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Silane nanofilm formation by sol-gel processes for promoting adhesion of waterborne and solvent-borne coatings to wood surface

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Abstract: The objective of this study was to promote the adhesion of waterborne and solvent-borne coatings [polyurethane (PU) and alkyd] on wood surfaces by silane nanofilm formation by means of sol-gel processes. Tetraethoxysilane and glycidoxypropyltrimethoxysilane served as sol-gel materials. The silane-based materials improved the adhesion strength. The positive effects can be explained by the changes in the wood surface chemistry induced by the sol-gel process. High-resolution X-ray photoelectron spectroscopy (XPS) showed an increase in -C-H and -C-C bonds and a decrease in -C-O bond. Microscopic observation by fluorescence and confocal laser scanning microscopy together with NIS-Elements analysis software showed that the silica component of nanosol covered the whole wood surface homogeneously, whereas alkyd and PU coatings were deposited preferentially in the surface depressions. The combined analysis of energy-dispersive X-ray analysis and XPS demonstrated that the surface was covered with silicon oxides (SiO₂) attached to hydrocarbon chains.

Keywords: adhesion, GLYMO, nanoparticle, sol-gel, TEOS, wood coating

Introduction

Adhesion failure between wood and coating is one of the major causes of coating failures. From a theoretical point of view, liquid coating is partly absorbed by capillary forces, and the adhesion is the result of surface energy action and a wetting process at the wood-coating interface (Pecina and Paprzycki 1995). In general, waterborne coating has much lower adhesion strength than the solvent-borne one probably due to some differences in the coating penetration or the swelling stresses (Meijer and Militiz 1998). Typically, priming film is a good choice to increase surface energy and to improve the adhesion of a coating. Recently, sol-gel processes have been developed to improve the resistance properties of wood against moisture and UV irradiation (Bücker et al. 2003; Tshabalala et al. 2003, 2011; Donath et al. 2004, 2006; Tshabalala and Sung 2007; Wang et al. 2013; Lu et al. 2014). The sol-gel process allows the deposition of hybrid inorganic-organic thin films on wood at room temperature. Tshabalala and Sung (2007) claimed that sol-gel deposits could be tailored to enhance not only the moisture and UV resistance but also the color stability of wood surfaces. Wang et al. (2011) developed superhydrophobic wood surfaces in a two-step process: (1) preparation of silica coatings on the wood surface by a sol-gel process and (2) fluorination treatment of silica coatings with the surface-modifying agent of perfluoroalkyltriethoxysilanes. Nanosized precursors derived from tetraethoxysilane (TEOS) were also helpful in sol-gel processes to get inorganic wood composites with improved properties (Bücker et al. 2003). Donath et al. (2004) and Pries and Mai (2013) applied sols derived from different silanes, TEOS, methyl triethoxysilane, and propyl trimethoxysilane in the course of sol-gel processes. These treatments improved significantly the antiswelling efficiency, decaying fungi, and moisture uptake. Mahltig et al. (2008) also pointed out the need to improve the weathering resistance of coating in outdoor applications. The sol-gel technology proved also of value in the case of polyesters and textiles (Chou and Cao 2003; Xu et al. 2005;