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Concept Paper

Scope of nanotechnology in forest product industry

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ABSTRACT

Along with the development of new products, research and development in the forest product industries are approaching new heights. A closer look into such technologies has been made in this review with special emphasis on the nanotechnology. Nanotechnology can transform the forest products industry in virtually all aspects ranging from production of raw materials, to new applications for composite and paper products and to new generations of functional nanoscale lignocelluloses. Continued research and development on forest product is essential for product property improvement that will meet future needs and provide products at reasonable costs.

Keywords: Nanotechnology; forest product; industry; product; uses

INTRODUCTION

The term nanotechnology was defined 1974 by Taniguchi (1974). Nanotechnology mainly consists of processing, separation, consolidation and deformation of materials by one atom or by one molecule. The prefix 'nano' is used in science to mean one billionth; a nanometer for example is one-billionth of a meter (www.ultraspray.com). For instance at nanoscale opaque substances become transparent (copper); solids turn into liquids at room temperature (gold); insulators become conductors (silicon). Much of the fascination with nanotechnology stems from these unique quantum and surface phenomena that matter exhibits at the nanoscale. There are several processes to create nanomaterials classified as top-down and bottom-up. In the bottom-up approach materials and devices are built from molecular components which assemble themselves chemically by principles of molecular recognition. In the top-down approach nano-objects are constructed from larger entities without atomic level control (Rodgers 2006). The properties of nanomaterials are different at the nanoscale for two main reasons viz with surface-area effects; quantum effects can begin to dominate the properties of matter as size is reduced to the nanoscale. These can affect the optical, electrical and magnetic behaviour of materials particularly as the structure or particle size approaches the smaller end of the nanoscale (Joshi 2010). Thus the nanoparticles have a much greater surface area per unit mass compared to larger particles. As growth and catalytic chemical reactions occur at surfaces this means that a given mass of material in nanoparticulate form will be much more reactive than the same mass of material made up of larger particles (Avadhanulu and Kshirsagar 2012).

Recent findings suggest that it may be possible to repair recovered fibres through the addition of nanoparticles to damaged surfaces of wood fibres (Eadula et al 2006). This raises the possibility that someday it may be possible to reuse fibres indefinitely.

Potential uses for nanotechnology in forest product industry

Significant improvements in surface properties and functionality will be possible making existing products much more effective and enabling the development of many more new products (Anon 2005). Some of the achievements or developments of nanotechnology with reference to the forest product industries are as under:

Wood seasoning: Hardwoods that are difficult to dry without incurring degrade might for example be made easier to dry through insertion of nanoparticles into the wood structure to facilitate moisture movement while at the same time eliminating collapse or preventing surface checking with moisture loss. Similar treatments might also be used to prevent readsorption of moisture by wood once it has been dried or to avoid undesirable migration of extractives to wood surfaces or fading with exposure to ultraviolet light (Bowyer et al 2006).

Carbon nanotubes (CNTs) composites: Carbon nanotubes (CNTs) were first observed by Sumio Iijima in 1991 (Iijima 2007). CNTs are allotropes of carbon with a cylindrical nanostructure. These cylindrical carbon molecules have unusual properties, which are valuable for nanotechnology, electronics, optics and other fields of material science and technology. Owing to the material's exceptional strength and stiffness, nanotubes have been constructed with length-to-diameter ratio of up to 132000000:1 significantly larger than for any other material (Wang et al 2009). In addition owing to their extraordinary thermal conductivity and mechanical and electrical properties carbon nanotubes find applications as additives to various structural materials.

Wood protection: Nanowood is a multifunctional water-based silane system for unvarnished wooden surfaces. It adds hydrophobic and oleophobic properties for plain wood or stained coloured wood. Contrary to alkoxysilanes-based coatings nanowood doesn't release alcohols or volatile organic compounds (VOCs) during application due to hydrolysis. Nanowood creates highly dense cross-linked networks bonded chemically to the substrate. It provides efficient and strong protection against weathering, microorganisms, soil and moisture. Low energy surface is achieved and protection lasts up to 4 years. Nanowood can be painted, sprayed and rolled or in case of smaller objects they can be sunk into solution. Product is environmentally friendly (http://www.nanoprotect.co.uk/wood-protection.html).

Paints : Incorporating nanoparticles in paints could improve their performance for example by making them lighter and giving them different properties. Thinner paint coatings (lightweighting) used for example on aircraft would reduce their weight which could be beneficial to the environment. However the whole life cycle of the aircraft needs to be considered before overall benefits can be claimed. It may also be possible to substantially reduce solvent content of paints with resulting environmental benefits. New types of foulingresistant marine paint could be developed and are urgently needed as alternatives to tributyl tin (TBT), now that the ecological impacts of TBT have been recognised. Anti-fouling surface treatment is also valuable in process applications such as heat exchange where it could lead to energy savings. If they can be produced at sufficiently low cost fouling-resistant coatings could be used in routine duties such as piping for domestic and industrial water systems. It remains speculation whether very effective anti-fouling coatings could reduce the use of biocides including chlorine. Other novel and more long-term applications for nanoparticles might lie in paints that change colour in response to change in temperature or chemical environment or paints that have reduced infra-red absorptivity and so reduce heat loss.

Concerns about the health and environmental impacts of nanoparticles may require the need for the durability and abrasion behaviour of nanoengineered paints and coatings to be addressed so that abrasion products take the form of coarse or microscopic agglomerates rather than individual nanoparticles (http://www.nanowerk.com/nanotechnology-applications.php).

Coatings and surfaces: Recently developed applications include the self-cleaning window which is coated in highly activated titanium dioxide, engineered to be highly hydrophobic (water repellent) and antibacterial and coatings based on nanoparticulate oxides that catalytically destroy chemical agents. A range of enhanced textiles such as breathable, waterproof and stain resistant fabrics have been enabled by the improved control of porosity at the nanoscale and surface roughness in a variety of polymers and inorganics (Thomas et al 2015).

Protection against ultra violet (UV) radiation: The use of nanotechnology is a real innovation in the development of wood coatings particularly in relation to UV absorption and penetration. Nanovations have introduced a new VOC-free technology for clear impregnating wood protection (http://www.nanowerk.com/products/product.php?id=95).

The coating also offers excellent stain resistance and is easy to clean and to maintain. Its extremely high coverage rate makes it one of the most competitive products in the market. The small size of the particles makes it possible to offer high protection without affecting the transparency of the impregnation. These products are most interesting in harsh outdoor environments (https://www.scribd.com/document/156388724/What-is-Nanopaint).

Scratching the surface: Nissan Motor Company lays claim to development of the first clear paint for automobiles that repairs scratches on its own (http://www.nissan-global.com/EN/TECHNOLOGY/OVERVIEW/scratch.html). Scratch guard coat contains a high-elastic resin that also helps prevent scratches in the first place. This type of coatings can also be coated over the wood where there is high wear and tear and to the decorative things which are made up of woods (http://findarticles.com/p/articles/mi_qa5350/is_200611/ai_n21405823/).

Applications in mechanical properties: Wimmer and Lucas (1997) and Wimmer et al (1997) conducted nanoindentation on red spruce latewood and found that the average S_2 elastic modulus was nearly twice that of the middle lamella while the average hardness for S_2 was about 10 per cent larger than that of the middle lamella. They showed that the nanoindentation is sensitive enough to measure differences between mechanical properties of different cell wall layers.

Gindl and Gupta (2002) completed nanoindentation on the S_2 layer of transverse section of Norway spruce woodcells in which lignin content in the mature woodcells was twice that in the immature cell. The study found that for the mature woodcell the elastic modulus was 22 per cent higher and the hardness was 26 per cent higher than that of immature wood cell. The results showed that degree of lignification will alter mechanical property of cellwalls.

Risks and unknowns

One of the characteristics of operating at the nanoscale is that the materials can behave very differently. These changed and new behaviours can lead to incredible opportunities for innovation and creation. However these changed behaviours may also have unintended consequences and how these changed behaviours will interact with the environment including the human body is not entirely understood. Concerns about the potential risks and unknowns of nanotechnology have been raised primarily in connection with medical applications but all industries exploring the use of this technology will likely need to research risk factors as well as the potential benefits (https://www.nano.gov/nanotech-101/special).

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