

Dielectric Barrier Discharge-Initiated Fiber Modification (2004)

A Dissertation by Lorraine C. Vander Wielen

Abstract: Dielectric barrier discharge (DBD) treatment has been integrated into surface modification schemes for papermaking fibers with limited success. This low temperature atmospheric plasma technology has been applied to enhancing the adhesion at interfaces between inks, coatings, and laminates with materials having flat surfaces such as paper, nonwovens, and polymeric films. However, treating individual fibers with this technology is complicated and much remains unknown regarding the mechanisms by which this technology interacts with papermaking fibers. Although DBD initiated increases in oxidation and wettability have been reported, many details of the impact of this technique on the surface chemistry and the physical properties of fibers remain unexplained.

In this study, a dielectric-barrier discharge low temperature atmospheric plasma was applied to fully bleached kraft (BKP) and unbleached thermomechanical (TMP) softwood pulp sheets in the absence and presence of chemical additives. Modifications to fiber surfaces were investigated using instrumental techniques including ESCA(XPS), ToF-SIMS, AFM, SEM and DCA; wet chemical methods; and the testing of physical strength and water affinity properties.

This study shows that DBD treatment can tailor fiber surface properties, providing increased surface acid concentrations of approximately 20-23%, surface roughness increases of approximately 31-42%, increases in surface energy of approximately 5-14%, and small increases in water uptake at low treatment levels. Further, DBD treatment initiates the in-situ grafting of additives, such as maleic acid, onto moving fiber webs so as to increase the total fiber acid content by 60%. DBD treatment at high levels reduces water uptake by as much as 34-58%, while wet tensile increases by approximately 70-275% and wet stiffness increases by approximately 138-144%. However, the balance between changes to surface chemistry, product performance, high energy requirements, and fiber degradation must be considered.

Results indicate that surface properties can be tailored by controlling treatment intensity, as several competing mechanisms for surface modification occur concurrently when DBD treatment is applied and are responsible for changes to water affinity and wet strength properties. Changes to surface properties include surface cleaning for extractives removal, surface roughening and smoothing, the oxidative degradation of polysaccharides,, and covalent cross-linking.