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Modification of cellulose-based materials and nanomaterials by cold, atmospheric-pressure plasma treatments

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Wood components made of cellulose, hemicellulose, lignin, extractives, etc. have been used as a building material for centuries. In light of the growing concern over the environmental impact of human industrial activity, wood has taken on a new importance worldwide. The main advantages of this widely-distributed and renewable resource lie in its versatility, strength-to-weight characteristics, ease of processing, aesthetics, and its sustainability as a green-material. Its bio-polymeric structure, however, renders it susceptible to degradation due to moisture, microorganisms, insects, fire, and ultraviolet radiation. In this context, important research efforts have been devoted to the further development of existing wood protection systems either through the application of paints, varnishes, stains, and water repellents or through direct modification by thermal, chemical, and impregnation methods. In recent years, we have shown that non-thermal plasmas represent a very promising approach for tailoring the surface properties of wood-based materials for both improvement of existing protection systems or as standalone treatment for the growth of functional coatings. In this presentation, the scientific and technological accomplishments associated with the use of plane-to-plane dielectric barrier discharges at atmospheric pressure for plasma activation [1,2] and plasma-enhanced chemical vapor deposition (PECVD) of various barrier coatings on wood surfaces are reviewed [3]. These aspects cover the effects of wood conditions and properties, such as wood inhomogeneities and wood outgassing, on the plasma deposition dynamics of SiOCH barrier layers using organosilicon precursors. This description is extended to more complex systems such as the plasma-assisted growth of nanocomposite coatings (for example TiO2 or ZnO nanoparticles embedded into a SiOCH matrix) using colloidal solutions as the growth precursor for PECVD [5]. For such applications, a combined low-frequency-high-frequency voltage waveform is used to achieve significant and spatially uniform deposition of nanoparticles across the whole substrate surface [6]. Finally, inspired by the development of advanced methods for deconstructing the de-lignified wood tracheids (fibres) into micro and nano fibres on an industrial scale, very recent studies on the plasma-assisted functionalization of highly porous microfibrillated cellulose (MFC) materials derived from the wood biomass are presented. This includes plasma deposition of functional, nanostructured coatings on films and foams made of MFC with the objective of establishing barrier properties to water, vapor, or gases for packaging and energy applications.

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Author: Prof. STAFFORD, Luc (Université de Montréal)

Presenter: Prof. STAFFORD, Luc (Université de Montréal)

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