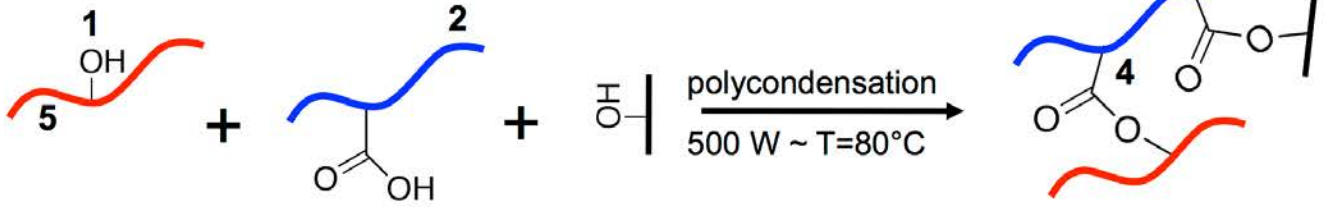
Microwave-assisted polycondensation

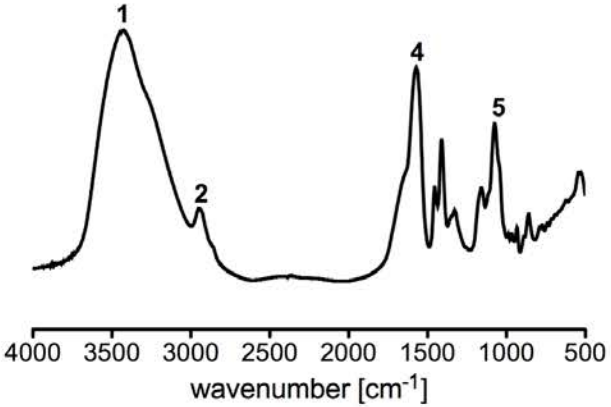




AC hydrogel

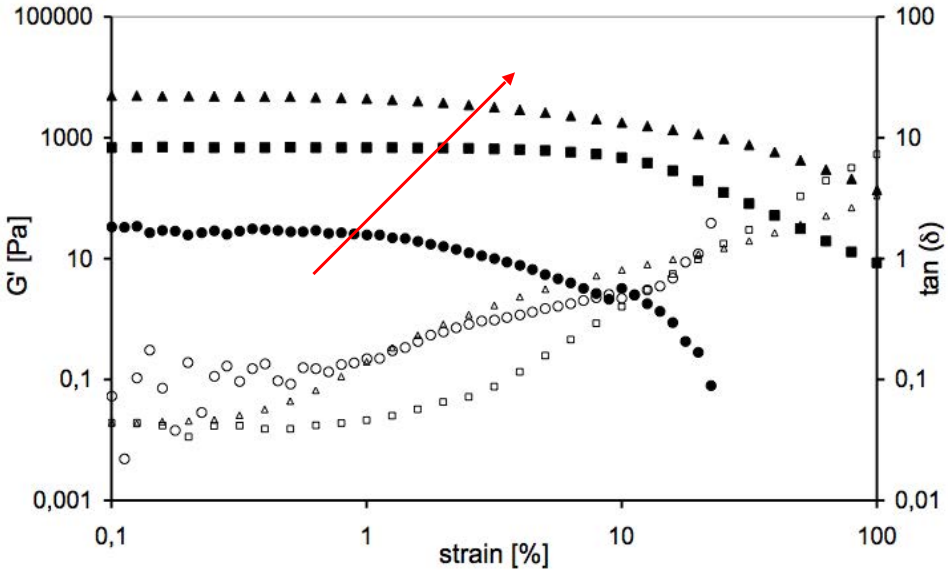
$$ROH + R'COOH \rightarrow R'COOR$$





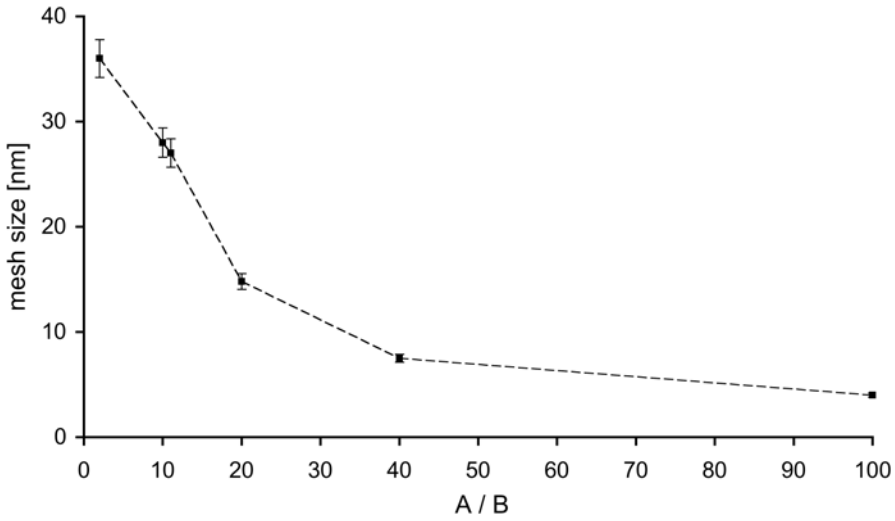
Formulation study

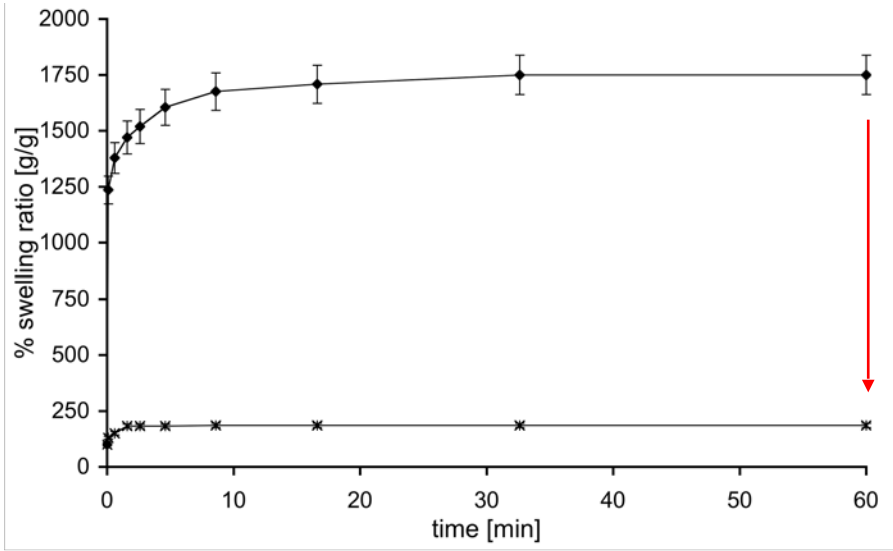
The tuning of our formulation is possible in order to adapt it at different applications:



$$\frac{-OH}{-COOH}$$

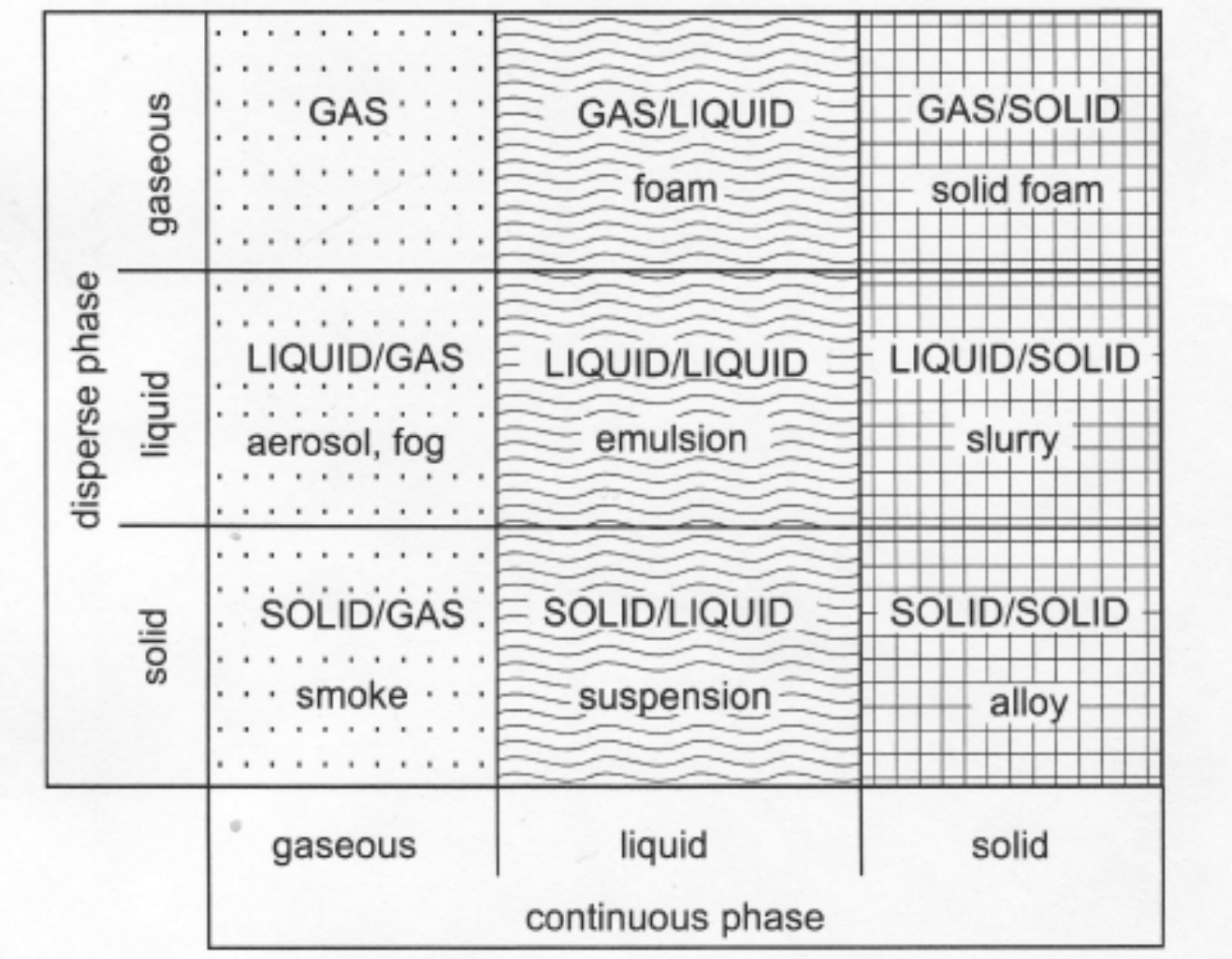
✓ Gel network exhibits higher compactness and less ability to swell as -OH/-COOH increases (different material for different needs)



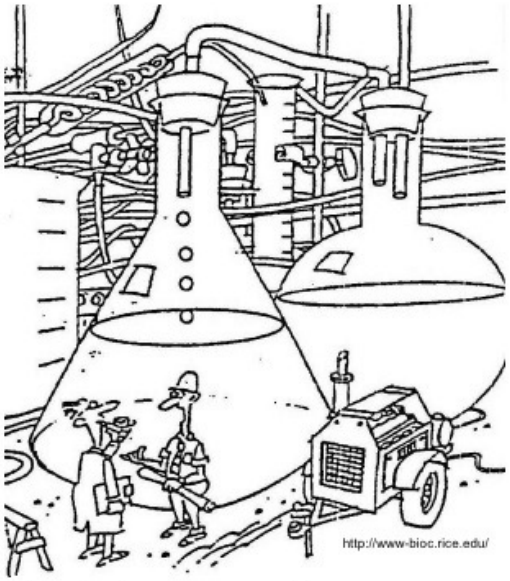


Formulation technology

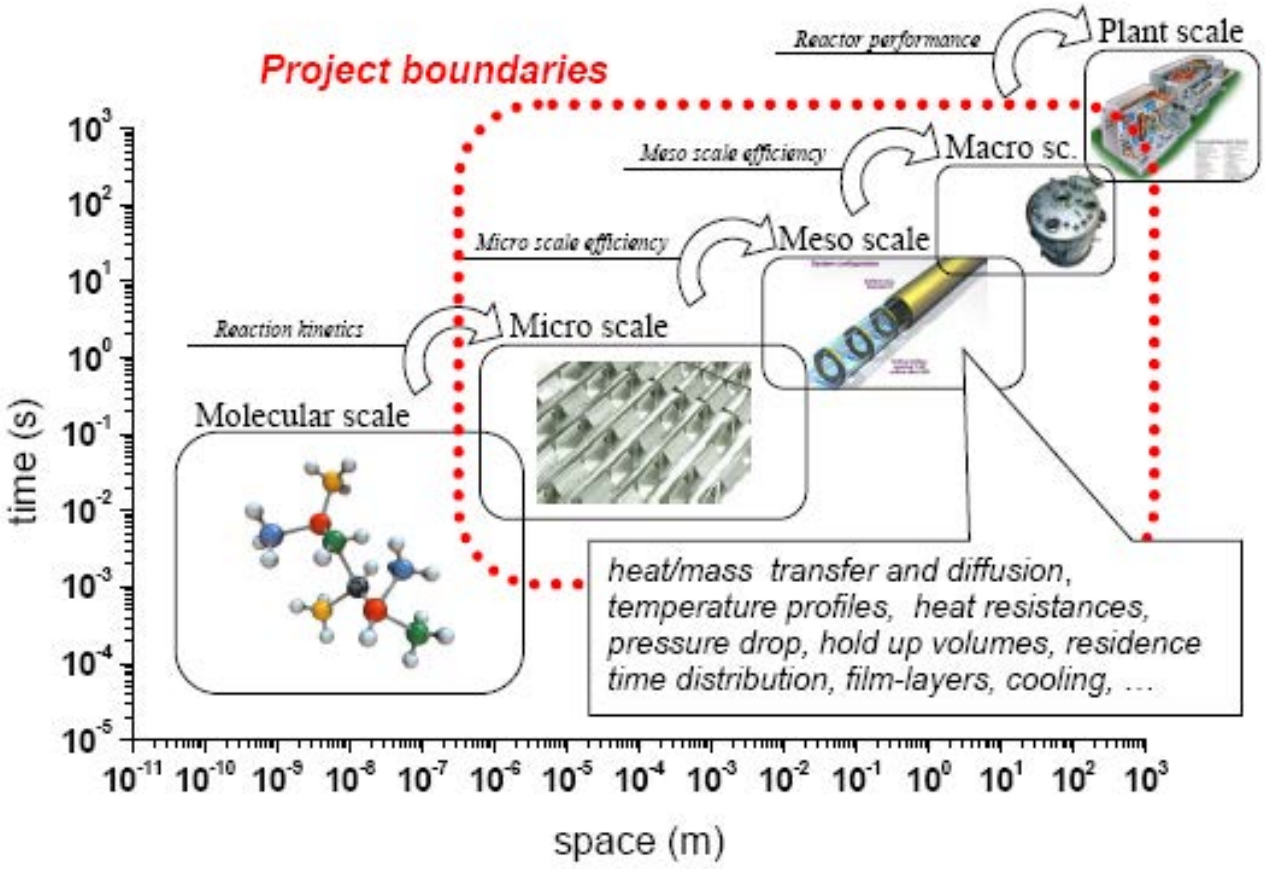
- optimization to develop a product ready for the market;
- satisfy market and industry needs.



Conclusions



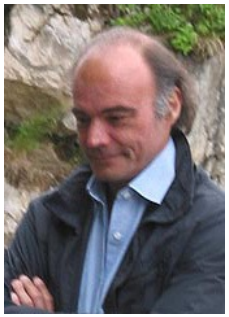
"We've had a few problems going from lab scale up to full-scale commercial."



People







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