Electrospinning
Technologie et application

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Stefan Ramsayr, and Herbert Keppner

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Historique

16e siècle: **William Gilbert** observe l'émission de gouttelettes d'eau à proximité d'une pièce d'ambre électriquement chargée.

1887: **C.V. Boys:**« *the old, but little known experiment of electrical spinning » extraction de fibres de cire, Shellac, cire d'abeilles, gutta-percha (1,4 trans isoprène).*

Mai 1900: **J.F. Cooley:** brevet: *« The process of electrospinning ».*

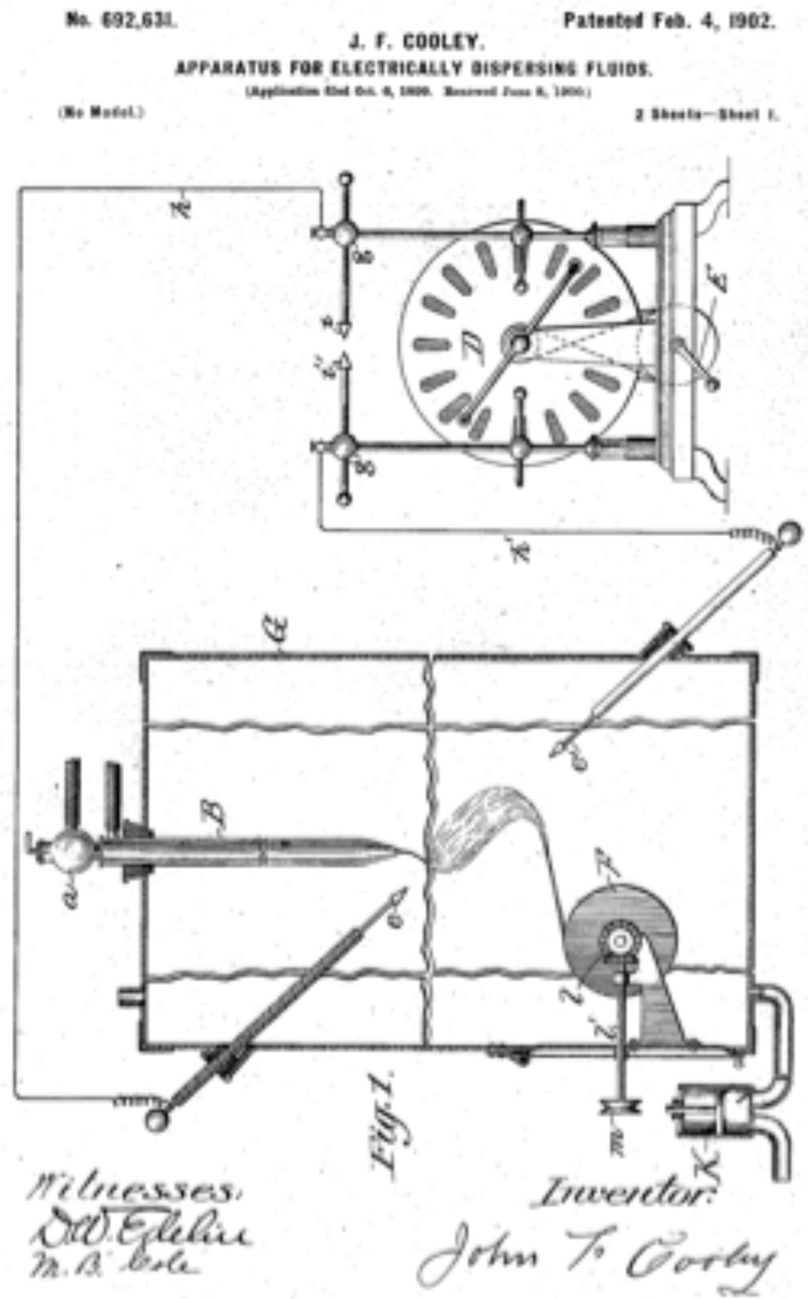
1934: **A. Formhals** *et al.* "*Process and apparatus for preparing artificial threads* » U.S. Patent 1,975,504 ; Octobre 2, 1934.

1938: Nathalie D et I. V*.* **Petryanov-Sokolov**: fibres par electrospinning de acetate de cellulose, pour faire des filtres dans les masques à gaz anti-fumées. En 1960 la production de 20 millions m^2 / année ont été revendiquées.

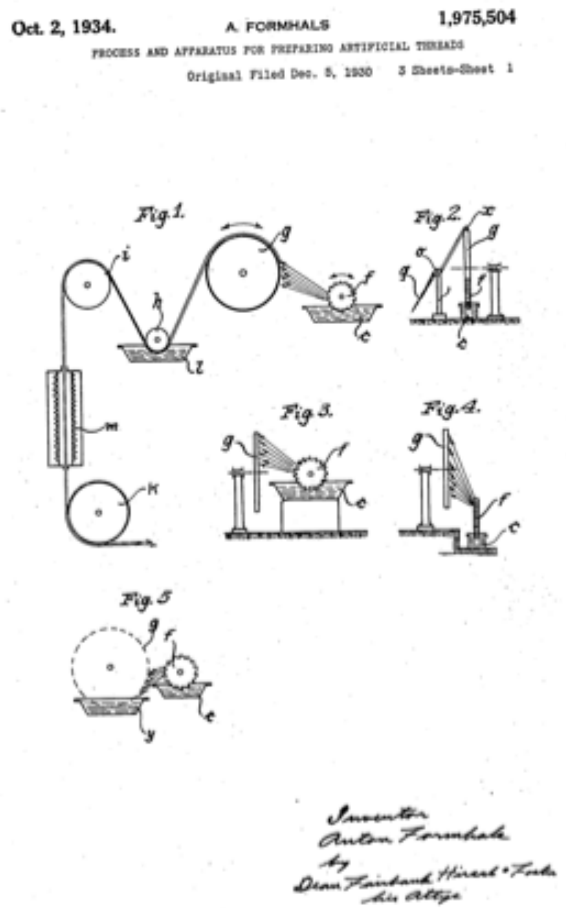
1964: Geoffry Ingram **Taylor** présente la théorie pour l'electrospinning; « *Disintegration of water drops in an electric field*; Proc. Roy. Soc. A 280 (1382): 383» la déformation caractéristique de la goutte s'appelle le cône de Tailor.

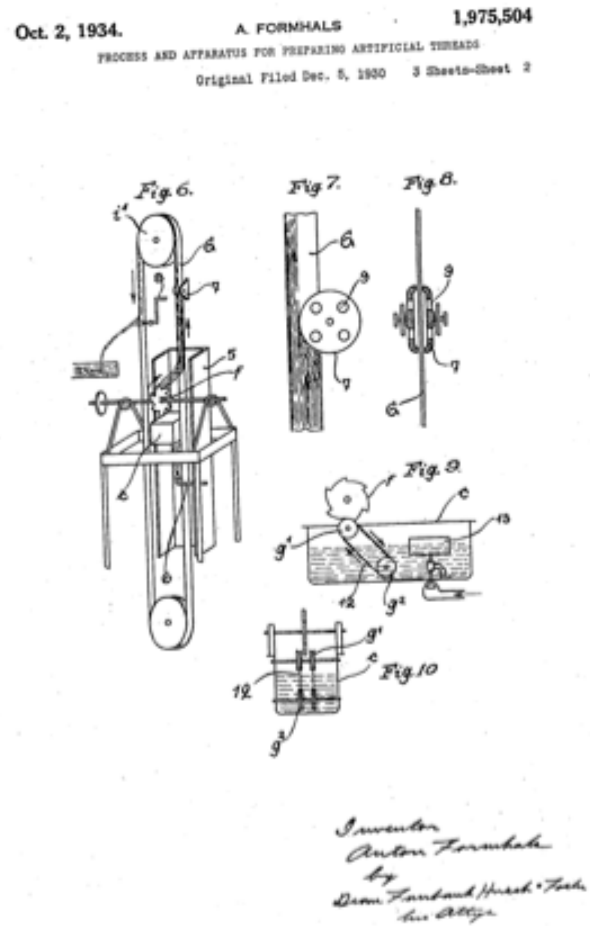
Cooley, J.F. Patent GB 06385

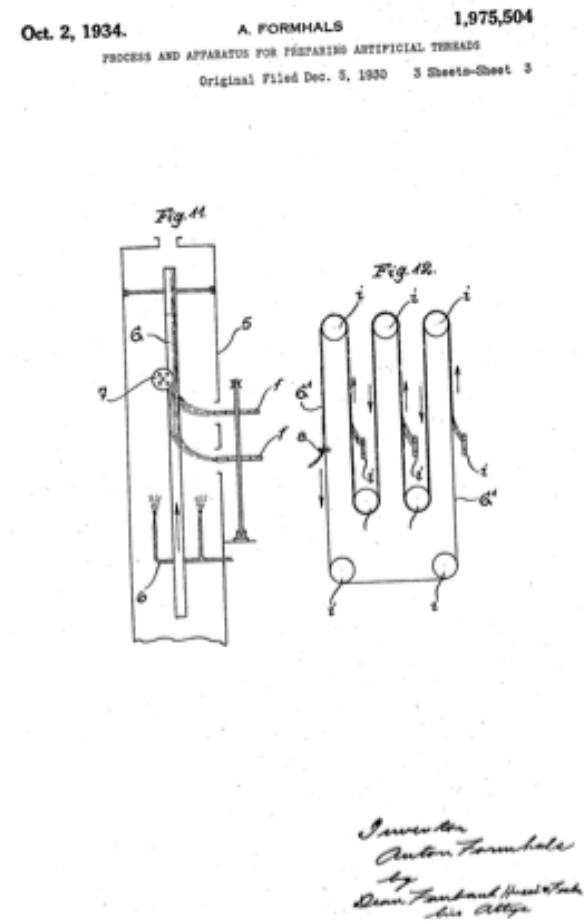
"Improved methods of and apparatus for electrically separating the relatively volatile liquid component from the component of relatively fixed substances of composite fluids" 19th May 1900



A. Formhals *et al.* "Process and apparatus for preparing artificial threads »
U.S. Patent 1,975,504 ; Octobre 2, 1934

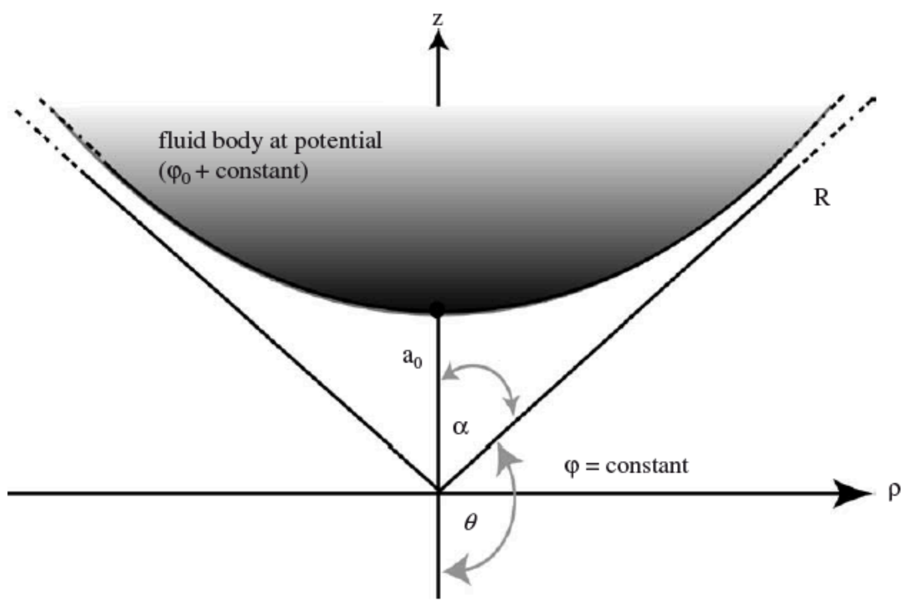




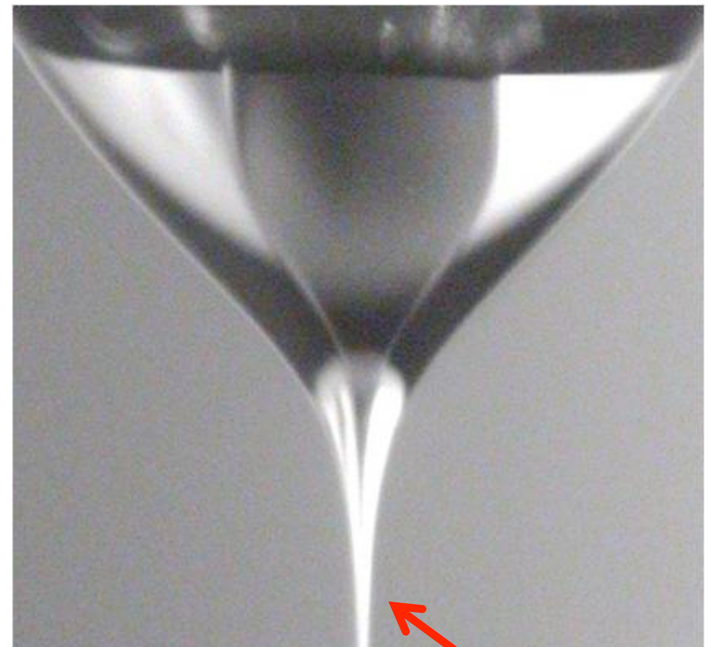


Théorie, compréhension, maîtrise

État initial
V = 0 kV



État initial
V > 20 kV

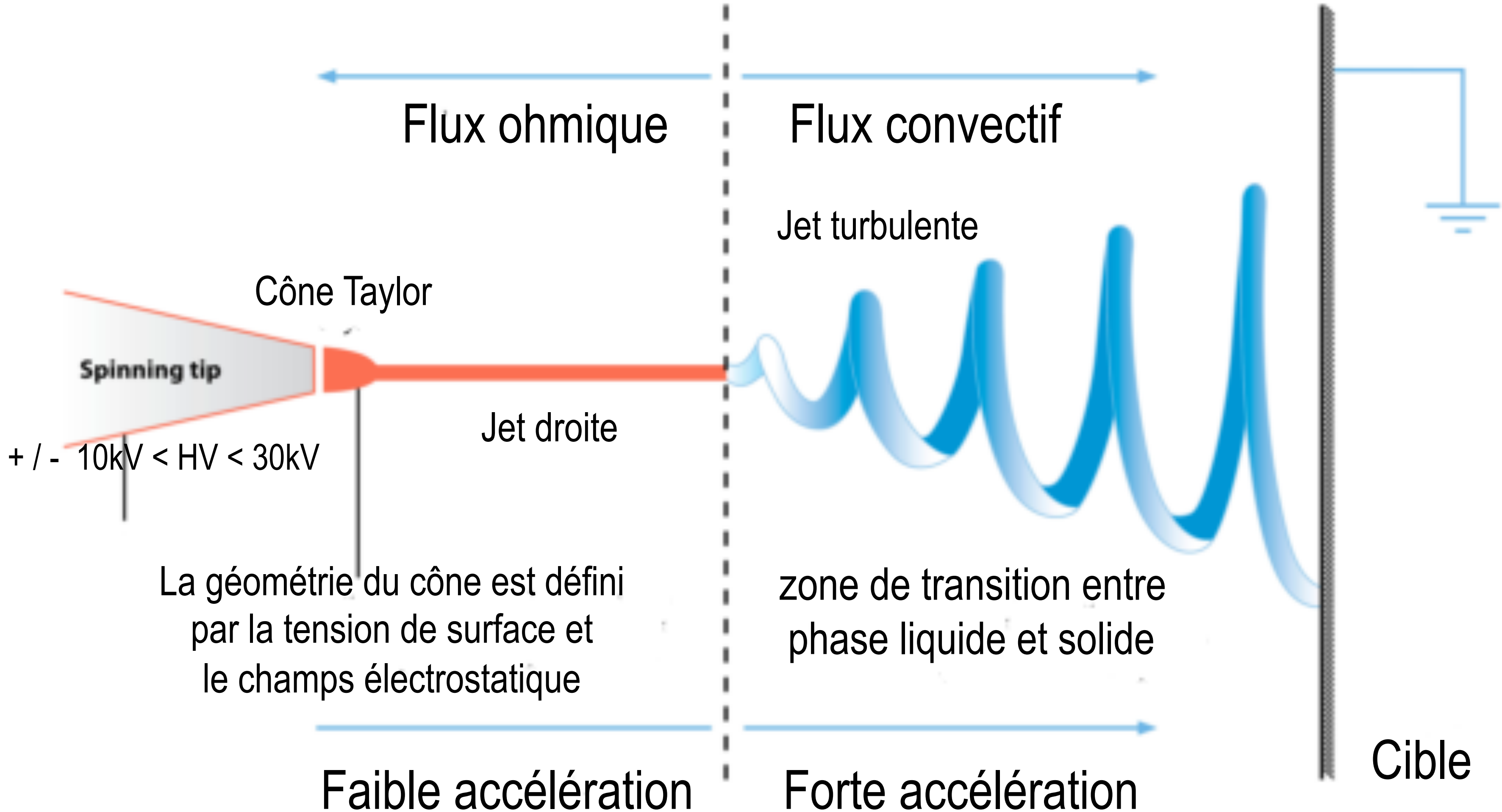


jet

D.H. RENEKER et al. Electrospinning of Nanofibers from Polymer Solutions and Melts
ADVANCES IN APPLIED MECHANICS, VOL. 41 43
ISSN 0065-2156 DOI: 10.1016/S0065-2156(06)41002-4

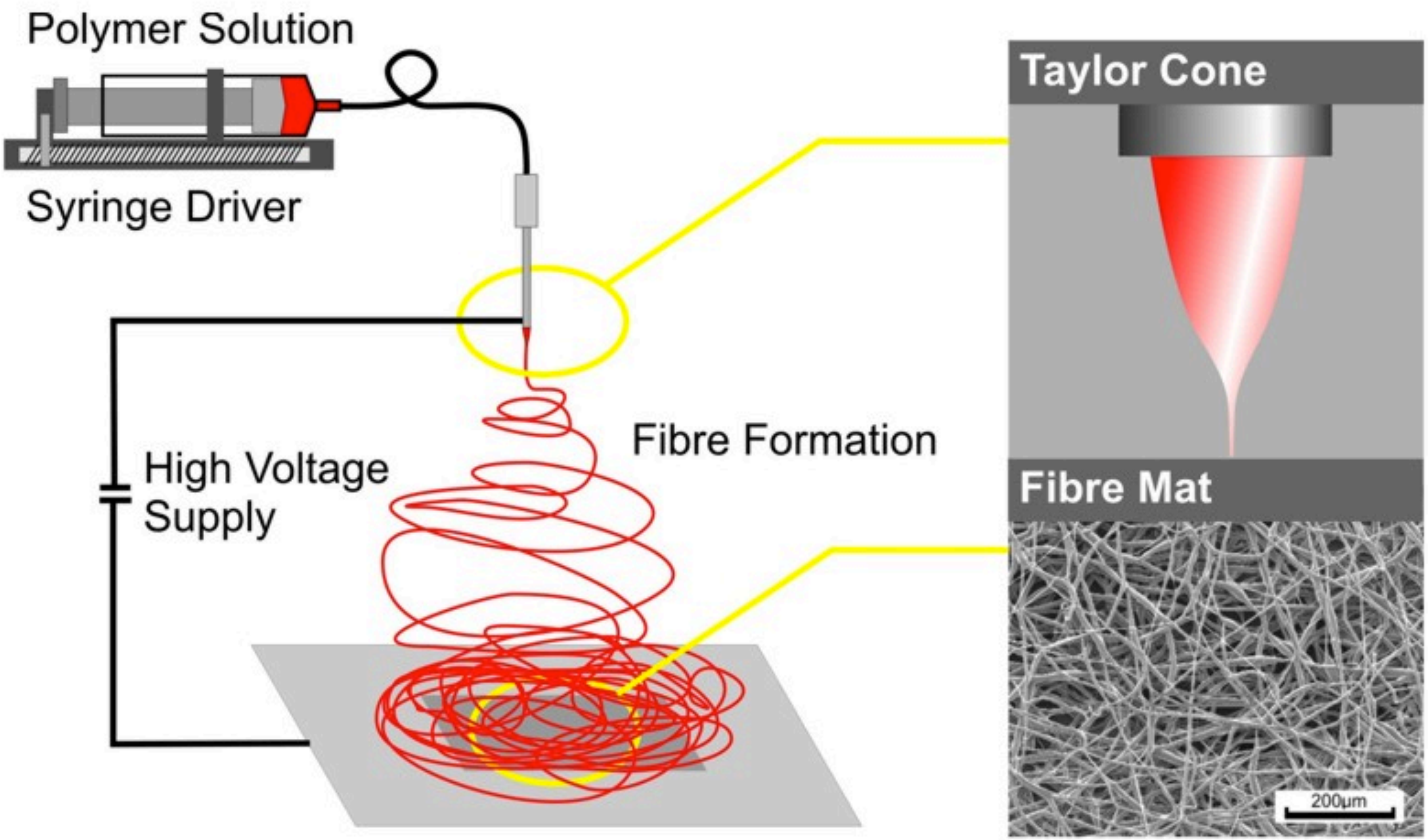
http://nanotechnologysolutions.files.wordpress.com/2013/07/imagen31.jpg

Principe de base, observation



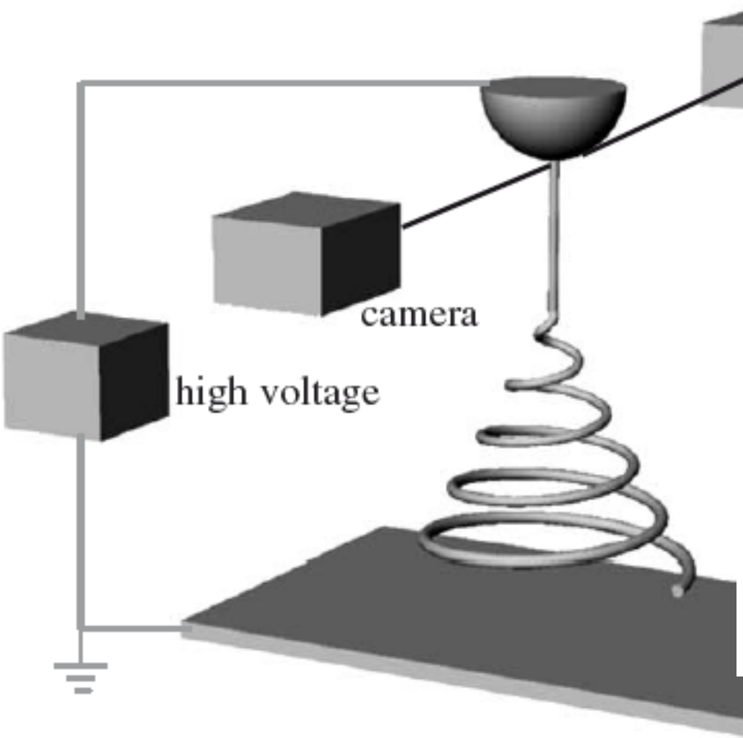
http://upload.wikimedia.org/wikipedia/commons/c/ca/Electrospinning_Diagram.jpg

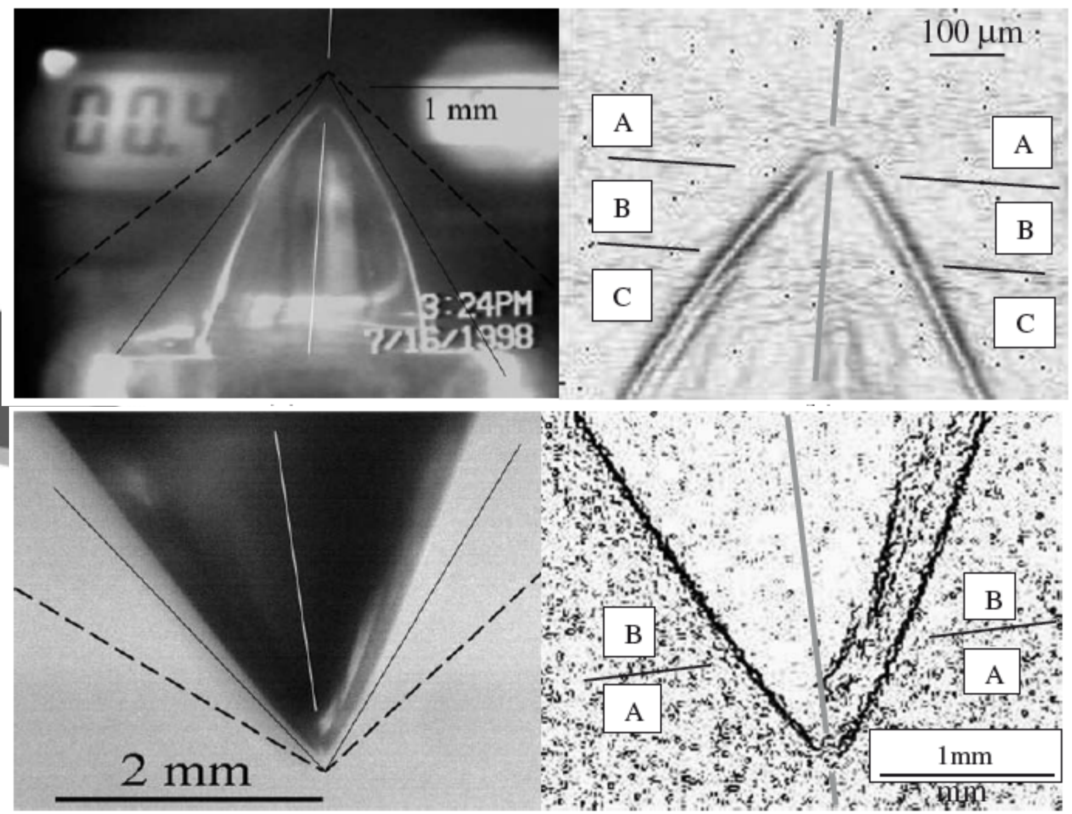
Principe de base



http://2.bp.blogspot.com/-w9f3G2z8a0g/UJLjHthj1hI/AAAAAAAAAEw/MmbresO7yXM/s1600/ElectrospinFigure.jpg

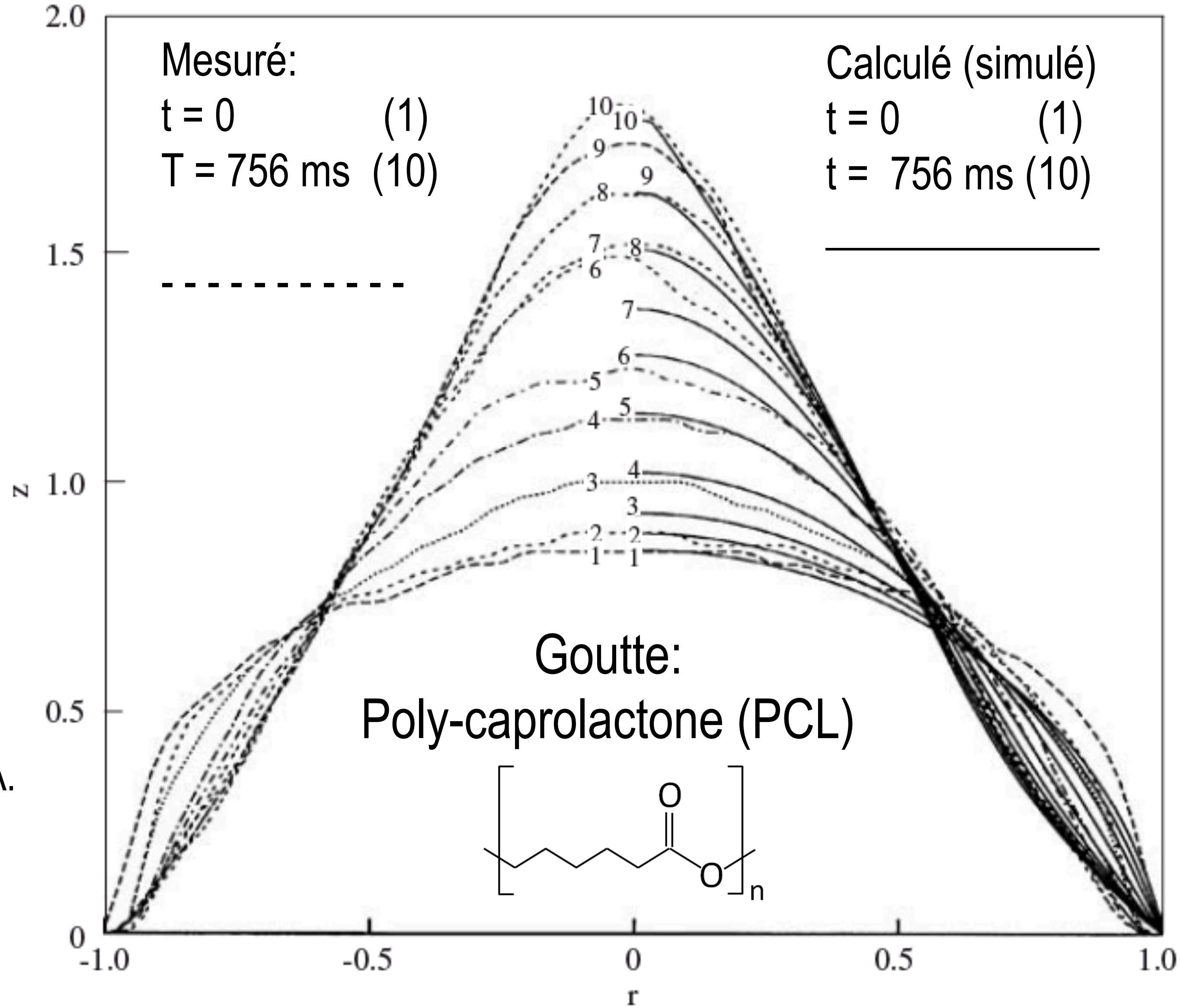
Théorie, compréhension, maîtrise





Yarin, A. L., Koombhongse, S., and Reneker, D. H. (2001b). Taylor cone and jetting from liquid droplets in electrospinning of nanofibers. J. Appl. Phys. 90, 4836–4846.

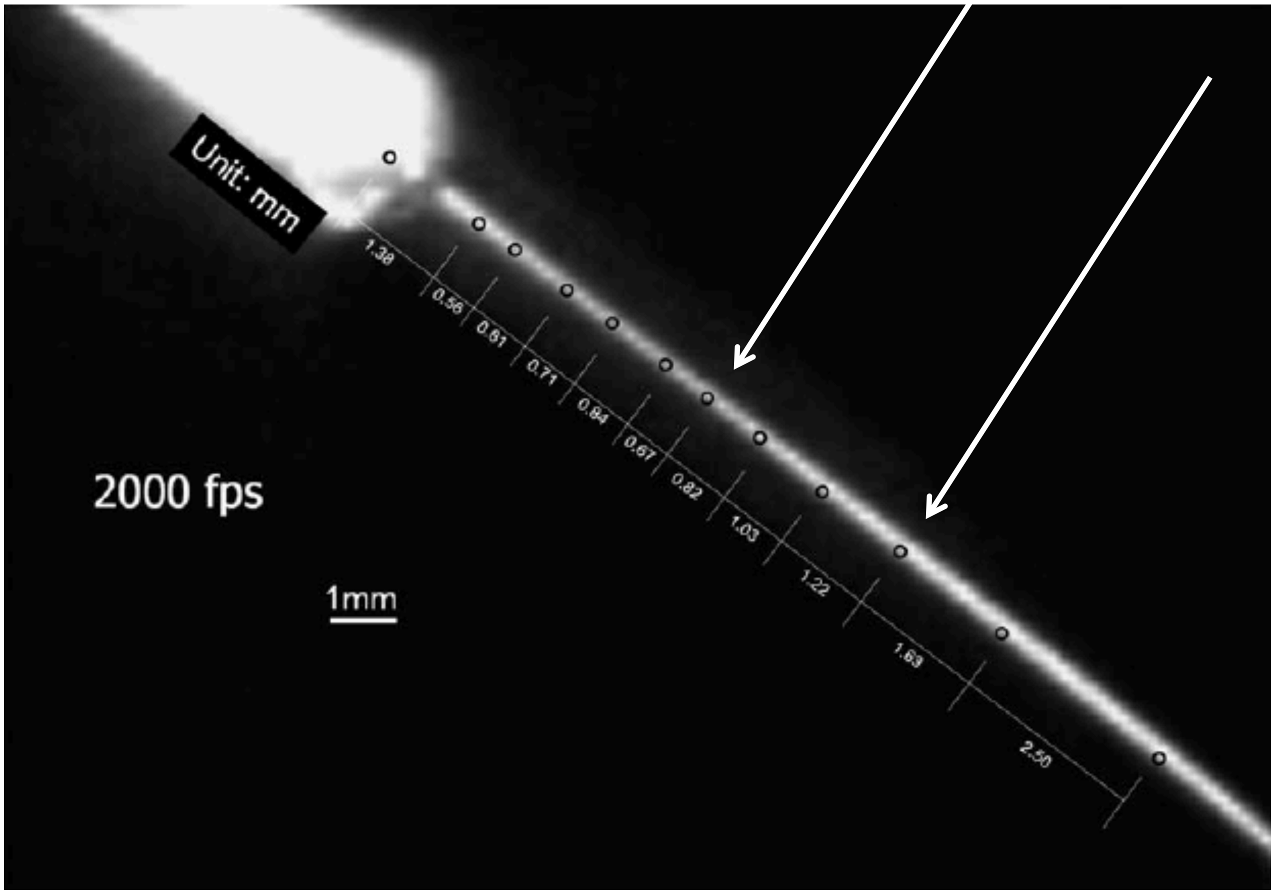
Développement de la déformation d’une goutte PCL par un champ électrique



Reznik, S. N., Yarin, A. L., Theron, A., and Zussman, E. (2004). J. Fluid Mech. 516, 349–377.

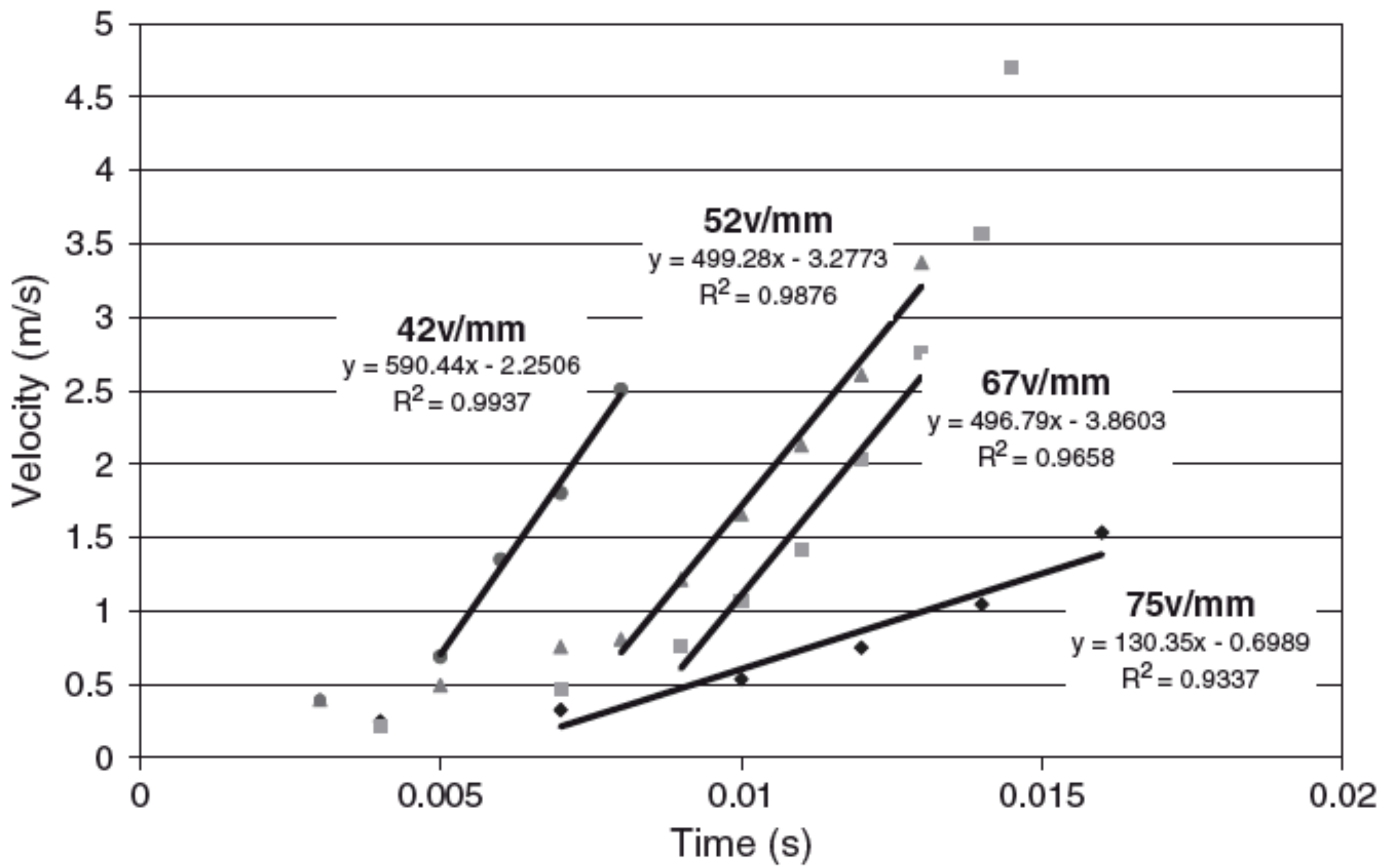
Vitesse et diamètre du jet, exemple PEO (polyethylène oxyde)

Billes en verre transporté par le jet pour mesurer la vitesse

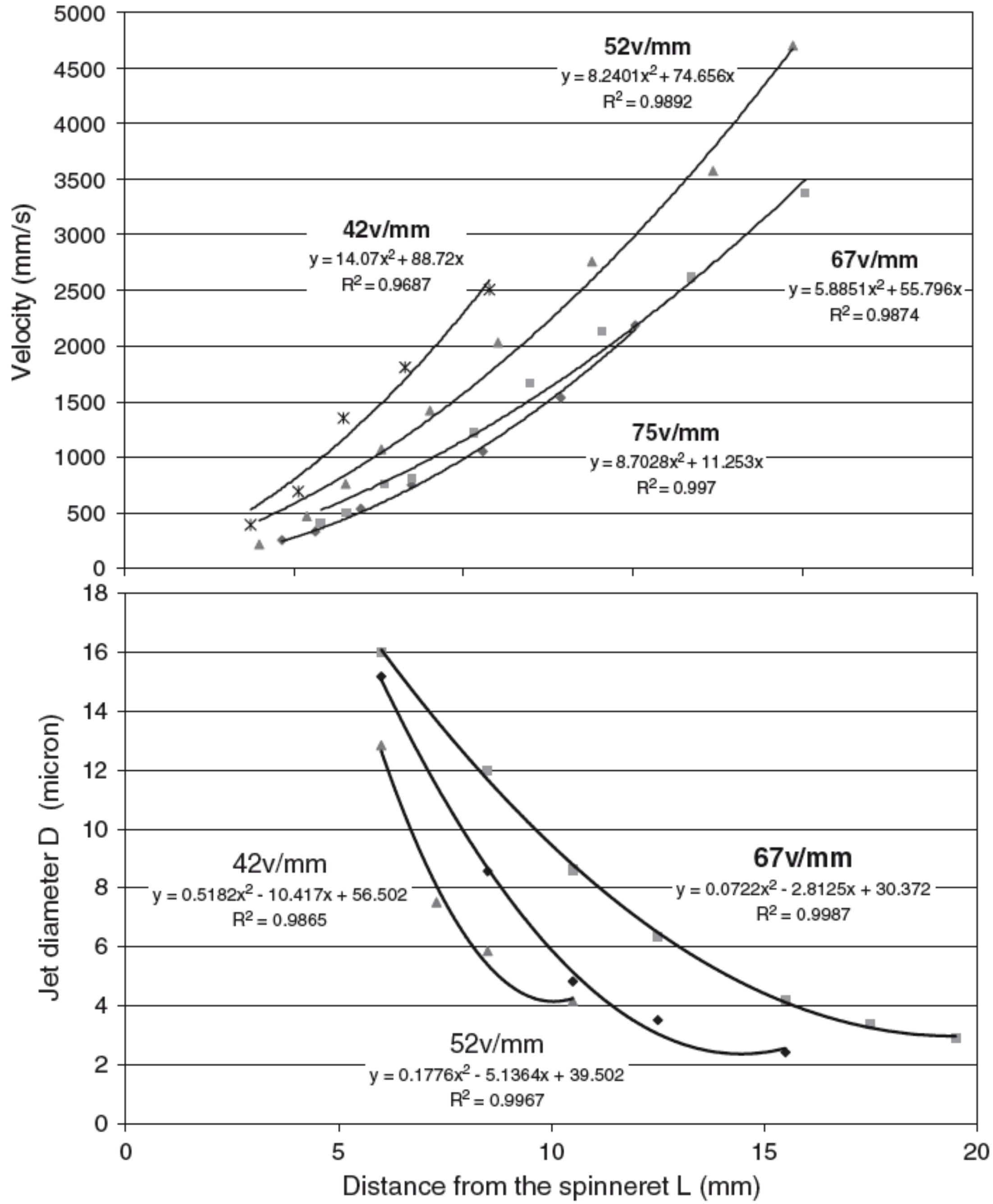


Xu, H., Yarin, A. L., and Reneker, D. H. (2003). Characterization of fluid flow in jets during electrospinning. Polym. Preprints 44, 51–52.

Vitesse et diamètre du jet, exemple PEO, jet droit



Vitesse et diamètre du jet exemple PEO jet droit

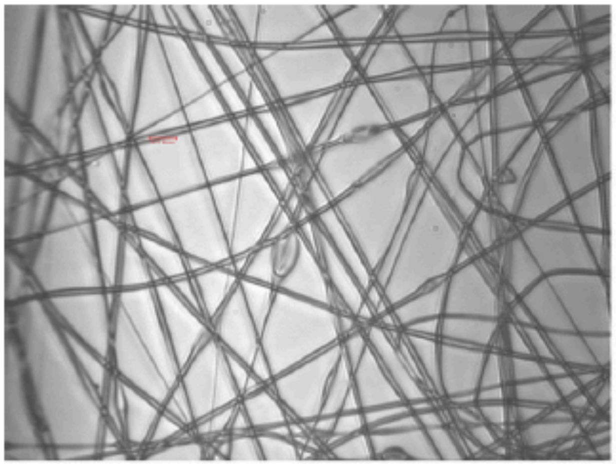


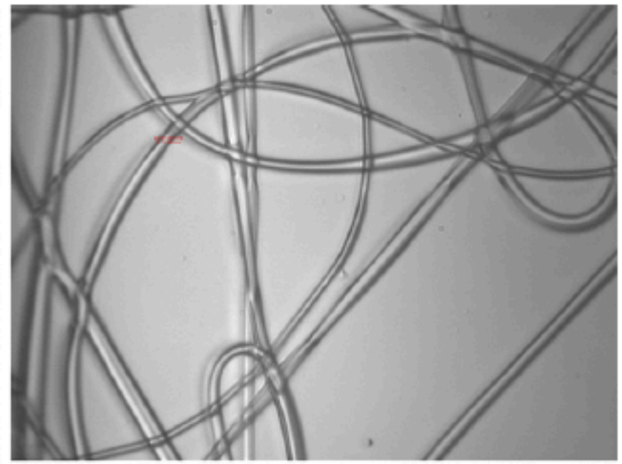
Xu, H., Yarin, A. L., and Reneker, D. H. (2003). Characterization of fluid flow in jets during electrospinning. Polym. Preprints 44, 51–52.

Influence de la concentration

Polyethylene co-vinyl alcohol dans 70:30 2-propanol

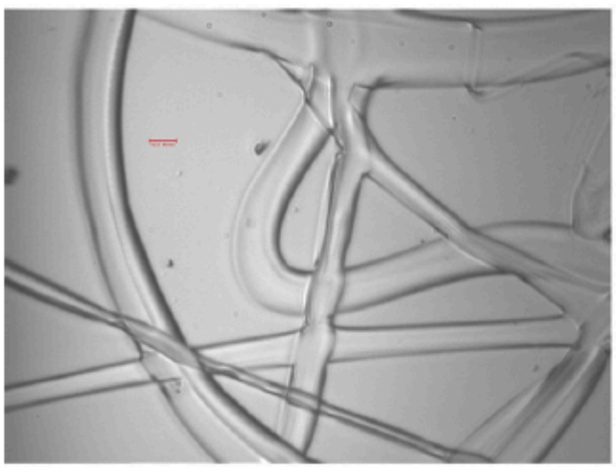
5.5 g /ml

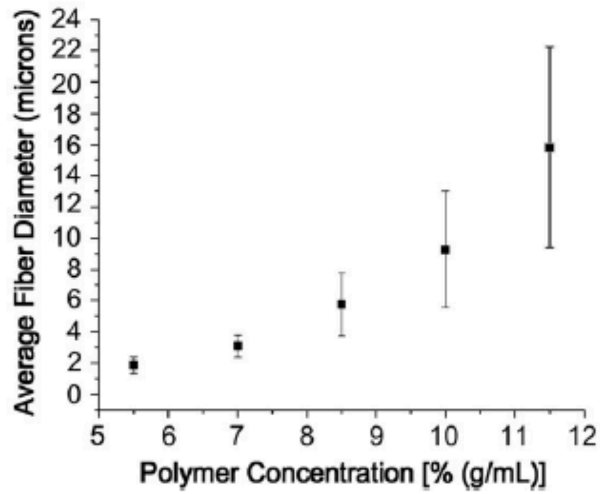




8.5 g /ml

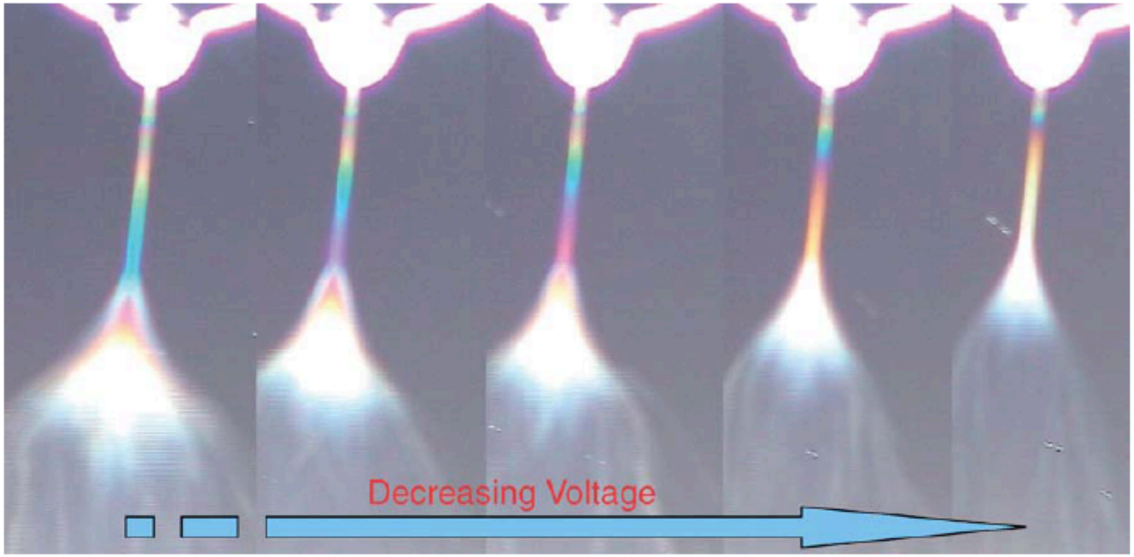
11.5 g /ml



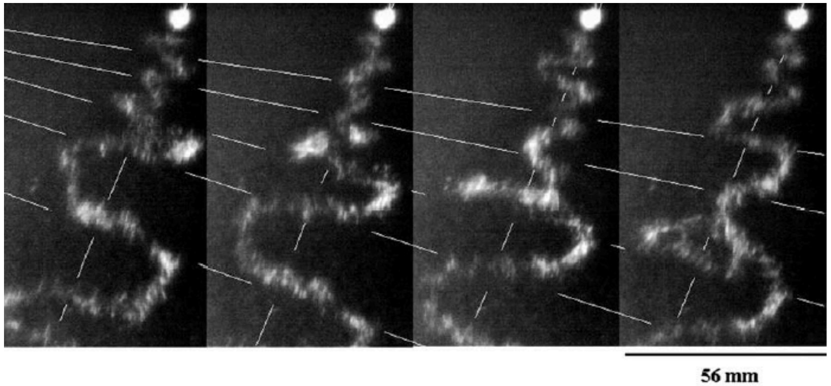


Megelski S, Stephens JS, Chase DB, Rabolt JF.; Macromolecules 2002 Oct 22;35(22):8456e66.

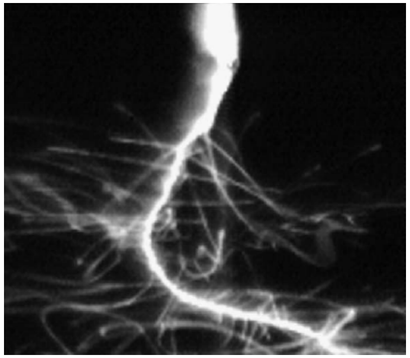
Flux convectif: bifurcation des jets



Xu, H., Yarin, A. L., and Reneker, D. H. (2003). Characterization of fluid flow in jets during electrospinning. Polym. Preprints 44, 51–52.



Guirlande de 15% PCL solution 7.5 kV, 140mm gap
(Reneker, et al. Polymer 43, 6785–6794.)



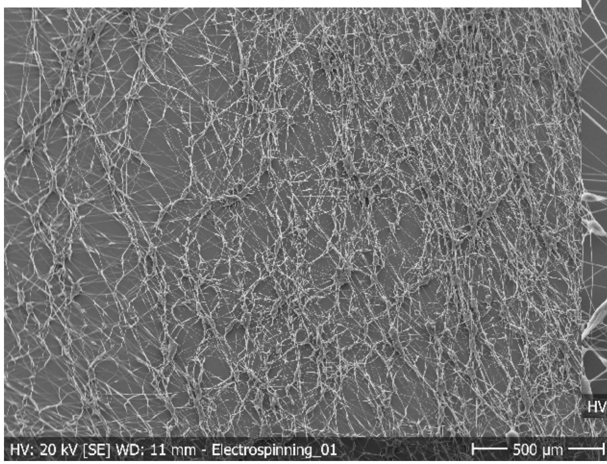
Bifurcation 15% PCL solution 10 kV
(Yarin et al., J. Appl. Phys. 98, 064501.)

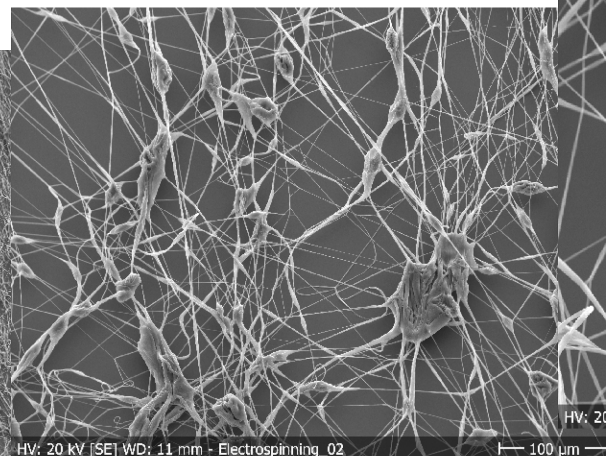
Conclusion intermédiaire

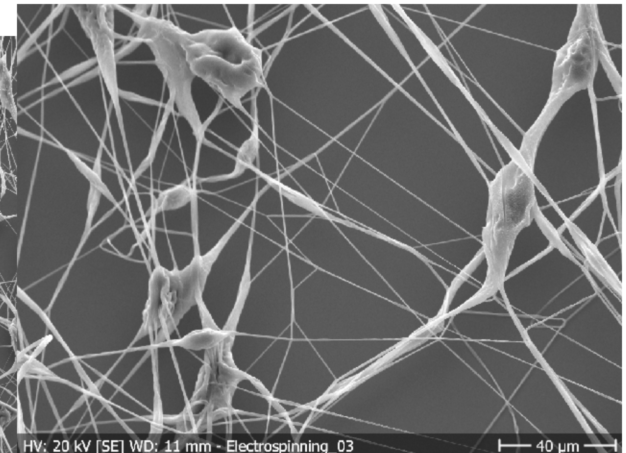
- Il est possible d’effectuer de l’électrospinning avec touts les matériaux condensables, notamment des polymères en solution, des sol-gels et des matériaux fondus.
- Le diamètre des fibres et l’arrangement est une fonction de la tension appliquée (typiquement entre 10kV et 30 kV), de la distance entre l’éjecteur et l’écran, du type de matière, des additifs.
- La viscosité du liquide « spinnable » contenant des solvants + précurseurs est typiquement entre 0.8 Pa·s et 4 Pa·s (800 centipoise et 4000 centipoise).

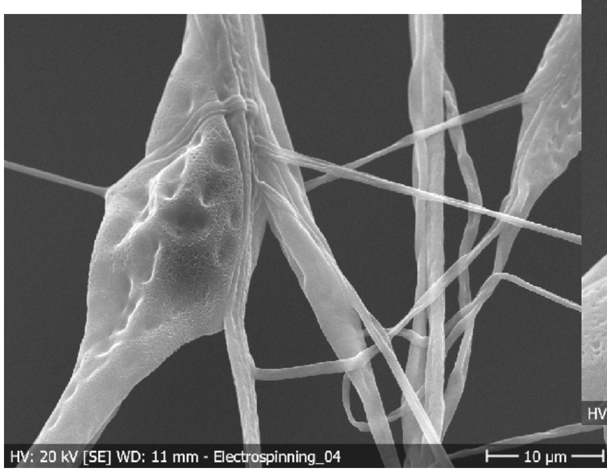
Résultats

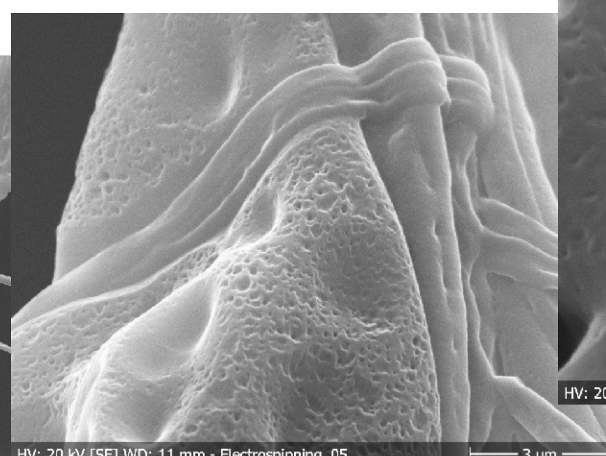
HE-ARC travaux pratiques, THV 20 (Dyneon) / Acétone

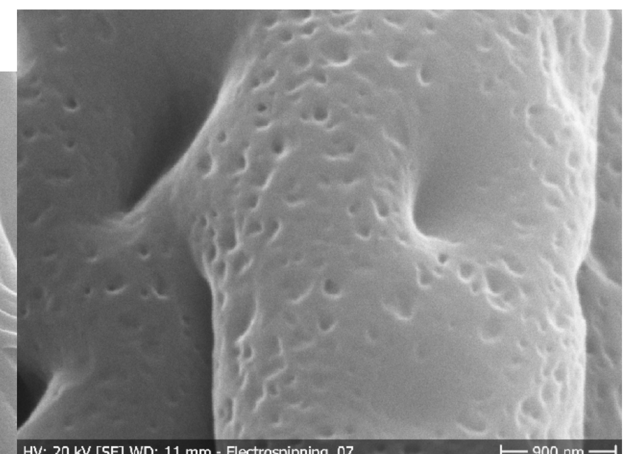






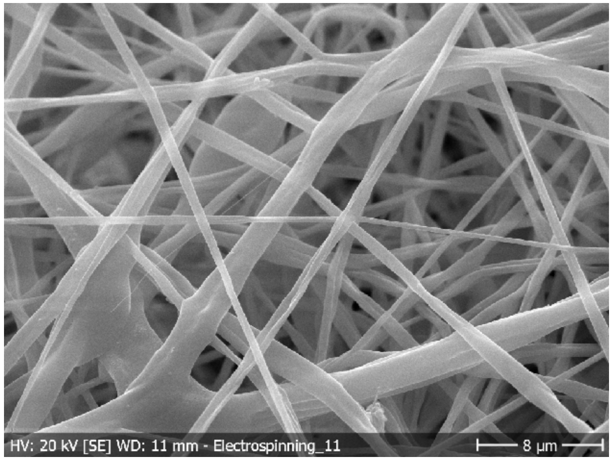


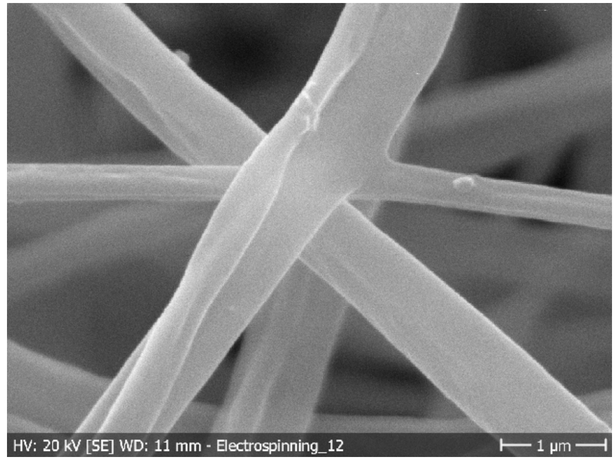


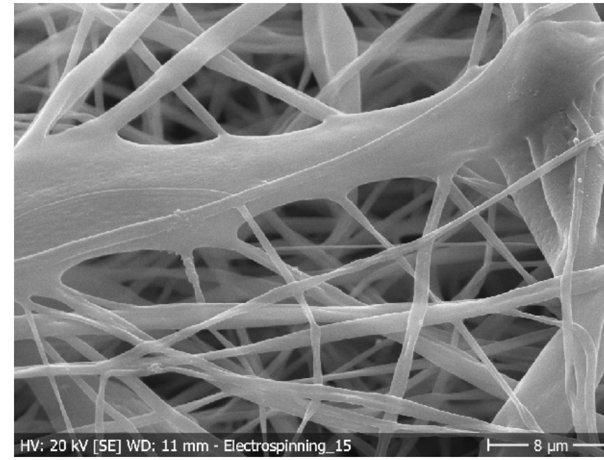


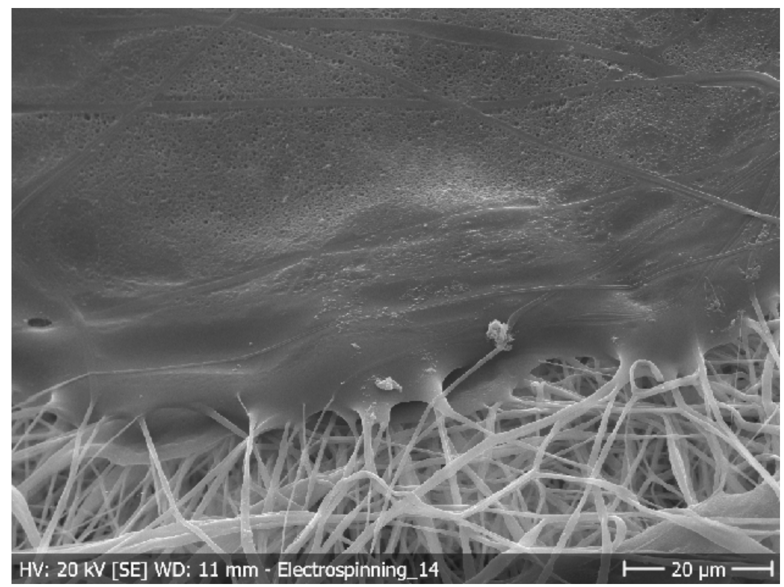
E. Laux, S. Ramseyer

Observations

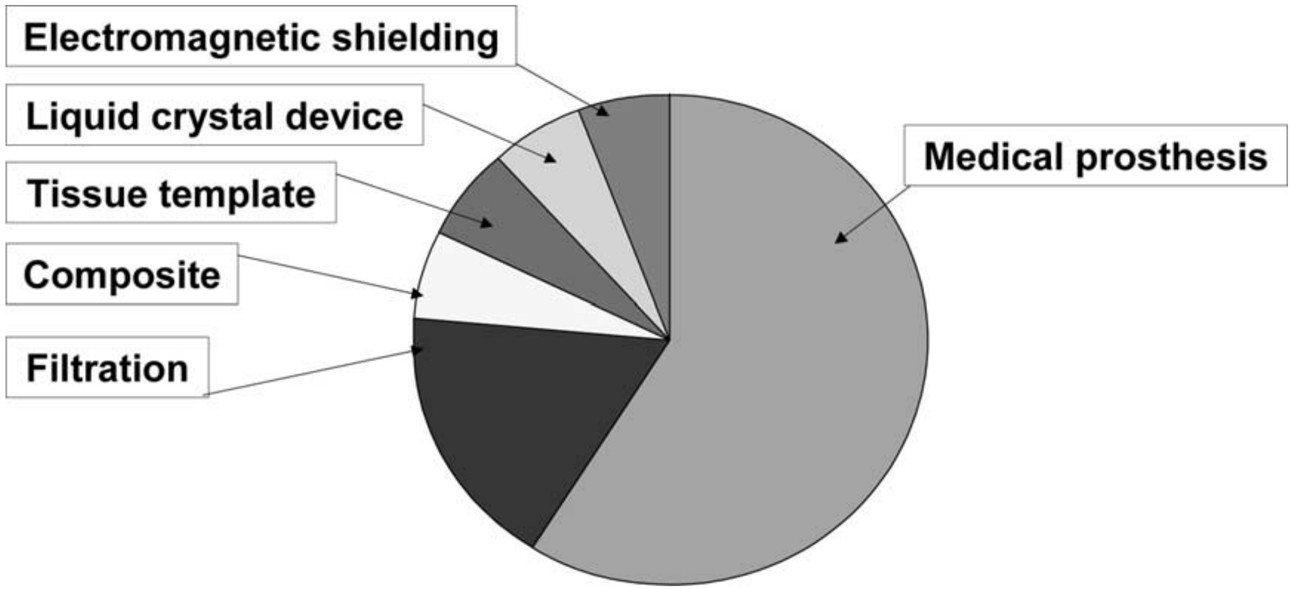


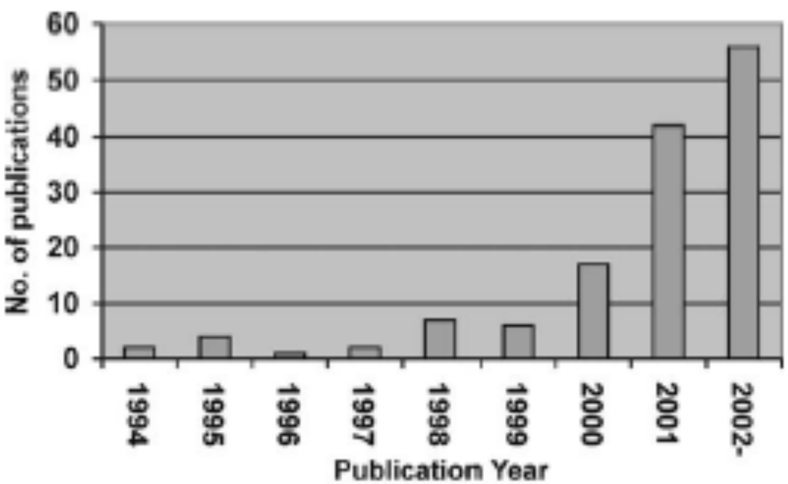


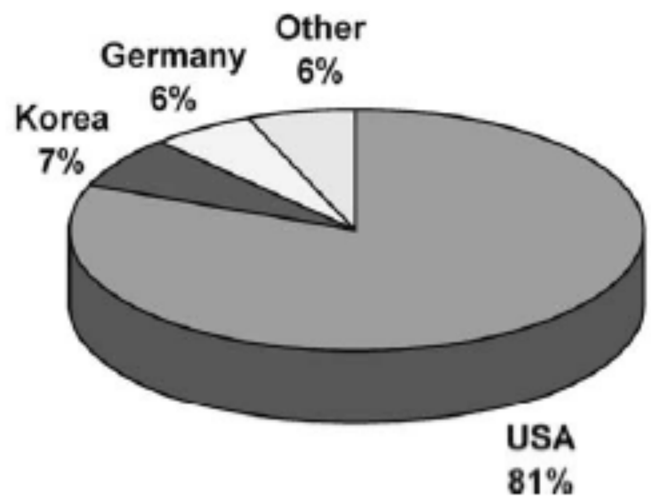




Applications

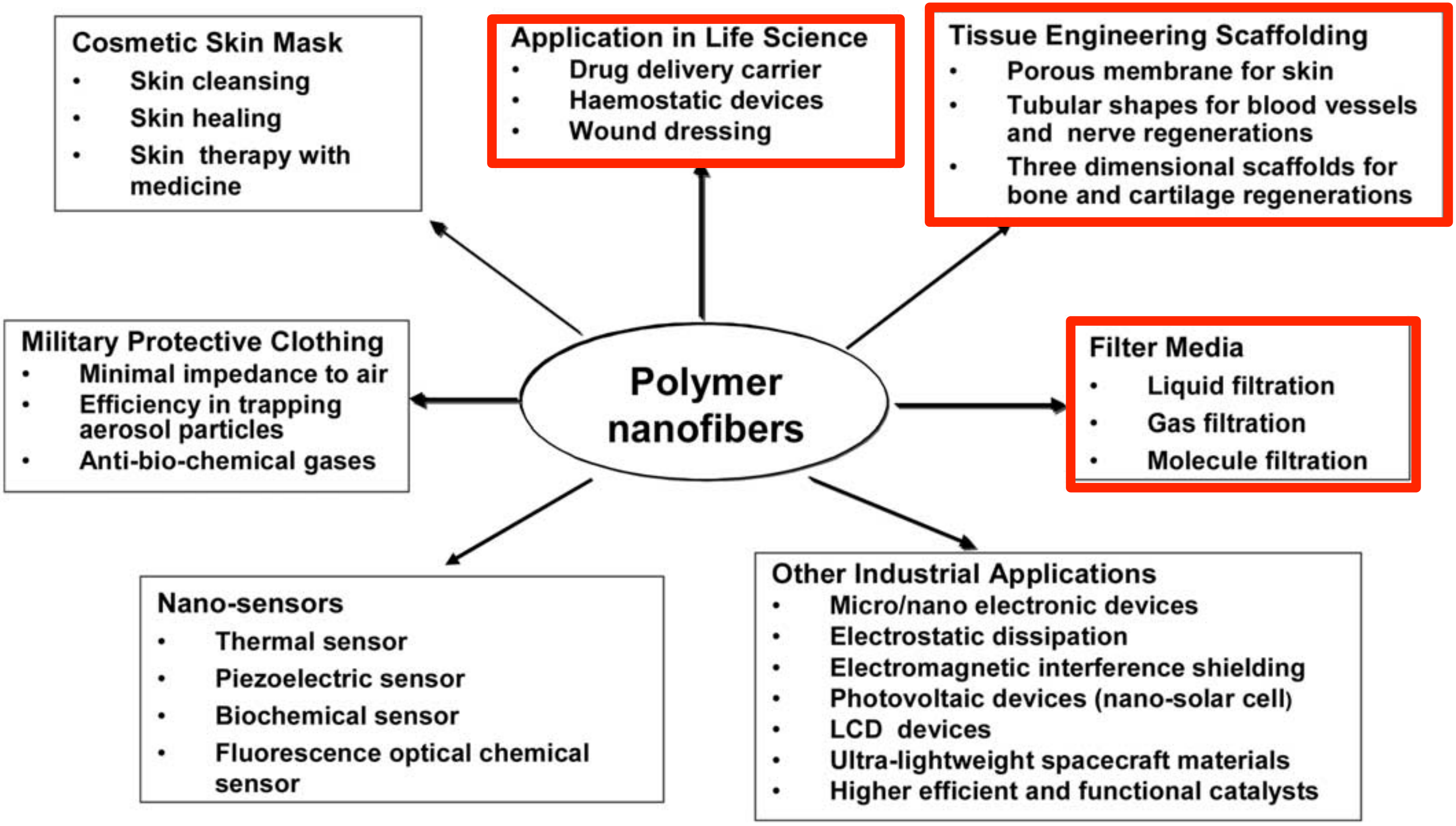






Z.-M. Huang et al. / Composites Science and Technology 63 (2003) 2223–2253

Applications pour l'électrospinning

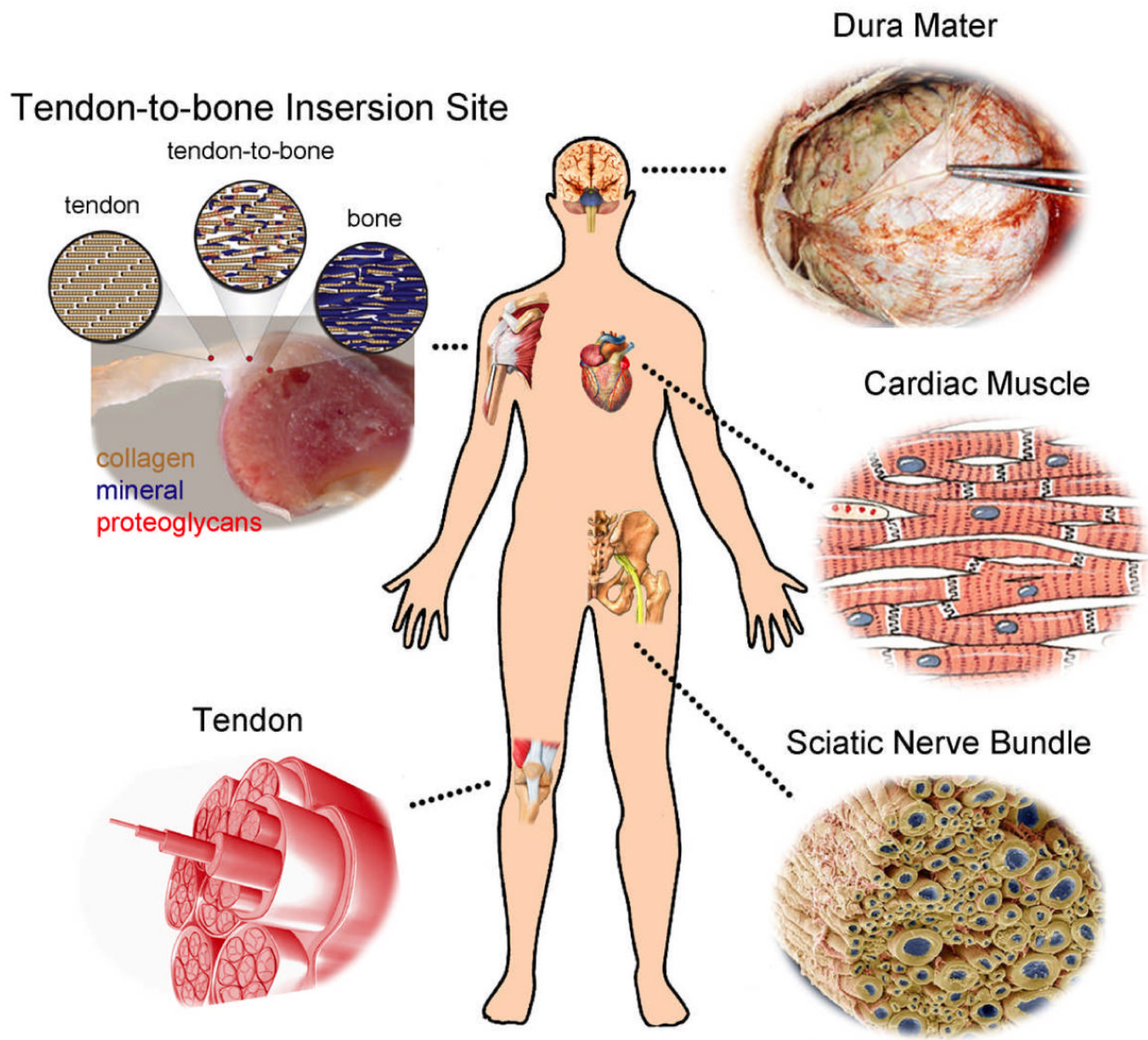


Z.-M. Huang et al. / Composites Science and Technology 63 (2003) 2223–2253

Applications dans la médecine régénérative

Des différentes organes montrent des structures cellulaires caractéristiques.

La grande variation des structures réalisés par electrospinning permettent d'adapter les structures pour favoriser la croissance (prolifération et différentiation) des cellules spécifiques (structures scaffold)



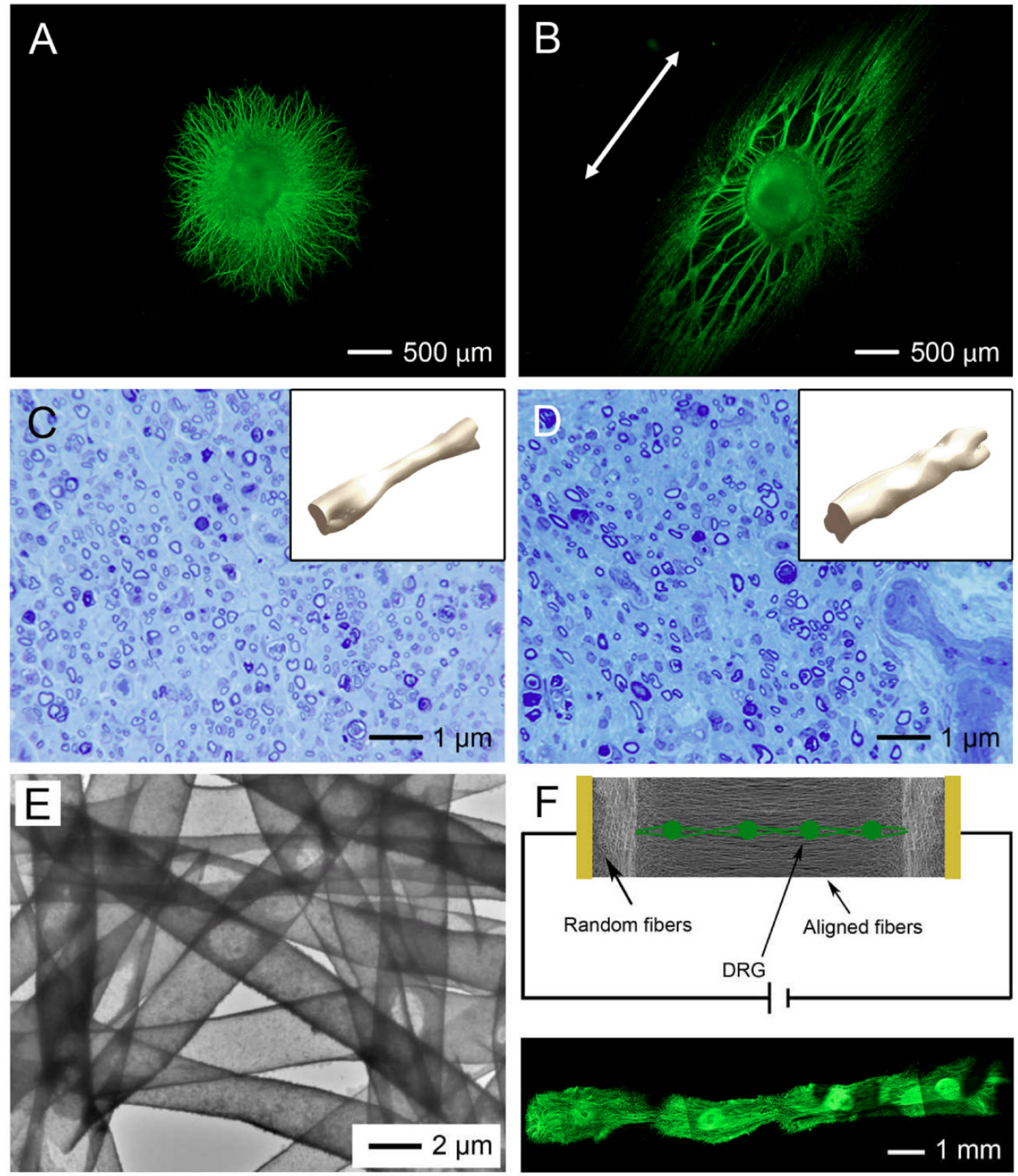
Wenying Liu et al., Adv Healthc Mater. 2012 January 11; 1(1): 10–25. doi:10.1002/adhm.201100021.

exemples

Ganglion spinaux
de poulet (DRG); croissance dans
un scaffold aléatoire (A)
Un scaffold orienté par
electrospinning

Section à travers des cellules DRG
dans une structure de scaffold
aléatoire (C) et des cellules conduit
conduit par un scaffold de poly(3-
caprolactone) nanofibers fait par
electrospinning (D)

Stimulation électrique de DRG
culturs sur des PPY nanofibres
alignés mène à une meilleure
connection intraneural (E, F)

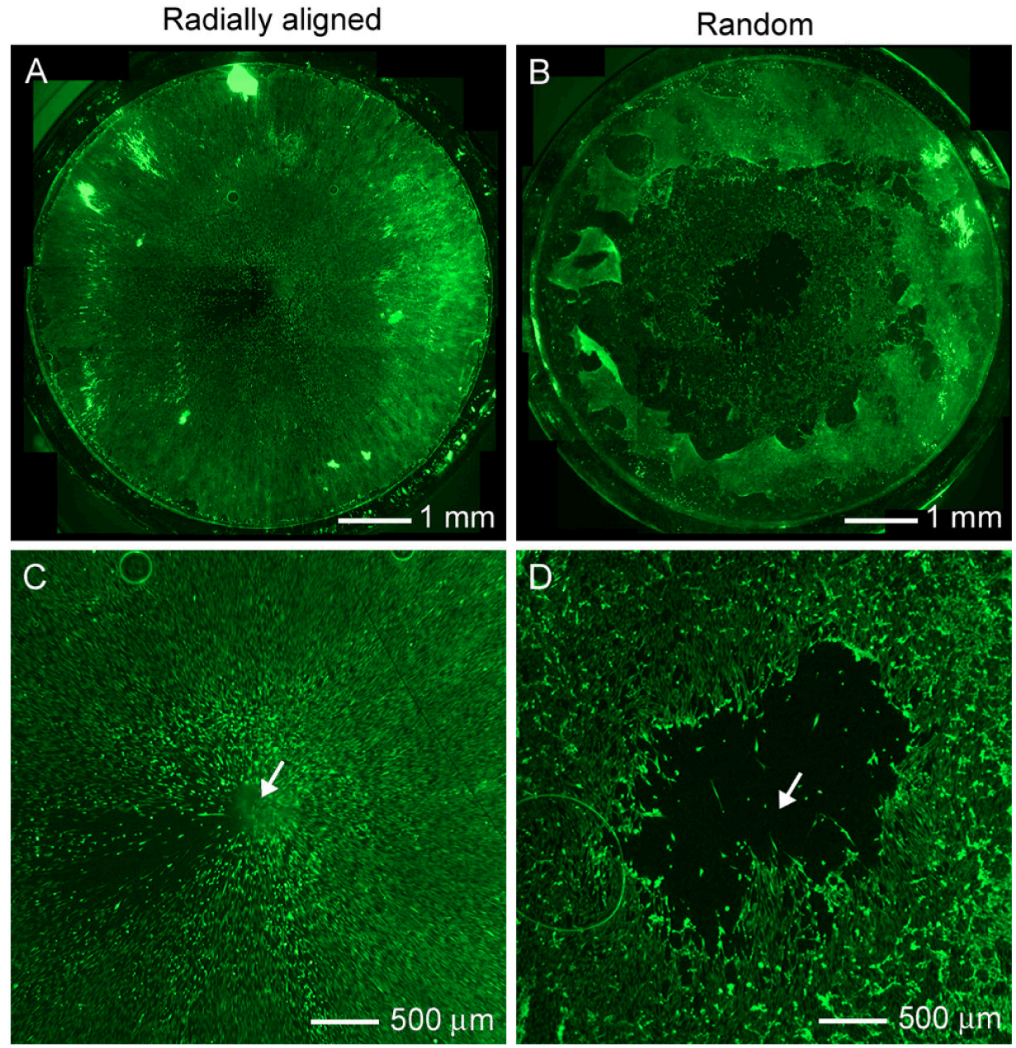


Xie J, MacEwan MR, Schwarz AG, Xia Y. Nanoscale. 2010; 2:35. [PubMed: 20648362]

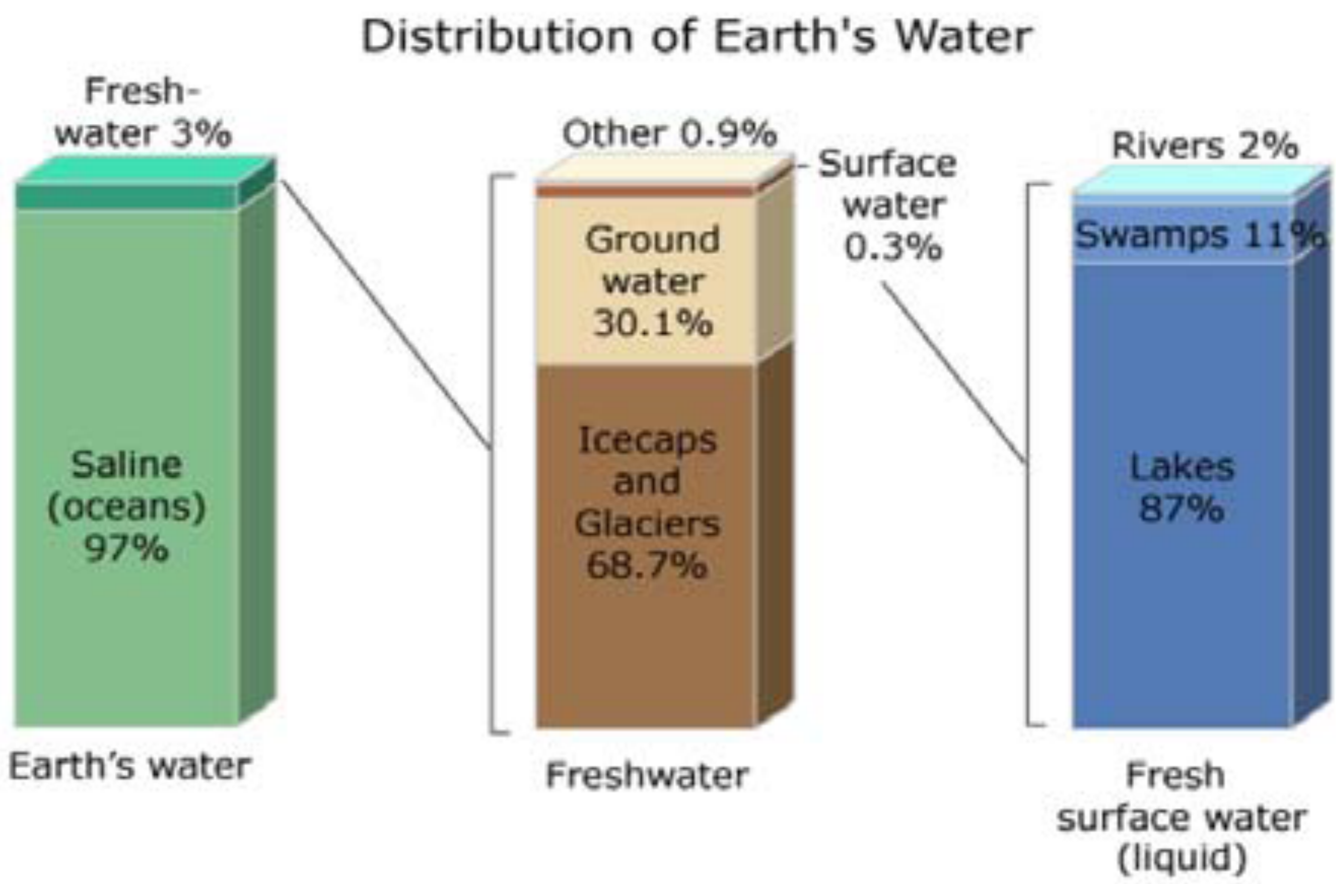
Plus d’exemples

Micrographe de fluorescence observant la réparation de dura mater: A: sur des structures radialement alignés, B des structures non-alignées.

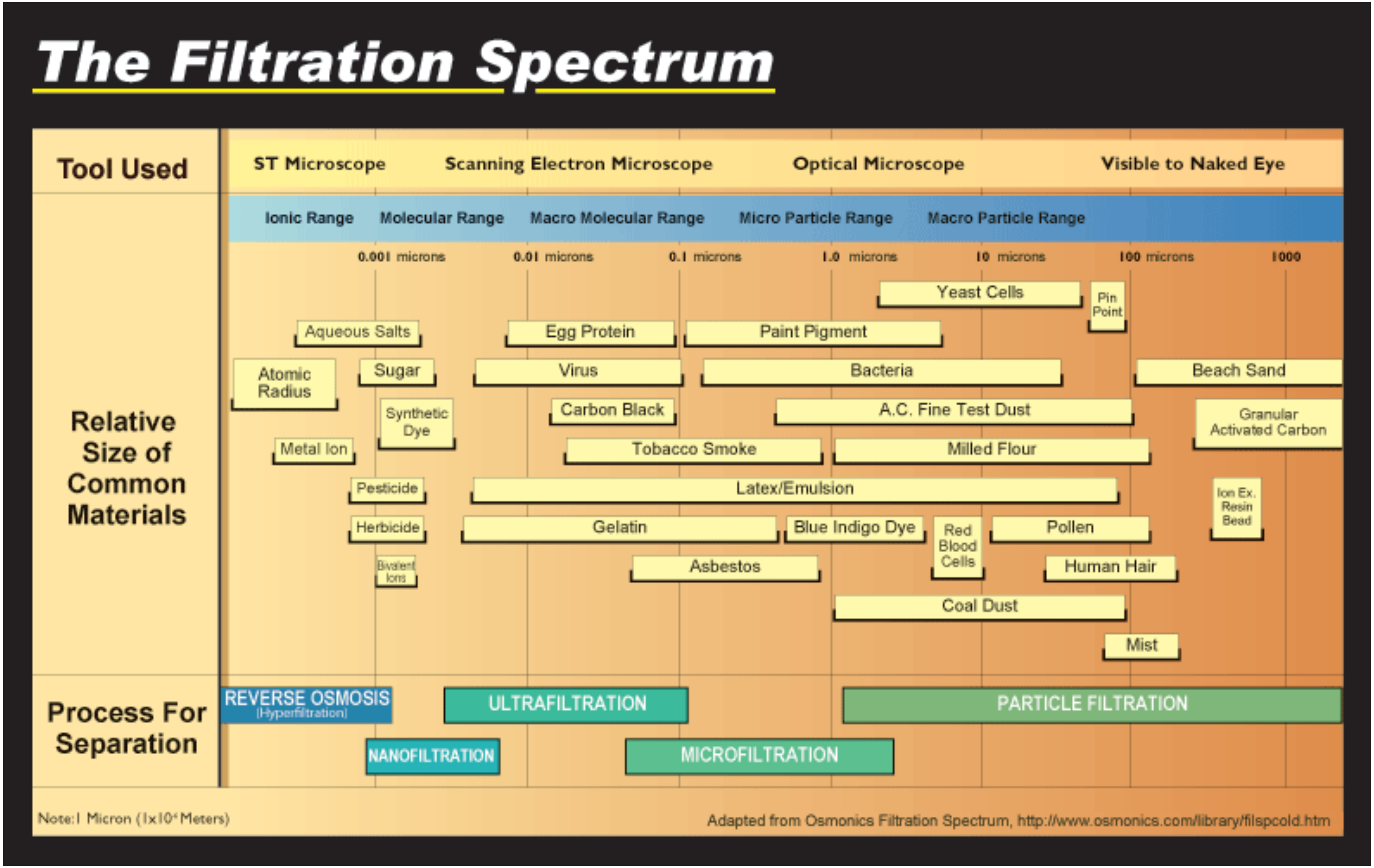
Xie J, MacEwan MR, Li X, Sakiyama-Elbert SE, Xia Y. ACS Nano. 2009; 3:1151. [PubMed: 19397333]



Nanofiltration d'eau



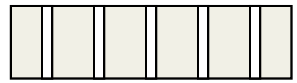
http://en.wikipedia.org/wiki/water_crisis



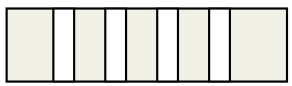
Source: Adapted from http://http://www.sasconsulting.ca/Files/Spectrum.jpg

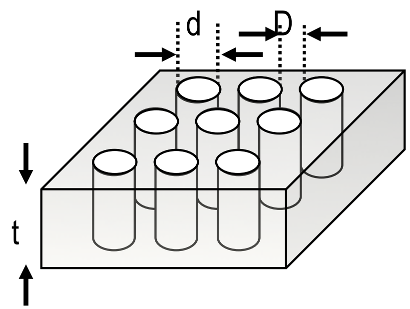
Problème à resoudre

Good separation efficiency
low permeate
Good membrane stability
High force on membrane

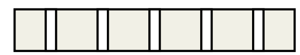


Poor separation efficiency
high permeate
Good membrane stability
Low force on membrane

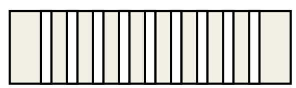


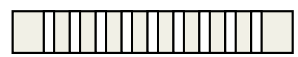


Good separation efficiency
high throughput
low membrane stability
high force on membrane

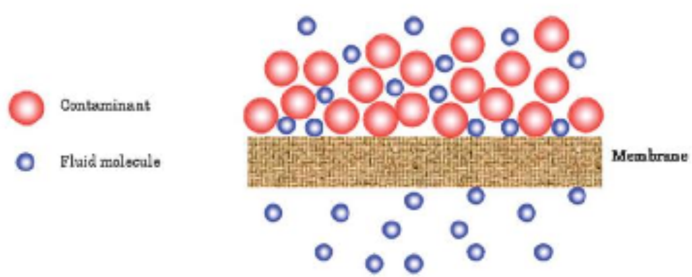


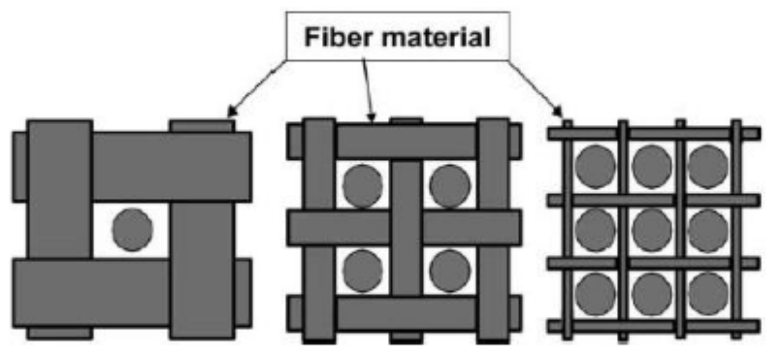
Good separation efficiency
high permeate
Good membrane stability
High force on membrane





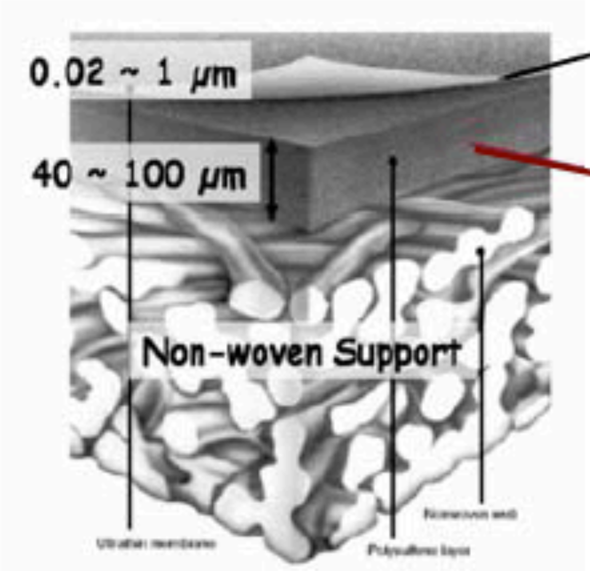
Good separation efficiency
Highest permeate
low membrane stability
reduced force on membrane





1. Composite membranes with conventional and E-spun support

Conventional composite membranes



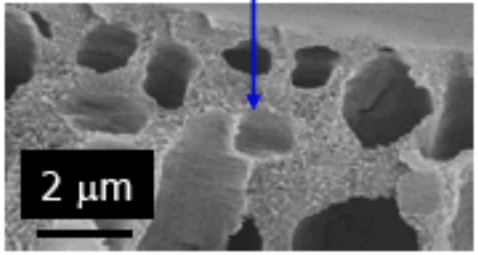
Top coating layer
(next slides)

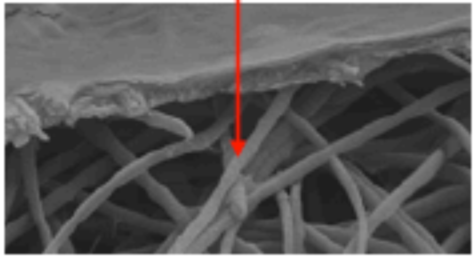
Flow rate/area is increased
Due to higher
surface pore density

1. Mid-layer Support

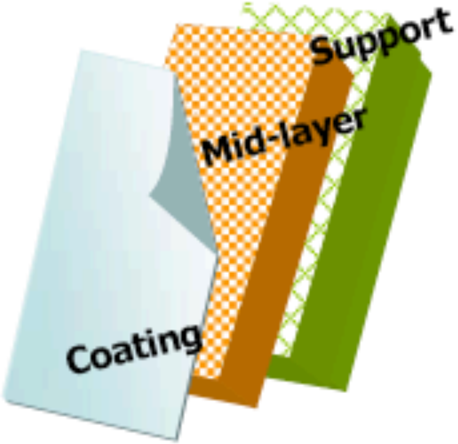
1. Conventional
mid-layer support

2. **Nano-fibrous**
mid-layer support





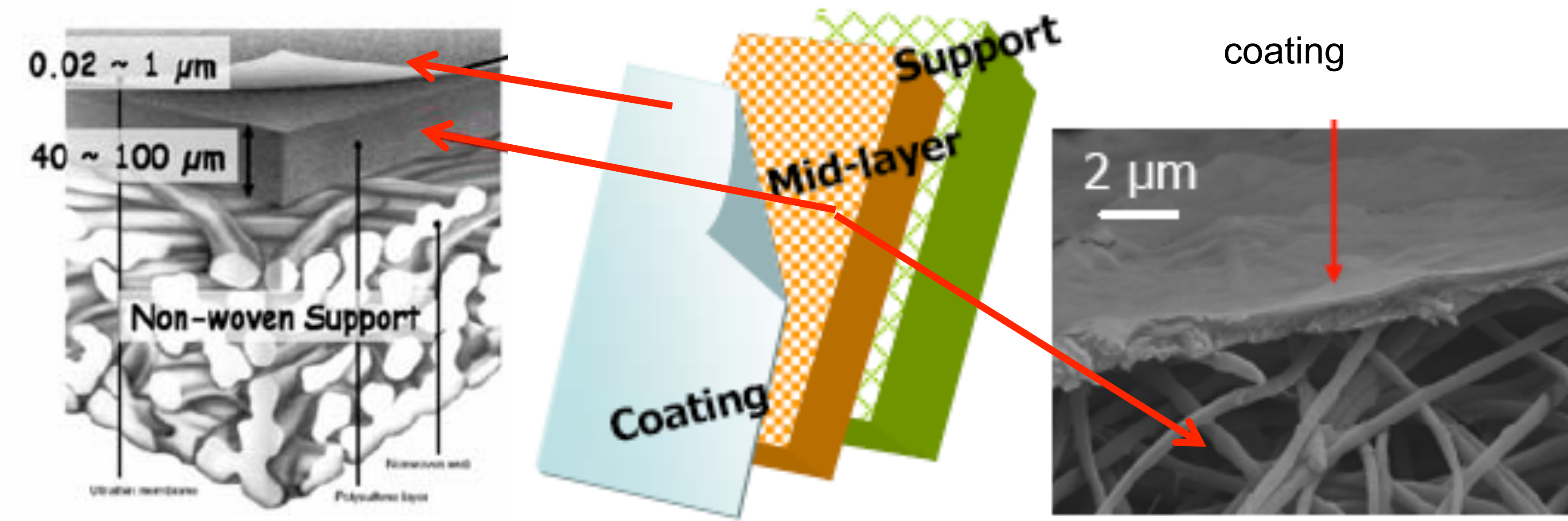
Three-Tier Approach



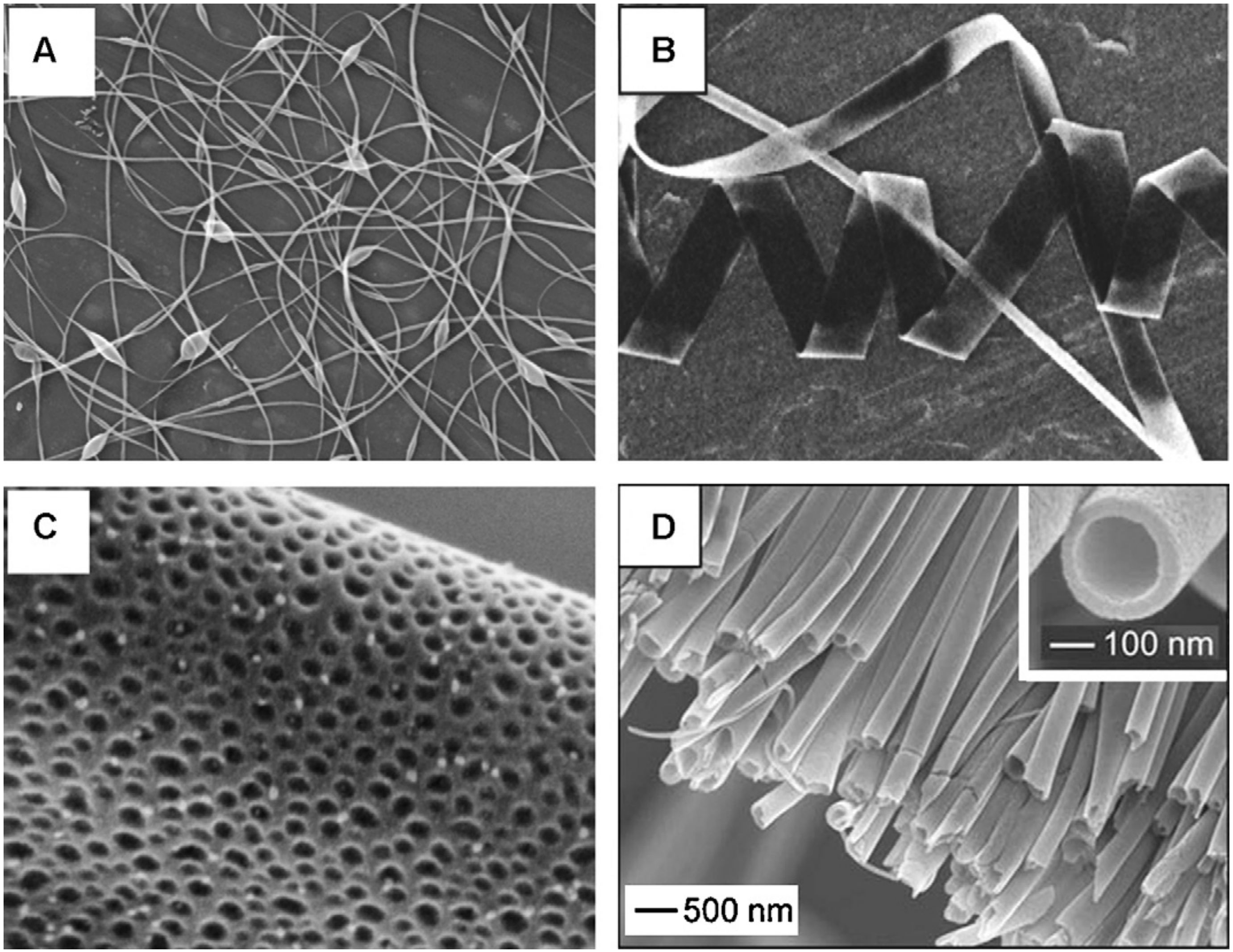
- Higher pore volume
- Much higher surface pore density

Payoff: up to~5 times
increase in filtration efficiency

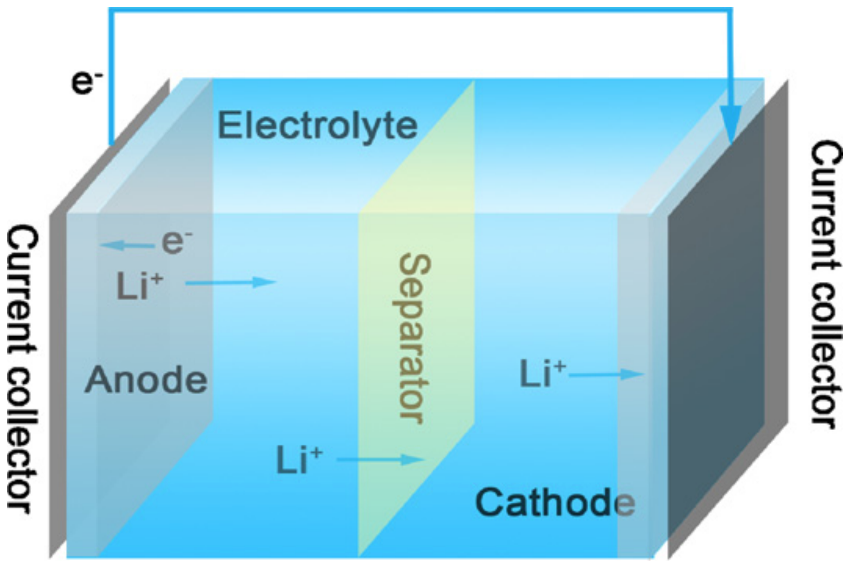
STONY BROOK


0.02 ~ 1 μm
40 ~ 100 μm
Non-woven Support
Support
Mid-layer
Coating
coating
2 μm

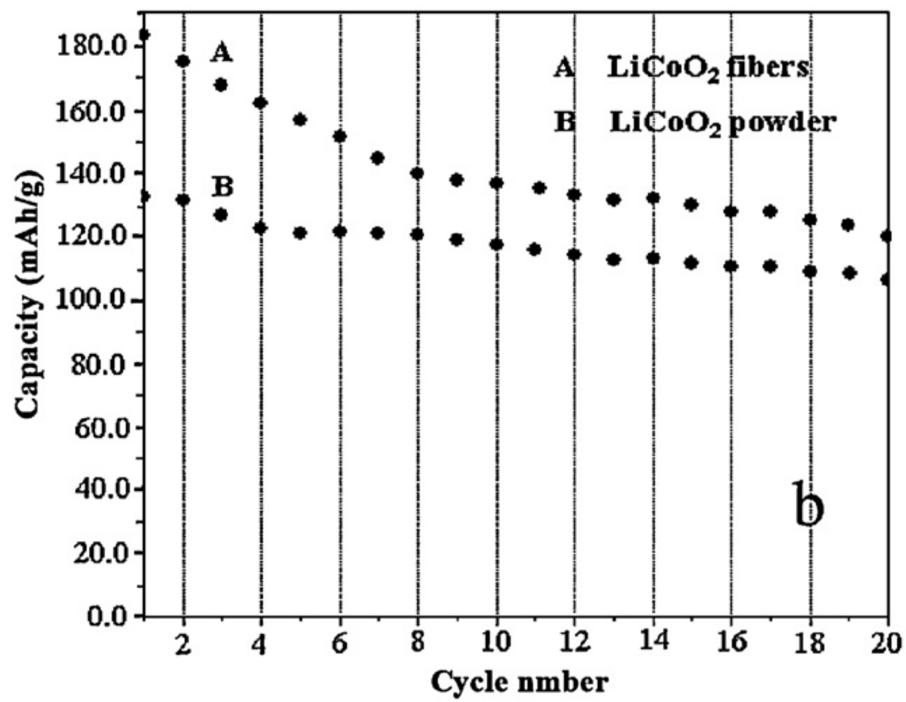
Application pour Li-Batteries



Piles à Lithium

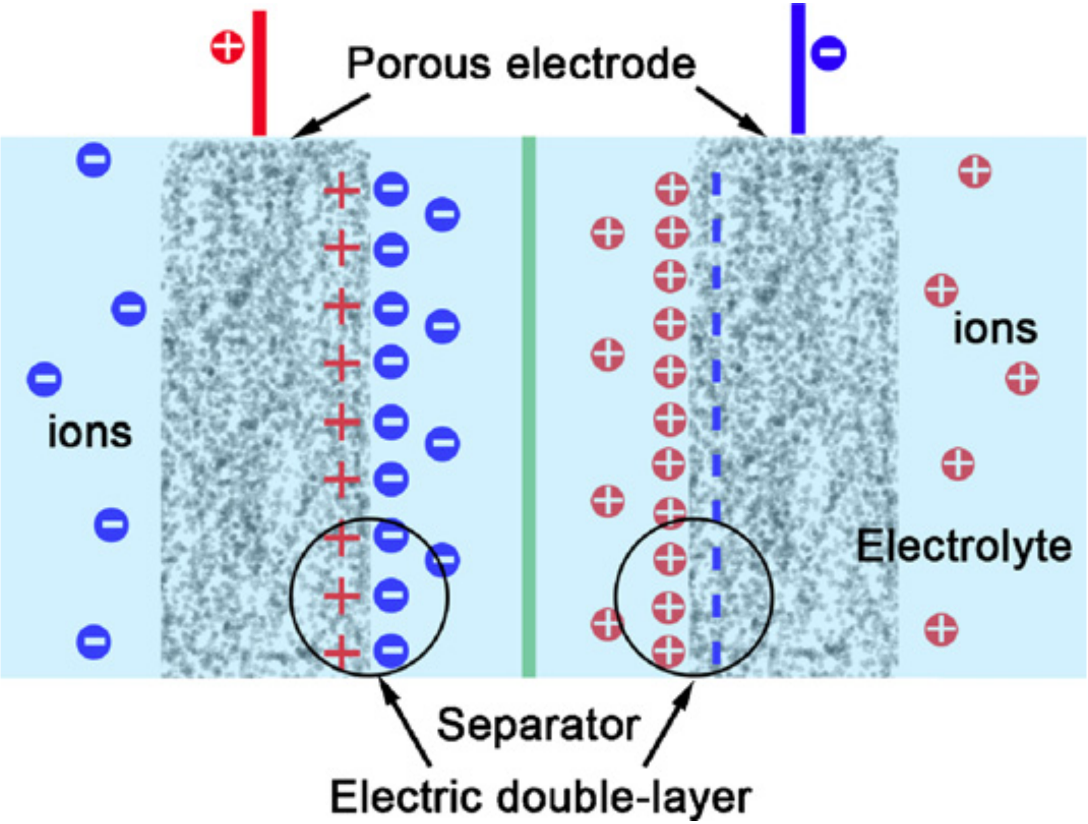


Comparaison de nombres de cycle charge-décharge d'une pile à Lithium avec des électrodes $LiCoO_2$ avec soit sous forme de poudre (B) ou des fibres par électrospinning / sol-gel.



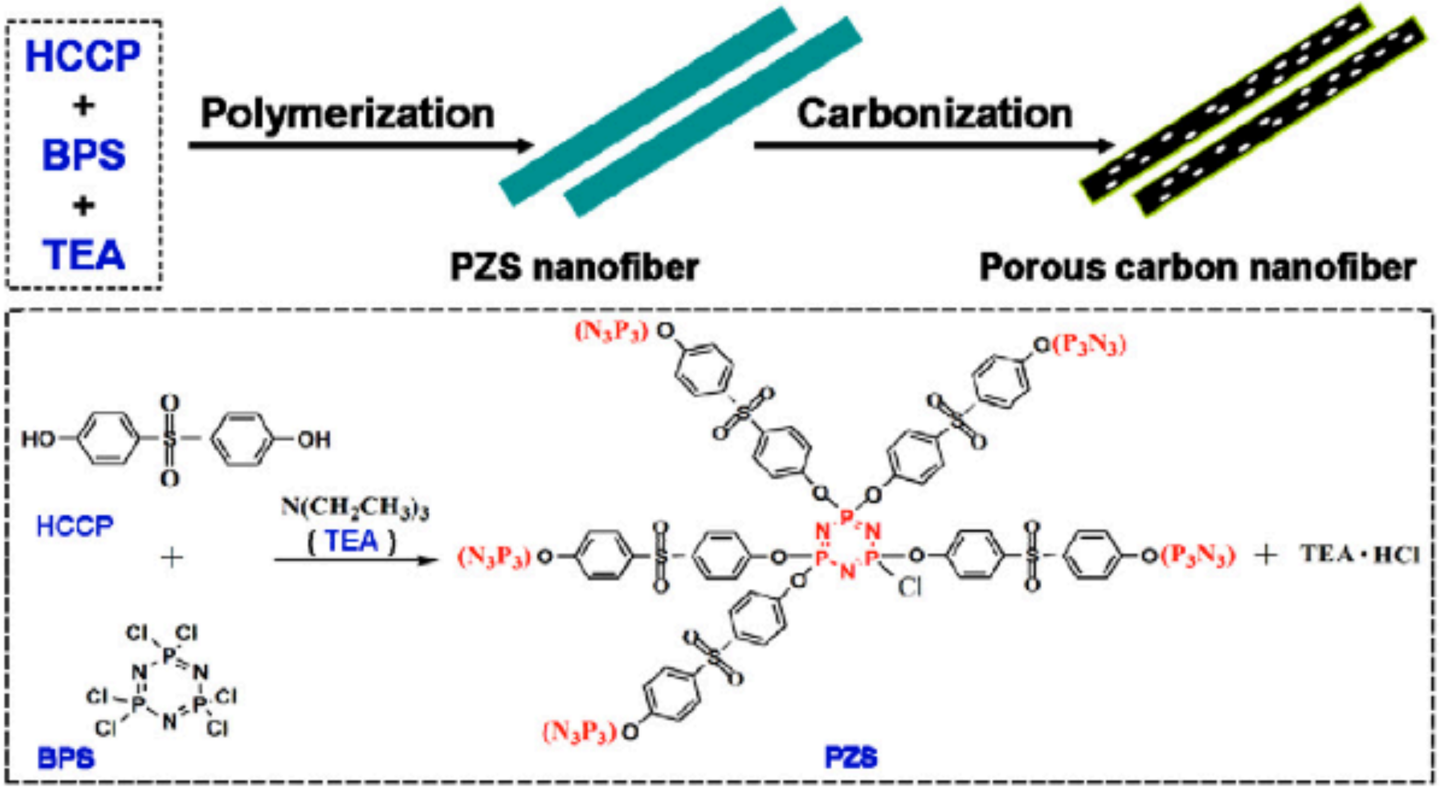
Y.X. Gu, D.R. Chen, M.L. Jiao, J. Phys. Chem. B 109 (2005) 17901–17906

Supercapacité



Potentiel: électrodes en carbone mais en très grande surface

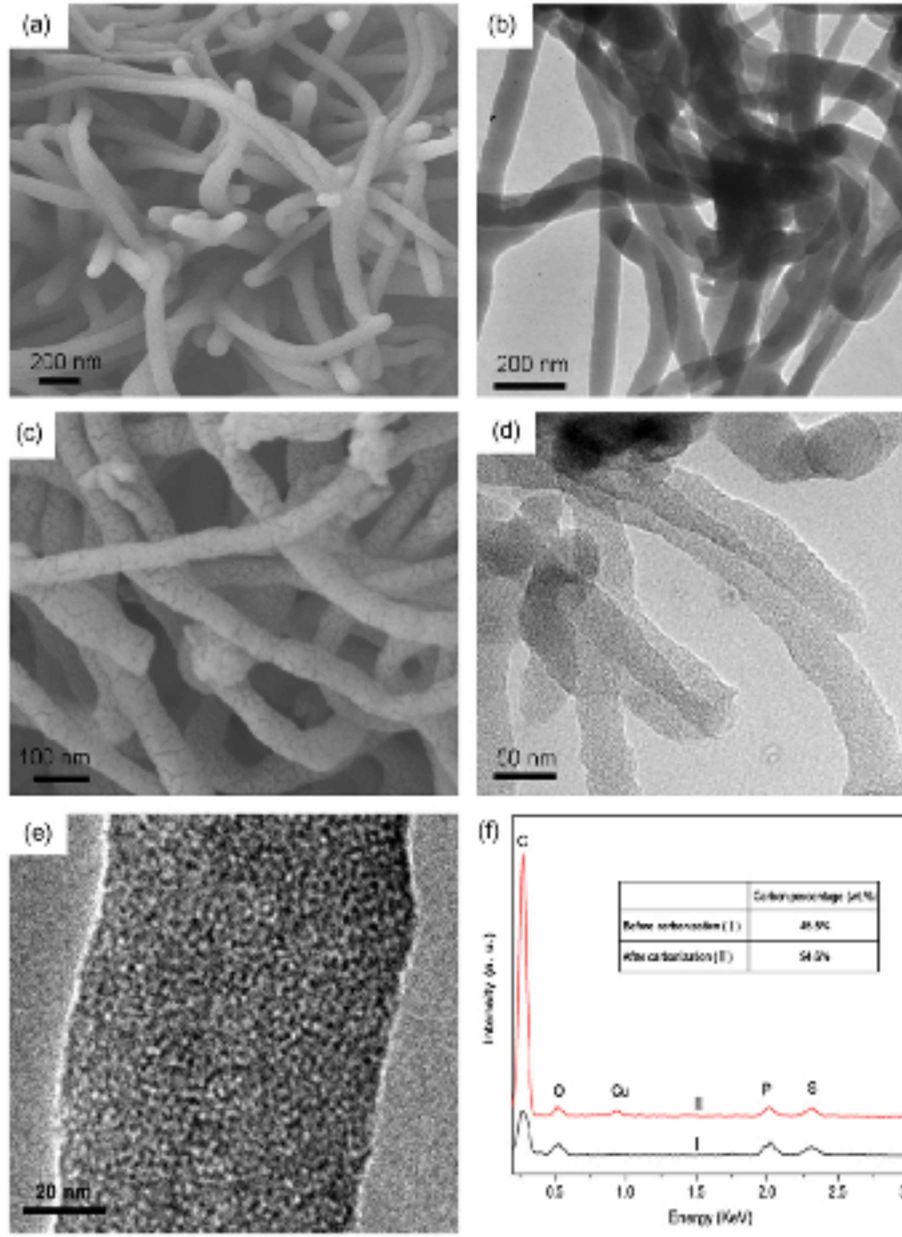
Carbonisation de fibres



Poly(cyclotriphosphazene-co-4,4 0 sulfonyldiphenol) (PZS)

Mise en forme des électrodes (a, b) poreuses et carbonisation à 900 °C en N_2 (c, d)
surface: $540 m^2 g^{-1}$
$0.37 m^3 g^{-1}$,

Jianwei Fu et al. CARBON 49 (2011) 1033 – 1051



conclusion

- La technique de l’électrospinning ouvre de multiples possibilités dans les domaines ou:
- Un grand rapport surface doit être généré
- Différent que les nano-poudres il y a un lien entre les nanostructures
- La grande surface peut être activé pendant le « spinning » ou par post-traitement.
- Les domaines en pleine développent sont:
  - La médecine régénérative
  - La nano filtration d’eau
  - Les systèmes de stockage d’énergie.


THE END