Nanolayer Self-assembly: Novel, Adaptable Fiber Surfaces

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We are using electrostatic self-assembly processes to add functionality to the surface of textile substrates without significantly altering the weight, bulk, or comfort of the modified textiles.

TEM Image of a cotton fiber coated with gold nanoparticles

The benefits of utilizing electrostatic self-assembly include its: Flexibility, the properties of the modified textile can be tailored to a specific application through control of the number and composition of the self-assembled nanolayers; Compatibility, the process can be readily incorporated into existing textile manufacturing infrastructure; Durability, the method is particularly tolerant to defects, as the layered structures have the ability to self heal; and its Environmental Friendliness, the process is water-based—no expensive or hazardous solvents are necessary, no vacuum system is required, and large excesses of the polyion solutions are unnecessary.

Electrostatic self-assembly (ESA) is a revolutionary technique, which allows the precise deposition of functional polymers. The ability to control the composition of the coatings at the atomic level creates unique properties not possible using existing bulk fabrication processes. Moreover, the process is compatible with an almost unlimited number of materials including antimicrobial, conducting, light-emitting, light-absorbing, and color-changing polymers, as well as electromagnetic materials and a variety of nanoparticles including fullerenes and nanotubes.

Scheme for introducing positive charges to cellulosic substrates

The first step in substrate preparation includes the creation of charged groups on the surface of these textile fibers. While anionic cotton and rayon can be produced with alkaline sodium chloroacetate, cationic cotton and rayon will be produced by reacting the fiber with 2,3-epoxypropyltrimethylammonium chloride. Anionic polyester, nylon and acrylic fibers as well as cationic nylon are commercially available.

The surface charge density is estimated by Zeta potential measurements and by adsorption of dyes of opposite charge. Furthermore, XPS and FTIR-Imaging will be performed in order to obtain chemical mapping of the functional groups and to estimate the charge density of the modified fabrics.

Nanomoieties such as nanolayers, nanoparticles or thin films can deposited over the textile substrates without compromising the comfort or the mechanical properties of the fabrics but imparting unique and value added properties

The deposition process involve the repeated sequential dipping of the charged textile fibers into the solutions of polycations, polyanions and charged nanoparticles with rinsing between each deposition step. The thickness of the individual nanolayers will be tuned at the molecular level by controlling the immersion time, ionic strength of the solution, the pH of the solution as well as the temperature. In addition, metallized and unmetallized direct, acid, and reactive dyes will be used. The presence of transition metal ions (e.g., Co, Cu, Fe) is anticipated to serve as sites for ligand interactions with ionic groups in the polymer layers, adding stability to the resultant assemblies.

Assessment of the Nanolayer deposition process: The structure, quality and stability of the nanolayers deposited
over textile fibers will be assessed as follows. High Resolution Scanning Electron Microscopy will be used to verify the homogeneity and quality of the nanolayer ensambles. Atomic Force Microscopy AFM and X-ray Photoelectron Spectroscopy will be used to characterize the structure of the nanolayers as well as to determine the arrangement of the ionic platelets, and the possible overlapping due to their high aspect ratio. The analytical instrumentation to be used is currently available at the Cornell Center for Materials Research CCMR and the Cornell Nanobiotechnology Center.

**Future work**

Absorption, diffusion and permeability tests will be performed on the modified fibers in order to determine the effect of the nanolayers on their barrier and permeability properties. Absorption characteristics of these materials will be determined by gravimetric and volumetric techniques using a dynamic mechanical analyzer equipped with immersion capabilities.

The modified textiles will be evaluated with test methods from the American Association of Textile Chemists and Colorists (AATCC). Color changes, wash fastness, light fastness, and other changes in appearance will be measured before and after laundering. The unique properties provided by the nanolayers will also be revaluated after laundering.

We will perform a scale-up engineering analysis in order to determine the critical parameters required to implement ESA as a novel finishing technique. Geometric, kinematics and dynamic similarity principles as well as dimensional analysis techniques will be used. The goal of this task is to determine optimum values for non-dimensional parameters such as Prandtl, Schmidt, Strouhal, Peclet and Sherwood numbers that will correlate mass transfer coefficients, polyelectrolyte concentration, charge density of the substrates, temperature and residence times with nanolayer thickness and uniformity. This fundamental engineering analysis will provide valuable information that can accelerate the introduction of ESA as a novel finishing technique at existing textile manufacturing facilities.

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**For Further Information:**

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