Surface treatment technologies applied to wood surfaces*

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The fibrous nature of wood has made it one of the most appropriate and versatile raw materials for a variety of uses. However, two properties restrict its much wider use: dimensional changes when subjected to fluctuating humidity and susceptibility to biodegradation by microorganisms. The varying moisture content of wood results in dimensional and conformational instability, which can compromise the performance of other materials combined with wood such as adhesives and surface coatings. Until relatively recently, these shortcomings were addressed by impregnating wood with appropriate hydrophobes. Wood may also be modified so that selected properties are enhanced in a more or less permanent fashion. This note discusses the technologies applied to the wood surface in order to bring about a desired performance improvement.

Changes to wood surface can involve chemical modification, biological modification using enzymes or physical processes such as plasma modification. The reaction is confined to the surface of the wood substrate and the accessibility of reagent and the subsequent clean-up of the modified material are easily accomplished. Surface modification of wood has been used to improve the ultraviolet (UV) stability of wood, to change the surface energy of wood, e.g. to reduce wetting by water and/or to improve compatibility with coatings or matrix materials, and to improve bonding between wood surfaces. Surface modification methods are summarized in Table 1.

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Table 1: Summary of surface modification methods

Modification method	***Example application(s)***
Conventional chemical modification	Stability to weathering, compatibilization
Chemical modification with bifunctional reagent	Polymer grafting, self bonding, stability to weathering
Surface thermoplasticization	Self bonding
Coupling agent	Compatibilization
Chemical activation	Self bonding
Enzymatic activation	Self bonding
Plasma or corona treatment	Compatibilization, stability to weathering

Surface chemical modification for UV stability

Wood degrades when exposed to UV light primarily due to the instability of the lignin polymer. Although clear coatings can be produced that are UV stable, degradation of the underlying substrate results in premature failure of the coating system. There is a considerable body of evidence that chemical modification with certain reagents leads to an improvement in the UV stability of wood, although the mechanism by which this happens is not fully understood. Acetylation has also been used as a potential method for altering the chemical nature of the substrate, so that it is more effectively protected against exposure to solar radiation. Such protection is considered to arise due to the production of acetyl peroxide during exposure, which results in bleaching of the fibers. An alternative approach is to graft UV stabilizers on the wood surface, such as dihydroxy-benzophenone (DHBP). DHBP modification also improves the performance of coatings.

In a recent research, the color changes in wood surfaces, namely from the species Scots pine, fir, Bosnian pine, chestnut and cherry have been modified by a new nanoparticulate treatment. Color values (CIE L*, a*, b*) for both control and treated wood samples have been studied for each of the five different species. The results have shown a certain effectiveness of the *anti-UV surface treatment* used, while lower effects were due to ultraviolet light induced photodecoloration. The largest improvements against discoloration were observed in cherry wood. It was observed that anti-UV compound applied on chestnut was particularly less effective (ΔL= -4.64) in respect to other species. It appears that the yellowness shows systematic trends with anti-UV treated samples. However, the UV irridation appears to change surface yellowness of coniferous species more than hardwood species. The anti-UV treated hardwood surfaces (chestnut and cherry) yielded higher gloss than the anti-UV treated softwoods (pine and fir).

Modification to render the wood surface hydrophobic

Silicon polymers are extensively investigated in order to change the wettability characteristics of wood. Modification with silicone reagents is found to render the wood extremely hydrophobic. It would seem that the high levels of water repellency achieved required only very low levels of siloxane on the wood surface.

Surface chemical modification for bonding

In this case, chemical modification is applied for the purpose of providing a means of bonding between wood surfaces. Wood particles, veneers and so on are bonded together using an adhesive. Many of the adhesive systems currently in use are derived from non-renewable petrochemical resources and concerns regarding the decline of these resources are driving research efforts based upon the use of renewable sources, or to find means of directly bonding wood surfaces without the need for an additional adhesive agent. Various approaches can be adopted:

- Altering the surface energy of wood to improve compatibility with low surface energy materials. The use of acetylation to improve the compatibility between wood fibers and thermoplastic matrices is widely used. In this case, a reduction in the surface energy (polarity) associated with acetylation is advantageous since this improves the compatibility of the fiber with the matrix material.
- Reaction of the wood surface with a functionalized coupling agent to improve compatibility with low surface energy materials. The most commonly employed coupling agents are maleated polymers. Coupling agents are added to the wood fiber polymer ingredients and subjected to energetic mixing involving high shear in extruders or high speed mixers. The attached anhydride moieties are capable of reacting with the surface of the lignocellulosic fiber.

- Bonding of a reagent to the wood surface in order to thermoplasticize the surface for self-bonding. In this case, wood is thermoplasticized using mainly benzylation.
- Bonding of a reagent to the wood surface that provides the appropriate functionality for bonding sites. In this case, chemical modification of wood surfaces is employed in order to provide active sites to allow for self bonding directly, or to allow for covalent bond between wood surfaces via an intermediary reagent. An approach is to chemically bond a group that has a double bond present on the wood surface. It is then possible to graft monomers on to the activated wood surface using free radical polymerisation reactions or directly bond the activated surfaces together.
- Activation of the wood surface by the use of chemical reagents to generate surface free radicals. This involves the production of an anionic polymer that is then reacted with a suitably modified lignocellulosic material. Wood surface can be treated with Fenton's reagent, ceric ion or the use of halide/peroxide system.

Enzymatic modification

In this case, enzymatic systems are employed to form binder less composites. Enzyme catalyzed bonding of wood can be achieved either by activation of lignin which is mixed with wood particles or by surface activation of the wood particles directly.

Treatments to impart resistance to leaching and UV damage

Several nanotechnology treatments can be employed to increase the biological resistance of wood to fungi and other destroying microorganisms. In recent work, Southern pine specimens vacuum-treated with nano-zinc oxide (nano-ZnO) dispersions were evaluated for leach resistance and UV protection. Virtually, no leaching occurred in any of the nano-ZnO treated specimens in a laboratory leach test, even at the highest retention of 13 kg/m^3. Protection from UV damage after 12 months exposure was visibly obvious on both exposed and unexposed surfaces compared to untreated controls. Graying was markedly diminished, although checking occurred in all specimens. Nano-zinc oxide treatment at a concentration of 2.5% or greater provided substantial resistance to water absorption following 12 months of outdoor exposure compared to untreated and unweathered southern pine. It was concluded that nano-zinc oxide can be utilized in new wood preservative formulations to impart resistance to leaching, water absorption and UV damage of wood.

Corona or plasma discharge

Atmospheric corona discharge is used to increase the surface energy of wood surfaces by oxidative activation. Plasma treatment results in an increase of hydrophobicity of the wood surface.

From the above discussion, it appears that the most promising area into wood surface modification is the self bonding and weathering stability. Although, the use of enzymatic surface activation for self bonding is attractive, it is unlikely that there will be commercial use of this technology in the short term at least. Little advantage appears to result from directly covalently bonding coatings to the surface of wood, in terms of long term improved weathering resistance. However, directly covalently linking UV stabilizers does appear to lead to improved performance.

An option to bring about a desired performance improvement of solid wood is to exploit the solutions that nanotechnology can offer. Nanotechnology can be defined as engineering in very small scale. But how small and what is a nanometer? To understand in simple terms, if 1 meter were the size of the earth, a nanometer would be the size of an apple, or in numbers, one billionth of a metre. Innovations do not always make it to the market. Employing nanotechnology on wood surfaces can result in a next generation of products having hyper-performance and superior service ability when used in severe environments, since it is well known that the cell wall of wood exhibits porosity of molecular scale dimensions due to the partial filling of space between the cellulose micro fibrils by lignin and hemicelluloses. The small size nanoparticles, of such nanotechnology compounds, can deeply penetrate into the wood, effectively alter its surface chemistry and result in a high protection against moisture. Nanoparticles actively repel water, blocking the decay of the wooden surfaces and eliminate the greening and mould that grows on surfaces, where rain and water leave their marks.

Nanotechnology treatments to impart wood hydrophobility

The potential of reducing the hygroscopicity of solid wood by applying a new nanotechnology compound has also being investigated; for instance, the application a new compound, namely SurfaPore W, an aqueous wood-water repellent reduced the total sorption by 26.5% at saturation. The same compound was applied on commercial wood-based panels and repellent resulted in a large improvement in the thickness swelling of the panels.

It appears therefore that nanotechnology compounds may be an option to reduce the hygroscopicity of solid wood and the thickness swelling of the wood based panels. In general, nanocompounds do not contain any preservatives or other hazardous solvents and can be applied as a primer before the application of varnish or any other coating.

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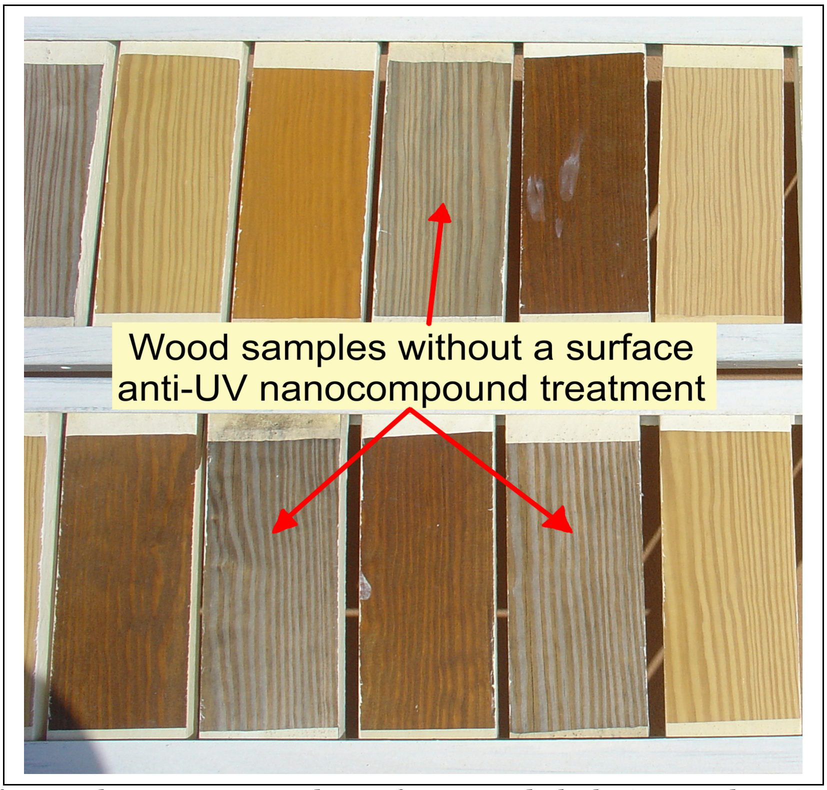
Characteristic appearance of a hydrophobic nano-treated wood surface (courtesy of NanoPhos SA, Greece)



Color differences between untreated & surface treated Black pine wood specimens using new anti-UV nanocompounds (courtesy of G. Mantanis, TEI of Larissa, Greece)