The Surface Modification of Synthetic and Natural Polymers using Deep UV (172 nm) Irradiation

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Abstract

The ability to modify the surfaces of polymers and impart desirable functionalities without affecting the bulk-mediated physical properties is vital for advanced materials development. Photochemical approaches to surface modification are particularly attractive as they eliminate the need for use of hazardous materials used in conventional wet chemical technologies, and are relatively faster and convenient to use. In this research, we undertook a combined experimental and computational approach to understand the effect of deep UV irradiation on a broad range of polymeric materials, and develop a scalable and deployable surface modification strategy that could be extended to all. Four polyesters, polyethylene terephthalate (PET), polytrimethylene terephthalate (PTT), polybutylene terephthalate (PBT) and polyethylene napthalate (PEN), Kapton polyimide, a polyolefin and cellulose were the polymers investigated. Technical grades of the material were used in order to understand the fundamental science as well as develop a scalable deployable technology. Surface analysis was done using the X-Ray Photoelectron Spectroscopy (XPS), Time of Flight Secondary Ion Mass Spectrometry (ToF-SIMS), Attenuated Total Reflectance-Fourier Transform Infrared Spectroscopy (ATR-FTIR), Atomic Force Microscopy (AFM) and contact angle measurements. The experiments were carried out using a high intensity 172 nm xenon microplasma lamp, and the effect of varying doses of UV irradiation, 0,8,16, and 32 J/cm^2 on the polymer surfaces were characterized. The effect of using two different intensity levels was also compared. It was found that 172 nm excimer UV lamp was successful in creating active surface radicals in all the polymers investigated. In case of the polyesters and polyimide, calculated UV/VIS absorption spectra using the ZINDO//B3LYP/321-G method or the AM1/ZINDO approach were used to give an indication of which orbitals were involved in transitions near 172 nm, a valuable tool for predicting future research and development. To develop a potentially useful low energy surface that would impart anti soiling and easy cleanability properties, a fluorocarbon was successfully grafted on each material. Water and light mineral oil contact angle measurements confirmed a marked increase in hydrophobicity and oleophobicity, in some cases reaching that close to pure polytetrafluoroethylene. The grafted surface was found to be significantly wash durable. This is a valuable development as the process is minimally hazardous, relatively simple, fast, efficient, economic, and easily scalable and deployable. Particularly in the case of some polymers, such as polyolefins and cellulose, this method bypasses the challenges of complex processing routes and harmful chemicals that are currently used to achieve the same goal.