Surface Modification of Polymer Substrates with Ionic Nanoparticles

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Abstract:
We explore the use of nanostructured coatings based on colloidal silica as a generic route to tune and regulate the surface properties of a versatile range of synthetic polymers. Our methodology relies on Coulombic forces of attraction between the cationically modified silica nanospheres and the localized negative charges on the argon/plasma treated substrate. Those interactions give rise to multilayer coatings that impart desired functionalities to the polymer and also exhibit remarkable stability and durability.

Summary of Research:
Nanostructured coatings carry a great potential for a wide range of applications such as preparation of ultraviolet radiation resistant, anti corrosive, self cleaning, photocatalytic, antibacterial, superhydrophilic or superhydrophobic materials. As a consequence of intensive research efforts in both academia and industry, a series of nanoscopic coating formulations has recently become commercially available.

Within the course of this project, we focus on the development of a simple, yet general, deposition process using functionalized inorganic nanoparticles on argon/plasma treated polymeric substrates varying from ideally smooth all the way through to highly textured surfaces. To that end, we have recently demonstrated that our approach can render polypropylene fabric superhydrophilic [1], a result not reported so far for that polymer.

Continuing our studies in this field, we extend the investigations by considering polycarbonate as the substrate, a polymer that exhibits exceptionally enhanced physical properties such as impact resistance and clarity, rarely seen in other materials. X-ray photoelectron spectroscopy (XPS) suggests that the level of surface oxidation (as monitored by the gradual evolution of O peak shown in Figure 1) depends on both the field amplitude and exposition time [2]. As shown in Figure 2a, the water advancing contact angles of the polycarbonate substrates are significantly reduced after plasma treatment, while subsequent deposition of positively charged silica nanoparticles gives rise to further improvement in the wetting behavior. SEM imaging (Figure 2b) suggests a complete and uniform coverage of the polycarbonate substrate after a single deposition cycle (immersion of the substrate to the suspension, solvent removal and repeated rinsings in water).

The coating quality critically depends upon the following parameters; the nature of the functional groups attached to the silica surface, the zeta potential, the size of the colloidal particles and the pH of the suspension. Furthermore, the topological characteristics of the bare substrate play a key role to the final morphology of the deposited layers and, by doing so, have a great effect on the final surface properties of the coated material.

References:
Figure 1: Water advancing contact angles of plasma treated polycarbonate substrate before (squares) and after (circles) deposition of the functionalized nanoparticles, as a function of plasma exposition time. (Black line corresponds to the untreated substrate).

Figure 2a: XPS spectrum of plasma treated polycarbonate substrate after deposition of silicon nanoparticles.

Figure 2b: SEM image of the plasma treated polycarbonate substrate coated with cationically modified silica nanoparticles.