“Luminescent electrospun micro-and nano-fibers for applications in photonics.”

The electrospinning technique is known for more than 120 years, but despite this fact, it is one of the few methods of producing nanomaterials that can be easily used on an industrial scale.

The basis of this technique relies on the ejection of a stream of polar polymer-solvent solution from the nozzle under the influence of an external electric field. When the viscosity of the solution is optimized to the speed of stream ejection, fibers of different shapes and sizes can be formed. Over a dozen years, this technique has become an efficient tool for producing new types of micro and nanomaterials for applications in optics, photonics, nanophotonics, and nanobiophotonics.

The main advantage of electrospinning is the ease of its application and the ability to control the fabrication parameters affecting the morphology of the micro and nanostructures. Typically, this technique allows obtaining fibers of very large lengths and diameters ranging from several tens of micrometers up to several nanometers. Depending on the duration of the electrospinning process, it is possible to obtain single fibers and entire fabrics of different thicknesses, a different number of layers, and degrees of disorder. In addition, such fibers can be easily functionalized, just by the simple addition of luminophore to a solution used for electrospinning to gain the ability of light emission or even lasing.

This research project aims to the development of new organic, luminescent materials based on electrospun fibers capable of emitting light in the broad spectral range of visible light. Such materials will be tested in lighting, sensing, and lasing applications. Materials made of polymer fibers can behave like a group of optical fibers as well as a material that strongly scatters the light, especially when the fibers form a highly disordered structure. The latter feature can be used in lighting systems to form different types of functional coatings. For example, strong light scattering is desirable in lighting systems where light diffusion ensures a uniform distribution of generated light. The coatings made of electrospun fibers can be an interesting alternative to the ceramic coatings currently used in white light-emitting diodes (WLEDs). Current technology is relying on phosphorescent materials to obtain white light. Such a strategy has some drawbacks related to a phosphoresce’s long emission lifetime, making it unsuitable for data transmission by optical methods based on Li-Fi concept (the optical equivalent of Wi-Fi). The use of fluorescent non-woven coatings can solve this problem.

In addition, light scattering is playing a key role in a particular type of laser action, so-called random lasing. This is an unusual type of laser action, which, unlike classical lasing, can generate beams of light in many different directions at once. Moreover, such lasers can generate polychromatic light, which is not affected by a typical noise for lasers – a speckle pattern. Thus they are perfect for imaging and lighting applications.

Within the framework of this project, the studies on the utilization of the electrospinning technique for the development of polychromatic and white random lasers will be carried out. Such devices can revolutionize lighting systems and imaging methods, allowing to obtain better images, higher contrasts, and intensities. They can also become alternative light sources for the super-continuum generators currently used in laboratories. As the laser action occurs very quickly (even thousands of times faster than spontaneous fluorescence), the laser-based lighting systems can increase data transfer rates for Li-Fi technology over three orders of magnitude with respect to systems based on spontaneous emission.

An additional advantage of micro and nano-fibers is the very large surface-to-volume ratio. This feature could be utilized for sensing applications. In general, the chemical compound that can undergo photophysical changes under the influence of external conditions can be used as dopants to polymeric matrices. Especially the luminescent ones are of great importance because their behavior can be remotely monitored from a great distance by detecting the changes in luminescence spectra. The high surface-to-volume ratio typical for nano-fibers can assure strong interaction of molecules with surrounding the nano-fiber environment and; thus, detection functionality is gained. As the sensing molecules are encapsulated in polymeric fiber, the material has the capability to be utilized repeatedly and will not cause contamination of the investigated environment.

Finally, electrospun fibers can be modified with sensing dyes capable of generating laser light. This part of the project will be extremely important and interesting as laser emission is strongly dependent on changes in initial conditions. Together with environmental influence on the photophysical properties of emissive molecules, the laser action could be essential for developing ultrasensitive, reusable probes for remote detection of ions and radicals presence and/or pH, polarity, and proticity changes.