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Nano galaxy - A novel electrospun nanofibrous membrane that’s out of this world
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Nano Galaxy- a novel electrospun nanofibrous membrane

Water scarcity as a global crisis is expanding gradually all over the world. The reasons should be sought in the dwindling of fresh water supplies and water pollution. The optimum solution could be water filtration based on efficient membranes with low energy consumption. During the course of the last decade, efforts to achieve energy saving membranes for water treatment have increased tremendously and have recently employed the solutions relying on the nanofibrous structures.

Electrospinning is the most suitable technique for production of nanofibers mainly due to its easiness, low cost, high speed, high versatility allowing control over fiber diameter, microstructure and arrangement and vast materials selection. This technique is based on three main components: a high voltage supplier, a capillary tube containing polymer solution/melt equipped to a needle of small diameter and a metallic collector. In this process, to make an electrically charged jet of polymer solution/melt out of the needle, a high voltage is applied between two electrodes connected to the spinning solution/melt and to the collector (normally as grounded). The electric field is subjected to the tip of the needle containing a droplet of the polymer solution thereby electrifies the surface of the droplet. The repulsion of the present charges at the surface also their contraction to the opposite electrode create a force overcoming the surface tension and ejecting a charged jet from the tip of the droplet. Due to the mutually repulsive forces of the electric charges of the jets, the polymer solution jet undergoes a bending instability and is elongated and becomes very thin. Meanwhile, evaporation of the solvent results in formation of a charged polymer nanofiber which is collected as an interconnected web on the collector.

The collected web is composed of randomly aligned nanofibers resembling a non-woven. Such a nanofibrous mat is highly porous and the pores are as small as only a few times to a few ten times the fiber diameter and interconnected. This promising structural features make the electrospun nanofibrous mats strong candidates for filtration applications as a membrane. The high porosity implies a higher permeability to fluid streams and the interconnected pores can withstand fouling better. Furthermore, the small pore size of the nanofibrous membranes could be beneficial in term of a high retention.[1] Optimum permeability of a nanofibrous membrane in a filtration process equals with a low energy consumption highly desired for the new generation of advanced membranes.

Despite an extraordinary permeability, due to a very high porosity and surface area, the nanofibrous membranes are susceptible to mechanical breakdowns.[2, 3] In addition, a combination of the hydrophobic membrane materials frequently used, a high surface area and roughness could bring about a high hydrophobicity and fouling tendency. The restricted selectivity to only microfiltration (MF) domain i.e. ability to discriminate only coarse suspended solids is another drawback of such kind of membranes.

To benefit electrospun nanofibrous membranes (ENMs) on an industrial scale such shortcomings should be understood and addressed properly. This objective besides innovation as development of novel nanofibrous membranes are in fact of the main research strategies at the “Nanochemistry and Nanoengineering group” of the Institute of Polymer Research of Helmholtz-Zentrum Geesthacht. For instance, in a recent study, polymer nanofibers were augmented using ceramic nanoparticles. Exposure of the nanoparticles on the surface of the nanofibers led to a very high hydrophilicity while a hydrogen bonding between the nanoparticles and the polymer chains resulted in a mechanically strong nanofibrous membrane.[4]

In term of selectivity, the ENMs possess a pore size in the range of microfiltration (100 nm-10 µm).[2] Hence, they are hardly able to catch particles smaller than this range of size. To address such a problem, in one of our recent studies, an ENM was functionalized through protein immobilization. The biofunctionalized nanofibers could catch very tiny nanoparticles as small as even 20 nm.[5] The other approach to be investigated is structural modifications leading to creation of smaller pore sizes.

This month's cover image is a SEM micrograph of an electrospun nanostructure composed of spheres (nano/micro) and nanofibers being investigated for membrane applications. This "nano Galaxy" structure is formed via electrospinning of a dilute polymer solution. Indeed, an unstable charged jet of the solution creates a hybrid of nanofibers and spheres.

This membrane possess a novel nanostructure in which spheres are assumed to limit the pore size i.e. a more optimum selectivity. Moreover, the presence of the spheres can change configuration of nanofibrous layers from a 2 dimensional stacked to a 3 dimensional and spaced one. This arrangement mode can probably be influential on the formation of the cake layer of the rejected particles and lowers its packing density i.e. a higher permeability. Such a novel nanostructured membrane fulfills our main research objectives that are innovation and modification of an electrospun nanofibrous membrane leading to a high filtration efficiency.

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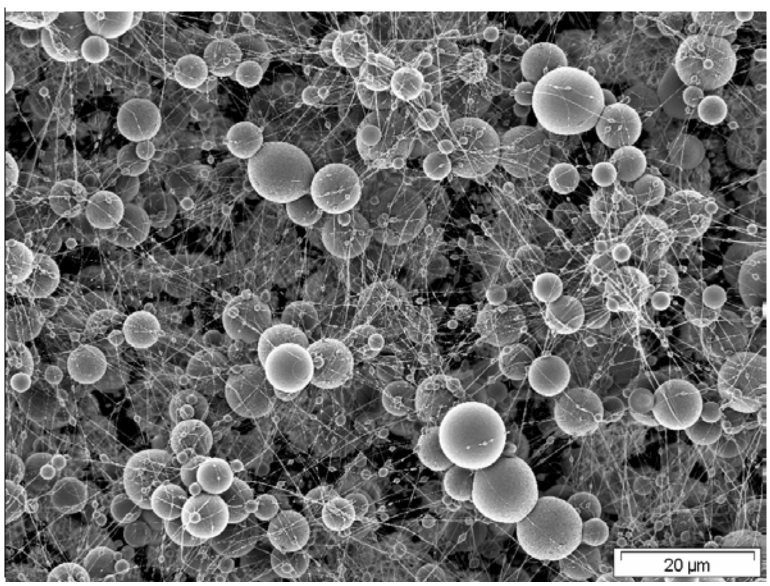

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