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Future of Transparent Wood: A Preliminary Review

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Abstract

The wood has unique structure and excellent mechanical properties. Wood is important natural source for human civilization. Wood is anisotropy structure. Wood was the important material and natural resource in human civilization. Wood is widely used in many sectors such as building, fuel, tools and other. In the ancient, wood played an important role in human cultural, economic, act and building. As a natural and sustainable material, wood has excellent mechanical properties cause by unique structures relative to its cost. Wood due to its natural growth can define as renewable and sustainable material. Due to the hierarchical and anisotropy structure, wood have properties of high strength, good durability, high moisture content and high strength. Wood is porous and fibrous structural tissue of wood. Roots and stems of wood made by natural cellulose fibres growing upward all the way to the top of canopy. This paper will present a preliminary review about the future of transparent wood.

1. Introduction

Wood is classified into two types: soft wood and hard wood. Hardwood, unlike softwood, has a higher density and denser structure [1]. Hardwood takes longer to mature and has a more streamlined, intricate structure. Table 1 shows the type of softwoods and hardwoods. Softwood has a more porous structure while hardwood has a denser structure and high density [2]. Typical softwoods used in woodworking, construction and furniture are Pine, Douglas Fir, Spruce, and Redwood. Hardwoods are generally stronger than softwoods. It's highly durable caused by large porous cells. It has a long lifespan due to large porous cells. Hardwoods take a longer time to grow, which is why they are more expensive than softwoods. Eucalyptus, Balsa, Mahogany, Blackbutt, and Red Ironbark are examples of hardwood. Commonly hardwood is more robust but has exceptions; Balsa wood is a type of hardwood but extremely low density compared to other species hardwood [4]

Table 1 *Different type of softwoods and hardwoods [12]*

Softwoods	Hardwoods
Douglas fir	Basswood
Southern pine	Willow
Western larch	American Elm
Hemlock	Mahogany
White fir	Sweet gum
Spruce	White ash
Ponderosa Pine	Beech
Western red cedar	Birch
Redwood	Cheery
Cypress	Maple
White pine	Oak
Sugar pine	Walnut

1.1 The Components of Wood

The components of a wood cell are cellulose, hemicellulose, and lignin. Fig. 1 shows the structure of a wood cell. Celluloses are contributed 40-45% of wood's dry weight. It is the main component in wood. It's a high-molecular-weight linear polymer made up of chains of one to four glucose monomers linked together. The cellulose molecules in the tree's cell wall are organised into fibrils, which are then organised into the larger structural elements that make up the cell wall of wood fibres. Cellulose acts as glue to glued hemicellulose and lignin. Hemicelluloses are polysaccharides related to cellulose. Lignin accounts for 25% of the wood structure. The main function of lignin is to act as glue to bond all the wood cells together and provide hardness and rigidity to the wood [5- 6]. Lignin also transports water and other ingredients in xylem tissues to meet the need for photosynthesis.

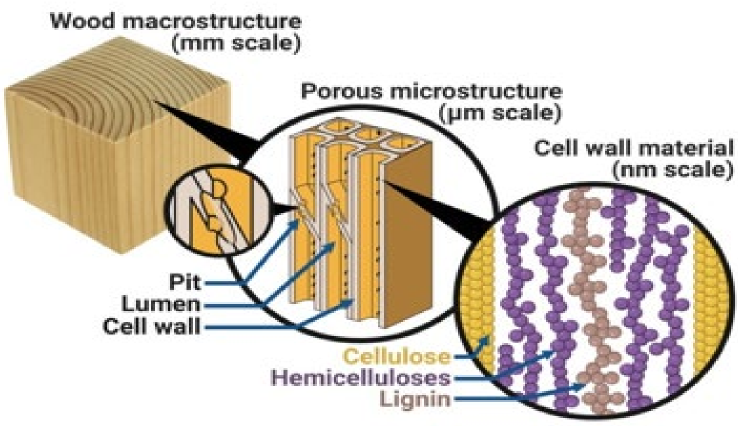

Fig. 1 *The wood cell structure [11]*

2. Introduction of Lignin

Lignin is one of the main components of the wood. Lignin is a class of complex organic nature polymer found in the structure tissues of plants or tree (Kai et al., 2018). It is naturally constituted of three phenylpropane units. Lignin is a group of poly-phenolics such as methoxy (CH3O), carboxyl (COOH) and carbonyl (C==O). Fig. 2 shows the chemical structure of lignin. Lignin is the major source of phenolic compounds on Earth and the second most abundant macromolecule group after cellulose (Tribot et al., 2019). Lignin is one of the main components of wood cells. Lignin is an opaque organic polymer that cause brown wood colour. Lignin is one of the factors of hierarchical of wood.

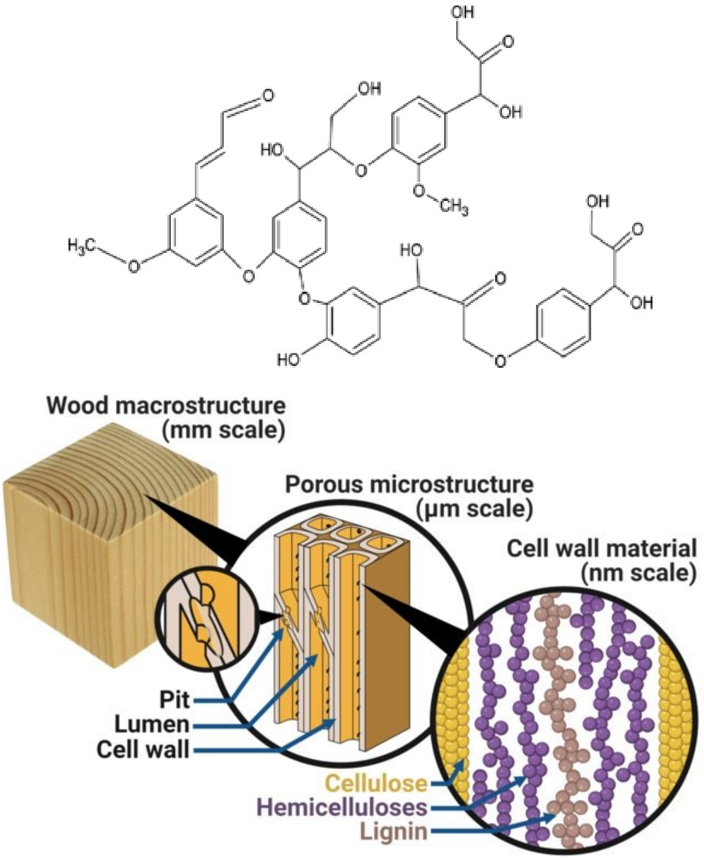

Fig. 2 *The chemical structure of lignin [7]*

2.1 Function of Lignin

Function of lignin in wood is transport the nutrient and liquid from root through the plant. Lignin provides the excellent strengthening structure of wood. The intramolecular hydrogen bonding between cellulose microfibers was enhanced to form higher stiffness structure that prevent cells to collapse. For transport liquid and nutrient, lignin is waterproof the cell walls. Lignin provides protection for the plant against biological stresses by inhibiting enzymatic degradation [7]. Balsa wood is one of the lowest densities of hardwood and fastest growing wood species. It is distributed at Tropical South and Central America. Balsa wood's density is in the range around 100 and 250 kg/m3 [8]. Because the property of low density of the balsa wood. It was the preferred main materials on the application of the wind turbine, boat, sporting, and others.

3. Transparent Wood

Transparent wood is a new type of transparent composite material. Transparent wood is a type of material fabricated by delignified wood infiltrated with polymer. Transparent wood was first prepared with preserved structures, for the purpose of wood morphology studies. Transparent wood has excellent mechanical and optical properties. It causes potential material for engineering and building. Fabrication transparent wood is removing the opaque lignin from wood then impregnating refractive index match polymers. While cellulose and hemicellulose are optically colourless, transparent wood was preserved cellulose and hemicellulose. A potential candidate material for light transmitting building materials and transparent solar cell windows is fabricated transparent wood with high transmittance and improved mechanical properties [9]. To fabricate transparent wood, need to remove light-absorbing lignin. Because of the redesign of wood, the hierarchical structure of wood is destroyed or altered. The structure of wood become weaken and is hard to work with fragile material. To resolve this problem, infilter index matched epoxy resin into wood to replace the position of lignin. Using Index matched polymer to minimize light absorption and scattering [8]. The type of polymer selected requires approach refractive index of delignified wood. Followed by the properties of transparent wood required, the hardness and tensile strength of polymers is one of the factors considered. Transparent woods have potential application at several sector of area such as intelligent building, solar cell, electronics, drug delivery, heat shielding, thermal energy storage and others. Because of the properties of transparent wood, it can be used as new alternate building material for roots and window to supply a light space. To reduce electricity in buildings and use environmentally friendly materials to replace convention glass. Transparent woods have lower thermal conductive and thermal expansion than common glasses. Basis on by polymer used, flexible transparent wood is enabled fabricate. Flexible transparent woods are application on flexible electronics, solar cells furniture and furniture [9-12].

3.1 Tensile Test of Wood

Tensile test is the type of testing used to measure the strength of the specimen. Tensile test is measured several properties such as ultimate tensile strength, maximum elongation, and reduction in area to determined Young Modulus, Poisson ratio, yield strength and strain- hardening characteristic. It is common mechanical testing techniques to test the material is how much can be stretched before specimen breaks. Young Modulus is measuring the ability of a material to withstand changes in length when under lengthwise tension or compression. It is defined as the ratio of tensile stress, σ to tensile strain, ε . The ultimate tensile strength is the maximum stress to which a test subject is exposed. Depending on whether the specimen is brittle, ductile, or has characteristics of both, this might not be the same as its breaking strength.

3.2 Polymer-Plastic

Polymers are the type of natural and synthetic material made up of macro-molecules, a composition of large molecules the macro-molecules are formed after numerous units of monomers or simpler chemical units are combined. The common type of polymers has three types: thermoplastics, thermosetting plastics, and elastomers. Thermoplastics easily transform to the shape by given heating then hardened when cooled back. It which why thermoplastics can be recycle compared to others type of plastics. Thermosetting plastics will not deform when heating, cause by the cross- linked structure. It is harder and brittle than thermoplastics.

3.3 Epoxy Resin

Epoxy resins are a type of step-growth polymerization reaction that consists of two main components: a fluid prepolymer chain with reactive epoxide groups on both ends and a hardener [13-16]. Fig. 3 shows the epoxy group structure. Epoxy resins are one type of thermosetting polymer with a wide range of application in various sectors. The commonly used epoxy monomer also called Bisphenol A diglyceryl ether (DFEBA) is prepared by bisphenol A and epichlorohydrin in alkaline medium. Fig. 4 shows the chemical formula of DFEBA epoxy resin.

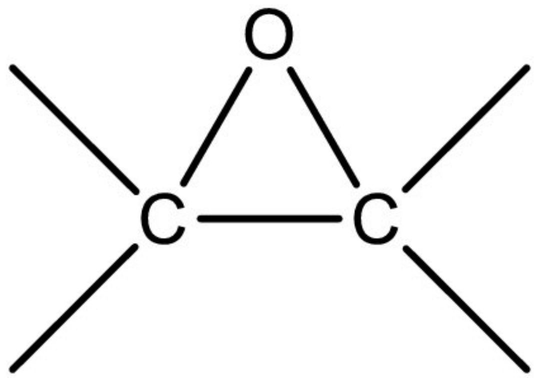

Fig. 3 *Epoxy group structure [10]*

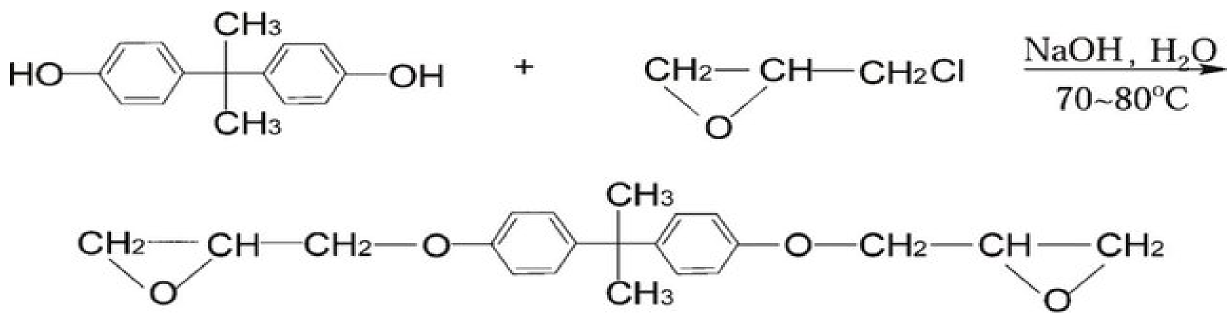

Fig. 4 *The chemical formula of DFEBA epoxy resin [13]*

Epoxy resin has excellent properties such as heat resistance, low shrinkage, water resistance, electrical insulation, high chemical resistance, and mechanical properties. Epoxy resin has wide range of application in industries sector. For example: paint and coating, adhesives, food packaging, semiconductor encapsulants and art.

4. Conclusion

Ultraviolet resistance states the ability of material to endure the degradation caused by exposure to ultraviolet (UV) light or sunlight. UV light will cause non-resistance material to fade or discolour. For example, if the polymer has low resistance, it will because of degradation cause the premature or unintended failure. It happens often on polymer because polymer is exhibiting covalent bond. Covalent bond is a type of bond sharing of electrons between two or more atoms. Covalent bond is relatively weaker than metallic and ionic bond. Hence, most polymers are susceptible to degradation by UV exposure. UV light is high energy photons that have enough energy absorbed by electrons to higher energy levels. UV degradation of polymer is called chain scission by photolysis. The physical properties of polymers as such strength and ductility will be affected by degradation. UV resistance enables increase by mixing or coating UV absorbers material to reduce the damage of UV light.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

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