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# Understanding mechanical properties of electrospun networks: Analysis, tailoring and simulation

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**Introduction:** Electrospun membranes are increasingly investigated for tissue engineering application due to their structure mimicking the extracellular matrix architecture. As one important parameter, implants should mimic the mechanical properties of the host tissue in order to achieve a successful integration. E-spun fibers can be tailored in terms of diameter, mechanical properties as well as their geometrical arrangement that alters membrane porosity. However, influences of these factors on mechanical properties of the whole membrane and their interdependence are still poorly understood. This project aims to bridge the gap between microscopic single fiber and macroscopic membrane mechanical properties as well as fiber-to-fiber interaction. For this purpose, influences of fiber diameter and of fiber-to-fiber cross-linkage are investigated at different mechanical scale levels.

**Methodology:** Poly-(lactic acid) as a prominent biodegradable polymer is focused for fiber development. Membranes are produced with the nanospider (Elmarco), a pilot plant for industrial fiber volume production by needleless electrospinning. Mechanical behavior of isolated single fibers is measured by 3-point-bending testing by atomic force microscopy and axial tensile testing with a nanomechanical testing system. Polymer structure of fibers is assessed by different methods e.g. wide-angle x-ray scattering and selective amorphous phase dissolution. Geometrical deformation of fiber networks during uniaxial testing is investigated by in-situ scanning electron microscopy- and in-situ small-angle x-ray scattering tensile testing.

**Findings:** Thinner fibers have higher crystallinity level and higher molecular orientation leading to greater young's modulus. Also, higher fiber alignment during uniaxial deformation is found in membranes made out of thinner fibers. These factors lead to a stiffer response of those membranes in the direction of loading.

**Outlook & Significance:** Cells cultured onto mechanically tailored membranes under cyclic stretching will help to understand the performances of e-spun scaffolds for regenerative medicine application. Furthermore, we are currently developing a 3D-numerical model of membrane formation and structure informed by experimental data.

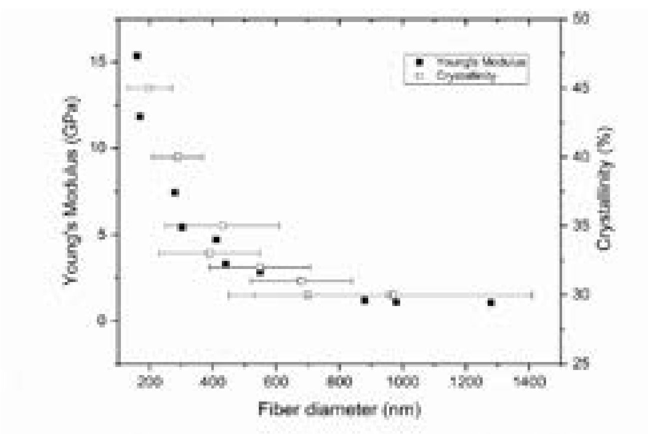


**Figure: 1 Young's Modulus of single PLLA fibers in functions of its diameter and measured crystallinity of whole membranes in functions of their mean fiber diameter; both factors follow similar relationship.**

**Recent publications**

1. Voorneveld J, Oosthuysen A et al. (2016) Dual electrospinning with sacrificial fibers for engineered porosity and enhancement of tissue ingrowth. Journal of Biomedical Materials Research Part B: Applied Biomaterials doi: 10.1002/jbm.b.33695
2. Bergström J S and Hayman D (2016) An overview of mechanical properties and material modeling of polylactide (PLA) for medical applications. Annals of Biomedical Engineering 44(2):330-340.
3. Bauer A J P, Wu Y, Liu J and Li B (2015) Visualizing the inner architecture of poly(caprolactone)-based biomaterials and its impact on performance optimization. Macromolecular Bioscience 15(11):1554-1562.
4. Yano T, Higaki Y, Tao D, et al. (2012) Orientation of poly (vinyl alcohol) nanofiber and crystallites in non-woven electrospun nanofiber mats under uniaxial stretching. Polymer 53(21):4702-4708.
5. Zhao X, Sun X, Yildirimer L, et al. (2016) Cell infiltrative hydrogel fibrous scaffolds for accelerated wound healing. Acta Biomaterialia 49:66-77.

**Biography**

Alexandre Morel's research interests are focused on applied tissue engineering to be highly interdisciplinary. He gained expertise in bio-microfluidics and cell culture working on the development of a cyclically-stretchable 3D-vascular network during his Master's thesis in ARTORG center in Bern (Switzerland). He worked on the development of a 3D-kidney model using bioprinting technologies during an internship at the University of Applied Sciences in Wädenswil (Switzerland). In addition to bio-microfluidics and bioprinting, expertise in electrospinning enables him to tackle tissue development with suitable solutions. During his PhD thesis, he acquired abilities to investigate mechanical aspects at different scale levels and could deepen his knowledge in mechanobiology. These new skills help to design scaffolds with appropriate mechanical properties for tissue engineering application.

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**Notes:**