Advanced Wood Products with Nanoengineered Surfaces

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ABSTRACT

Wood and wood products are widely used as construction, furnishing and decorative materials for ecological reasons and also by reason of the appealing appearance of wooden surfaces. However, wood and wood products also have some disadvantages. For example, dimensional changes in response to altering atmospheric conditions, susceptibility to biological attack and changes in appearance due to weathering restrict the end-use of wood. Recently, it has been observed that one of the most promising methods to improve and provide new properties for wood materials is to modify wood surfaces with multifunctional alkoxysilanes by sol-gel technology. The advantage of the sol-gel process is that it allows deposition of inorganic-organic polymeric networks on various substrates as a result of controlled hydrolysis and polycondensation of alkoxysilanes. The properties of sol-gel coatings, such as abrasion resistance, barrier properties, moisture behavior as well as adhesion to different substrates, are controlled by the surface properties of the coatings and the sol-gel process variables. In this work, the moisture behavior of pine (*Pinus sylvestris*) sapwood and heat-treated spruce (*Picea abies*) was studied. The results indicated that water uptake especially of pine wood was diminished by the hydrophobic sol-gel-coating.

Keywords: moisture, pine, sol-gel, spruce, water repellence, water up-take, wood

INTRODUCTION

Wood and wood-based composites are favorable construction, furnishing and decorating materials for ecological reasons and due to the appealing appearance of wooden surfaces. However, due to its chemical and structural composition wood easily absorbs water and water vapor, which causes dimensional changes in wooden products and even biological problems if the moisture loads are severe and prolonged. Nano-coatings with functional properties provide a new way to modify surface properties of wood and to gain added value to wood-based products. Improvement of different properties such as moisture, UV and abrasion resistance, as well as anti-soiling of wood surfaces have been achieved with thin sol-gel coatings [1, 2, 3, 4]. The objective of this study was to evaluate the effect of alkoxysilane-based sol-gel coatings on the water repellence, water uptake and water vapor absorption of pine sapwood (*Pinus sylvestris*) and heat-treated spruce (*Picea abies*).

EXPERIMENTAL

Materials and methods

The study included two sol-gel coatings based on multifunctional alkoxysilanes developed at VTT. The sol–gel route involves the hydrolysis and condensation reactions. Hydrolysis acts as a rapid initial reaction of sol–gel process, where reactive alkoxide groups react with water molecules to form hydroxyl groups. After the initiation of the reaction, the hydrolyzed alkoxides react easily with each other and produce the backbone of the sol–gel network [3, 4]. In this study, the ceramic backbone of alkoxysilane sol–gel coating was modified with alkyltrialkoxysilanes. Ethanol was used as a solvent and the stoichiometrical amount of water was also used for the hydrolysis. The two coatings used differed from each other in terms of the length of the attached organic aliphatic chain. The coatings were applied on to the planed pine sapwood (*Pinus sylvestris)* and thermally treated spruce (*Picea abies*) samples by spilling. The coatings were cured at 110 ^{o}C for 30 minutes. The samples were conditioned at RH 50 % relative humidity before the measurements.

The analysis of surface characteristics and penetrations properties of sol-gel nano-composites to wood material was carried out by the means of SEM-EDX, AFM and ToF-SIMS- techniques. The moisture behaviour of sol-gel-treated and untreated samples was evaluated by means of contact angle measurements, water floating tests and water vapor permeability tests.

Results and discussion

The surface analysis (SEM-EDX) results showed that the both sol-gel nano-coatings were able to penetrate into the wood. The deposition of the sol-gel coating having a short organic aliphatic chain appeared more on the surface and in the upper layers of the wood substrate, whereas the coating with longer aliphatic chains penetrated deeper within the wood. According to the AFM measurements, the sol-gel coating having a long organic aliphatic chain increased slightly the RMS roughness of the surfaces indicating that the treatment was following the original surface structure of wood and penetrating more into the material. In addition, the Tof-SIMS analysis indicated quite even deposition of the sol-gel coatings onto pine sapwood.

The results of the contact angle measurements showed that the coating with long aliphatic chains (B) was more hydrophobic in nature than the one with short aliphatic chains (A). The former coating clearly improved the water repellence of the both wood materials studied (Figure 1). The water floating tests showed also clearly that both of the developed sol-gel nano-coatings decreased the water uptake of pine sapwood and thermally treated spruce. The treatments had no effect on the water vapor permeability of the samples.

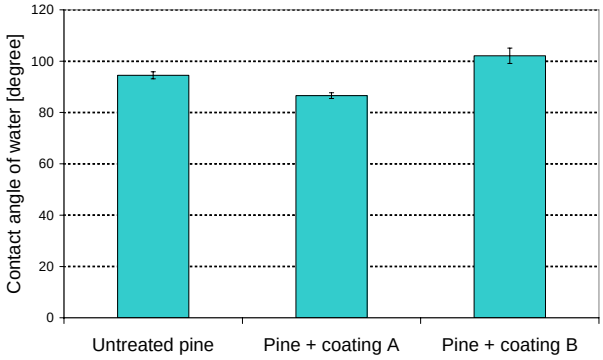

Figure 1. The effect of the sol-gel treatments on the water repellence properties (initial contact angles) of pine sapwood.

Conclusions

The newly developed silane-based sol-gel hybrid coatings have provided efficient barrier treatment against unwanted water uptake by wood-based materials. In addition, it was observed that the sol-gel based nano-treatments did not affect the water vapor permeability which allows the natural functionality of the wood based materials. This leads to the conclusion that sol-gel hybrid nano-coatings designed for wood material have selective barrier properties with prevention of water penetration while permitting water vapor movements.

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