STRUCTURE AND MECHANICAL RESPONSE OF METALLIZED ELECTROSPUN POLYMERIC MATS AND FOAMS FOR FILTER APPLICATIONS

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Polymeric non-woven structures for filters are often formed from wet-laid melt blown or spun-bounded fibers, where the polymeric fibers are on the order of microns in diameter. Ultra-filtration applications use finer diameter fibers (100s to 1000 nm) which can be formed via electrospinning. In these cases, composite filter structures have been shown to enhance flow rates of fluids by tailoring multiple polymeric structures of mixed spacing, diameters, and hydrophobicity [1]. Adding anti-microbial functionality to these filters has been achieved through the addition of metallic nanoparticles, such as silver. The particles have been introduced by a variety of methods, ranging from incorporating silver nitrate and subsequently precipitating silver nanoparticles during electrospinning [2] to simple immersion. Silver is not the only metal that exhibits antimicrobial properties; copper has also been shown to exhibit antimicrobial applications when present in nanoparticle form [3].

In this current work we explore the ability to electrospin both hydrophobic and hydrophilic polymers and their ability to subsequently be processed using electroless deposition of copper to form nm-scale copper particles which are well adhered to the underlying electrospun mat. Polycaprolactone (PCL) and polyacrylonitrile (PAN) were chosen as the hydrophobic and hydrophilic polymers. Electroless deposition on these structures was carried out using either a pre-treatment of PdCl2 solution or from a copper sulfate solution. The copper metallization was then compared to a silver metallization using classical silvering processes from mirrors for the PAN system. Electron microscopy of the resulting metallization was used to quantify the particle size and distribution of metallization as a function of processing conditions (see Fig. 1 for typical scanning electron microscopy results, transmission electron microscopy will also be presented), and chemistry and crystallography was determined using both FTIR spectroscopy and X-ray diffraction, which identified 10’s of nm scale crystallites of Cu were present. The deposition process was modeled using first-principles simulations density functional theory, and a possible route to deposition was identified. Finally, the effect of metallization on the mechanical response of the mat to pressure (a key parameter to provide adequate flow rates through filters) was explored using indentation testing of membrane geometries, with particular emphasis placed on the differences in the fiber-fiber joint deformation with and without metallization procedures. The results will be discussed in light of the design parameters for metal-polymer composite filters.

References:

Figure 1 – Cu deposition on PCL nanofibers