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Emerging Trends in Wood Science through the Intervention of Nanotechnology

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Introduction

Nanotechnology is science, engineering and technology transmitted at the nanoscale which is about 1 to 100 nanometers through precisely manipulating atoms and molecules for fabrication of macroscale products. Nanotechnology is one of the recent impressive wood protective technologies that can mount the way for new economic development for the application of wood in adverse environments by integrating smart materials to the traditional wood modification techniques (Evans *et al.* 2008). Where, wood science focuses on timber and various effects bearing on the quality of the physical, chemical and anatomical qualities of wood. Wood is obtained from the trees on the earth. Wood is secondary xylem produced by the division of vascular cambium. Structurally and chemically, this is based on the formation process of wooden cells by combining separate distinguishable layers *i.e.* middle lamella, primary wall and secondary cell wall (S_1, S_2, S_3) layers. Cell wall layers are composed from three main chemical components *viz.* cellulose, hemicellulose and lignin. A complex entanglement of cellulose fibrils, surrounded by a soft matrix of hemicelluloses and lignin in combination with the extractives are composed wood and all attributing to the physical and chemical properties of wood. Wood is characterized by its density, thermal conductivity, strength and elasticity, corrosion and fatigue resistance and insulating properties (heat, sound, electricity). However, there are several limitations of wood such as flammability, expressed

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hydroscopic behavior, dimensional changes and bio-degradation. There are various uses of wood directly or indirectly for human being. In the climate change era, the one use of wood is consider as carbon store house through CO_2 fixation in the xylem during wood formation and prevented for a certain time from being discharged into the atmosphere. Therefore, it is necessary to increase the life of produced wood through new technological tools. Furthermore, the physical, mechanical and chemical property should be increased for longer time. Since, recent trends in wood science emerged through the application of nanoparticles on/in wood modification. Wood modification includes approaches that have a concentrate on the surface of wood, like in-situ growth of nanoparticles and impregnation of nanoparticles or nanoemulsions. The metal oxide nanoparticles from zinc, zirconium, cerium, titanium, aluminum, indium and tin and mixtures thence are applied on products of high commercial importance. The prerequisite for a successful wood modification consists in the improvement of the existing properties, delivering an advanced material which doesn't result in bigger environmental hazard (Fufa & Hovde 2010) at the ending of the life cycle than the unmodified wood. Thus, the current trends on nanoparticles utilization techniques developed for wood protection treatments.

Classification of Wood Treatments Based on Nanoparticle Application

Nanoemulsions and suspensions are most applied on bulk wood modification treatments, while growth of nanorods and nanoparticles are more targeted on wood surface modification methods (Mishra et al. 2018). Various methods of wood treatment are classified as following:

1. Coating Treatments

- **Scratch Resistant Surface Coating:** Surface scratch resistance is a required property of wood synthesized nanoparticles added to coatings or in-situ synthesis methods. Both type and concentration of nanoparticles affect the viscosity, flexibility, mechanical properties and haze of the coatings. For example, ceramic nanoparticles have notably increased the scratch resistance. The various types nanoparticles was used for coating such as spherical metal oxide, carbon nanotubes, oxide of Si, Al, Ti, Zr and mixture, ceramic or TiO_2, SiO_2, nano- alumina, nano-silica. In general, scratch resistance ascribed by coating treatments is a notable area of current research aiming on the best possible result but also with lesser hazards to health and environment.

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- **Antimicrobial Surface Coating:** The water wetting of surfaces results in the retention of water droplets on the surface and triggers wood degradation and infestation with microorganisms or growth of algae, fungi, lichen, mosses, bacteria etc. A range of organic, photocatalytic and silver ion antimicrobial agents has been used for coatings. The list of agents with antimicrobial effect contains silver nanoparticle (Ag), combinations of metal ions and metal nanoparticles (TiO_2, Ag), as well as combinations and photocatalytic agents (Ti, Zr, Mo, Nb, Hf, oxides, TiO_2, Ag, ZnO). The organic antibacterial agents do not meet the environmental requirements, since they are toxic and prone to drug resistant microorganisms.
- **Super-Hydrophobic and Self-Cleaning Surface Coating:** Super-hydrophobicity (lotus effect) of a surface results in a particularly easy dripping or rolling-off of water stagnating on the surface. A photocatalytic agent as active component (oxide of titanium, zinc, iron, manganese, molybdenum and tungsten) is commonly used to achieve a self-cleaning surface on wood.
- **Formaldehyde and VOCs (Volatile Organic Components) Emission Decrease Coating:** All types of wood-based panels (particleboards, fiberboards, plywood and oriented strand boards) are usually tied with formaldehyde-based containing adhesives. Formaldehyde is soluble in ethanol and water with melting point at -92°C and boiling point at -21°C. However, inhaled amounts of formaldehyde have been accused of causing severe health effects such as chronic poisoning, mucosal congestion, skin irritation, genotoxicity, carcinogenicity, allergic dermatitis *etc*.
- **UV Radiation Protective Coating**: UV radiation absorptive coatings are used to prevent lignin degradation by UV light. In wood coatings, organic absorbers and many inorganic absorbers have been used comprised mainly by titanium and ZnO particles. However, both compounds are photocatalytic in nature which renders them rather unsafe in case of degradation of coating matrix.

2. Wood Modification

- **Surface Modification:** Wood surface contains a large number of hydroxyl groups getting receptive to the growth of surface nanomoieties. This allows the development of various techniques for wood surface modification by nanoparticles such as sol gel method, in-situ synthesis, injection filling method, hydro-thermal synthesis method,

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chemical vapor deposition and vacuum ion sputtering based on ZnO nanoparticles loading.

- **Bulk Wood Modification (Impregnation):** Wood impregnating formulation mainly concentrated on flame retardancy includes $CaCO_3$, nanosilica and nano-TiO_2, nano-tourmaline and nano-$SnCl_2$. In common, hydrophobizing wood by applying nano-emulsions or CeO_2 based formulations.

Advantages of Nanotechnology in Wood Formulation

- Retains the quality of timber Surface
- Coats, penetrates and protects porous timber surfaces
- Water repellent (hydrophobic) and Dirt repellent (oleophobic) properties
- Significantly reduces timber surfaces from weathering
- Resistance against UV incision
- Simply wash off contaminants (including grease and oil)
- The water rolls-off the surface forming a Self-Cleaning Effect
- Long lasting protection for timber surfaces against dirt, grease, oil, moss, fungus, algae *etc*
- Low cleaning and maintenance cost
- Ecologically beneficial and biologically safe
- Stablibity at varying temperatures

Limitations of Nanotechnology in Wood Formulation

Different wood treatment methods that have been developed to protect wood offer new opportunities as well as new problems in wood used as building and construction material as follows:

- The potential health, environmental and safety risks of nanomaterials
- Ageing effect and colour change such as UV exposure and thermal stress
- Some adverse toxicological effect on health

Conclusion

The drawback of timber was noticed that important wood properties such as durability, surface colour and hardness were less efficient of underutilized timber species. Now, these can be modified in order to assure more efficient utilization through intervention of nanotechnology in wood science. Dimensional instability, biodegradability, flammability, degradation and

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ultraviolet radiation can be prevented by cell wall chemistry (wood) modification, although nanotechnology has accosted various hazardous issues on health and environment. Intensive research and technology development should be necessary to avoid such negative impacts in such a way for more ecofriendly wood products.

Future Prospects

Presently, two main trends have been practically followed *viz.* modifying and coatings of nanoparticles practiced on wood. There is huge demand such nanoparticled wood in present scenario and will be vast industry growth in this area near future.

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