Surface Modification of Polymer Fabrics with Ionic Nanoparticles

CNF Project # 1714-08
Principal Investigator(s): Emmanuel P. Giannelis
User(s): Jason Fang, Antonios Kelarakis

Affiliation(s): Department of Material Science and Engineering, Cornell University
Primary Research Funding: Kimberly-Clark
Contact: epg2@cornell.edu, cf89@cornell.edu

Abstract:
Negatively charged plasma treated polypropylene fabrics exhibit strong hydrophobic characteristics and their surface properties can be altered by appropriate coating. Plasma-treated polypropylene surfaces can attract silica nanoparticles bearing positive charges. Deposition of dilute silica suspensions on those fibers and subsequent evaporation of the solvent, give rise to homogenous coatings, that cannot be easily removed by washing. Furthermore, the coated surfaces exhibit extreme hydrophilic behavior and excellent wetting in water. The surface properties of those materials are compared with the corresponding behavior of fibers covered with polyethylene glycol/silica and glutaraldehyde/silica hybrids.

Summary of Research:
Polypropylene (PP) nonwoven fabrics produced by melt-blowing and spun-bonding have found widespread use in several engineering and biomedical applications. A number of physical properties of polypropylene can be independently optimized with respect to the final application via a variety of modifications. For example, the surface properties of polypropylene can be altered by chemical modification [1], graft polymerization [2] and plasma treatment [3].

Figure 1: Pedant drop testing of water contact angle on substrates. Original polypropylene fabric (top) has water contact angle around 120°; Nanoparticles-deposited polypropylene fabrics (bottom, snapshot) were wetted with water drop immediately.
In our current research activities, we explore a novel approach to coat and render the fiber surface essentially hydrophilic. In our studies, we consider argon/oxygen plasma-treated polypropylene fibers, given that this material possess surface charges while their mechanical properties remain unaffected. Characterization studies by x-ray photoelectron spectroscopy and Fourier transform infrared spectroscopy (FTIR) indicated that the extent of surface oxidation can be controlled by varying the field amplitude and the exposition time. Several peaks can be seen in the FTIR spectra of the treated surfaces characteristic of C = O, O-C = O and C-O vibration modes. The negatively charged surfaces can attract silica nanoparticles bearing positive surface charges. It was shown that deposition of dilute functionalized silica suspensions on the plasma treated fibers results in a dense and stable coating on the polymer surface. After complete solvent evaporation, the surface properties of the fibers were found to be dramatically changed. Interestingly, water contact angle measurements indicate the extreme hydrophilic character of the functionalized silica covered polymer as opposed to the original plasma treated material that has strong hydrophobic character. The wettability of the surface can be precisely tuned by varying the geometry of the core and/or the nature and the density of the silica functional groups. It should be noted that the homogenous coating this obtained can effectively resist washing.

Current studies are focusing on investigating the effect of different type of coatings to the energy dissipation mechanism on the surface of polypropylene fibers. Besides the functionalized silica nanoparticles presented above, we also consider the effect of deposition of shear-thickening fluids such as polyethylene glycol/silica hybrids. In this case the increased wettability of the surface can be traced back to the hydrophilic nature of polyethylene glycol. However, this type of coating can be easily removed by washing.

Finally, the deposition of silica/glutaraldehyde hybrids was also considered. The cross-linking density of the final network highly depends on the size of nanofillers, which in turn determines the mechanical properties of the fibers.

Figure 2: SEM images of polypropylene fabrics (a) plasma pretreated PP fiber; (b) ionic nanoparticles could not form the uniform coverage on PP fiber without plasma pretreatment (self-assembling pattern came from water drying); (c) ionic nanoparticles uniformly deposit on plasma pretreated PP (a clear boundary); (d) ionic submicro-particles deposit on plasma pretreated PP; (e) shear thickening fluids (particle + polyethylene glycol) fully infused into inner texture of PP; (f) three-component composites (particle + glutaraldehyde + polyethylene glycol) cross-link with PP fibers.

References: