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Review Article

Evaluation of Eco-Friendly Nanomaterial Modified Water-Based Varnish Systems

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Abstract: Nanotechnology is science, engineering and technology carried out at the nano level with matter with at least one dimension between 1-100 nm in size controlled at different levels. Today, nanotechnology has very important applications in the forest products sector. One of these applications is for the modification and improvement of materials such as paints/varnishes, glues, etc. used in the relevant sector. In this context, it is important to modify and develop water-based systems that cause the least harm to human and environmental health. In recent years, many studies have been carried out to modify and improve water-based systems with organic and inorganic nanomaterials. Studies carried out with nanocellulose, which is environmentally and human friendly, which will minimize the harm of water-based varnish systems to human and environmental health, are of particular importance. The aim of this study is to review the academic studies on water-based varnishes modified with nanocellulose, an environmentally friendly nanomaterial, and to present and discuss the important results obtained and to develop various suggestions. As a result of the studies examined; it was observed that nanocellulose and its derivatives improve the optical, surface, physical and mechanical properties of water-based systems in wood materials from layer properties, and make them resistant to the effects of chemicals and aging.

Keywords: Water-based varnish; nanocellulose; nanotechnology; wood materials; environment and human health

Çevre Dostu Nanomalzeme Modifiyeli Su Bazlı Vernik Sistemlerinin Değerlendirilmesi

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Öz: Nanoteknoloji, en az bir boyutu 1-100 nm arasında olan ve farklı seviyelerde kontrol edilen madde ile nano seviyede yürütülen bilim, mühendislik ve teknolojidir. Günümüzde nanoteknoloji alanında orman ürünleri sektöründe çok önemli uygulamalar görülmektedir. Bu uygulamalardan biri ilgili sektörde kullanılan boya/vernik, tutkal vb. malzemelerin modifikasyonuna ve geliştirilmesine yöneliktir. Bu kapsamda insan ve çevre sağlığına en az zararı veren su bazlı sistemlerin modifiye edilmesi ve geliştirilmesi önem arz etmektedir. Son yıllarda organik ve inorganik nanomalzemeler ile su bazlı sistemlerin modifiye edilmesi ve geliştirilmesine yönelik birçok çalışma yapılmaktadır. Su bazlı vernik sistemlerinin insan ve çevre sağlığına zararını minimum düzeyde tutacak olan çevre ve insan dostu olan nanoselüloz ile yürütülen çalışmalar ayrı bir öneme sahiptir. Bu çalışmanın amacı, çevre dostu bir nanomalzeme olan nanoselüloz ile modifiye edilmiş su bazlı vernikler ile ilgili yapılmış akademik çalışmaların incelenerek, elde edilen önemli sonuçların ortaya konması ve tartışılması ile çeşitli önerilerin geliştirilmesidir. İncelenen çalışmalar sonucunda; nanoselüloz ve türevlerinin su bazlı sistemlerin ağaç malzemelerde katman özelliklerinden optik, yüzey, fiziksel ve mekanik özelliklerini geliştirdiği, kimyasalların ve yaşlandırma etkilerine karşı dayanıklı hale getirdiği görülmüştür.

Anahtar Kelimeler: Su bazlı vernik; nanoselüloz; nanoteknoloji; ağaç malzeme; çevre ve insan sağlığı

1. Introduction

Nanotechnology refers to the understanding, processing, control and characterization of matter at the nanometer scale (1-100 nanometers) [1], [2]. The goal of nanotechnology is to create new products from existing materials using new production processes. This means innovation in materials and production methods using atoms and their strings, as well as the emergence of new, higher quality products that can meet consumer demands [2], [3].

Today, products produced with innovative, various nanomaterials and nanotechnology are being used and developed for today's and future needs, moving away from the traditional production approach. While the reduction in material dimensions provides us with convenience and flexibility in production and design, it increases the cost of the work. Various experiments and projects are being carried out in many different fields to produce eco-friendly and renewable materials with nanotechnology. At the same time, the sustainability and environmental awareness of societies is increasing day by day. In this context, R&D and P&D studies on nanomaterials, production with nanomaterials, modification of various products with nanomaterials are carried out both in our country and in the world [2], [4]-[6].

Some of the most important developments in nanotechnology occur between biological and inorganic systems. One of the aims of the new branch of chemistry known as "nanotechnology" is to improve macro-structured materials with nano-structured materials. Wood material is considered a natural nanostructured composite material due to its anatomical properties and especially its main components cellulose, hemicellulose and lignin. Natural nanocomposites derived from forest products offer important applications in nanotechnology. Nanotechnology can be used to protect the wood material from degradation when exposed to UV light, moisture and bio-organisms, while increasing its durability and strength. In recent years, nano materials have been used in new architectures and restoration works. It is also used in the modification and development of materials such as paints/varnishes, glues, etc., which are widely used in the forest products and furniture industry [5], [7]- [10].

In this context, wood material as a natural nanocomposite can potentially offer important applications in the field of nanotechnology. With nano-structured coatings, it is possible to give wood materials surface functionality such as self-cleaning, photocatalysis, water resistance, fire resistance, hardness, scratch resistance and antibacterial properties, as well as outdoor weather resistance, long-term durability and good adhesion resistance [5], [10], [11].

Today, solvents are used as solver in paint/varnish production. In many European countries, the use of solvents has started to decrease as the importance given to environmental protection and human health has increased. Increased challenges to these issues and legislation to help resolve them have increased the use of water-soluble polymers in paint/varnish production. Water-based varnishes are environmentally friendly varnishes as they contain low VOCs (volatile organic compounds). In a globalizing world, paint demand is increasingly trending towards place, more complex and more specialized projects. For this reason, it is stated that water-based and highly additive paint/varnish types are prioritized in R&D studies [12]- [17]. Since nanomaterials have high yields compared to micrometric particles, they are a viable way to improve the durability of waterborne coatings [2].

In recent years, nanocellulose varieties obtained by reducing the fibers of cellulose, which is one of the most important elements of plants, bacteria and algae, to nano-sizes have been studied in the modification of water-based varnishes and the improvement of their properties. The aim of this study is to examine the academic studies on water-based varnishes modified with nanocellulose, an eco-friendly nanomaterial, to reveal and discuss the important results obtained and to develop various suggestions.

2. What is Water Based System and Nanocellulose?

2.1. Water Based System

The fact that the production, consumption and utilization of water-based systems have been increasing at a rate well above average in recent years is due to the ability to produce resins with different properties used in the production of water-based systems. The wide variety of binder resins that allow water-based systems to be formulated has enabled them

to develop more rapidly than other environmentally friendly systems. Water-based paint/varnish is a type of paint/varnish produced from alkyd, polyester, epoxy, acrylic, polyurethane and many other resins [2], [12], [14], [15], [18].

Water-based paint/varnish systems have been known and used for many years. It has been used in the construction industry for a long time and has a wide range of applications. Waterborne systems were introduced late in the wood industry and became widespread late. The reason for this is that the water-based system causes texture and fiber blistering in wood materials and the maintenance difficulties of the system [12]. Today, many of the disadvantages of water-based systems in application and use have been overcome by nanotechnology. With nanotechnology and nanomaterials, many functions such as flame retardancy, antimicrobial properties, self-cleaning with UV light or sunlight, scratch resistance, abrasion resistance, corrosion resistance, sound insulation, high resistance to corrosion and external factors, resistance to sunlight, easy cleaning can be provided together or separately in the paint and coating sector. Thus, nano-structured water-based systems have started to be used in many areas. Nanotechnological acrylic modified polyurethane, hybrid, polyurethane, advanced acrylic, ultra-fast oxygen reacted polyurethane and their derivatives, single and two-component water-based paints/varnishes have started to be used in many materials such as wood, aluminum, PVC, etc. in space technology, architecture and military fields. These paints are shown as the paint technology of the future because they have very low VOCs values. They contain no HAPs (Hazardous Air Pollutants) and POPs (Persistent Organic Pollutants) along with low VOCs. Water-based rocket paints, aircraft and radome paints, unprimed aluminum paints, PVC paints, galvanized paints, aircraft attack edge paints, paints applied directly on rust, military camouflage paints, anti-static, anti-microbial, anti-graffiti paints, ultra-matt or ultra-glossy, transparent or colored paint / varnish types in wood are examples of nano water-based system products. Since nanotechnological paints/varnishes have excellent water vapor permeability in wood materials, they do not warp and on-site painting and maintenance is also possible [2], [19], [20].

2.2. Nanocellulose

Cellulose is a renewable, biodegradable, non-toxic, organic (carbohydrate) polymer found in the cell structure (cell walls) of plants, abundant and easily found in many plants, especially wood materials. Nanocellulose refers to cellulose fibers or particles (with at least one dimension (1-100 nm)) that are fragmented down to the nanometer scale and is a biopolymer. Nanocellulose is produced in three main types: nanocrystalline cellulose (NCC), microfibrillated cellulose (MFC) and bacterial nanocellulose (BNC). The size of the product resulting from production may vary in terms of the source of production and its characteristics. In general, they are used in many different ways in many fields due to their many superior properties such as advanced mechanical properties, increased specific high surface area, high aspect ratio, unique optical and barrier properties, flexibility, viscosity [5], [6], [21]-[25].

3. Results of Some Recent Studies on Water-based Varnish and Nanocellulose

In this section, recent studies on the modification of water-based varnishes with nanocellulose and its derivatives are presented. It is aimed to shed light on what can happen in the near future with eco-friendly nanomaterials in the eco-friendly water-based varnish system.

Tamantini et al. [26], modified commercial water-based acrylic varnish with 2% gel nanocrystalline and different biocides in their study. They applied fungal, aging, physical and chemical tests to the varnish layers and compared them to the control groups. As a result of the study, it was stated that the nanocrystal decreased the viscosity of the varnish, increased its permeability and this decreased the adhesion strength of the varnish. They found that the nanocrystal increased the hydrophobicity, scratch resistance, gloss, resistance to artificial aging conditions and fungi of the varnish layer.

Hochmanska-Kaniewska et al. [27], modified commercial water-based acrylic varnish with nanocrystalline at 1%, 3% and 5% by weight in their study. They found that varnish layers improved wear resistance, impact and gloss properties.

Naide et al. [28], modified water-based marine varnish with bleached and unbleached microfibrillated celluloses. As a result of the tests, they reported improved performance of

the varnish layer. They found that especially unbleached microfibrillated cellulose increased the contact angle in wettability, 10% blend ratio did not cause a statistical difference in abrasion resistance and improved adhesion resistance.

Pacheco et al. [29], modified commercial acrylic water-based varnish with mixtures of different nanoparticles in different ratios with titanium dioxide, silica dioxide and nanocrystalline celluloses (ionic liquid NCC-IL and tempo oxidized TONCC) obtained from blueberry pruning waste. As a result of the study, optical and surface (color, gloss, roughness) and mechanical properties (adhesion strength, hardness, abrasion) of the varnish layers were improved. They also found that resistance to chemicals and aging conditions increased. It has been reported that these properties are improved especially in mixtures containing nanocellulose derivatives.

Vardanyan et al. [30], modified UV-water based varnishes with different dispersions of nanocrystalline cellulose and nanocrystalline cellulose. It was found that the nanocrystalline cellulose additive did not worsen the properties such as hardness, abrasion resistance, scratch resistance, adhesion resistance, on the contrary, it improved them and the quality of the distribution of nanocrystalline cellulose in the layer was increased with different dispersions, thus further improving the properties of the varnish layer.

Veigel et al. [31], modified water-based acrylate/polyurethane varnish with nanocrystalline cellulose (NCC) and microfibrillated cellulose (MFC). They found that the gloss of the varnish layers decreased depending on the surface roughness, nanocellulose increased the hardness, scratch resistance and adhesion resistance, while the abrasion resistance was not clear. They also stated that microfibrillated cellulose was more effective on these properties than nanocrystalline cellulose.

4. Conclusions

Water-based systems are the least harmful to the environment and human health as they contain low VOCs values and do not contain HAPs and POPs products. The disadvantages of these systems in application and end-use have been overcome with nanotechnology and are constantly evolving. The development of water-based systems needs to be done in the context of sustainability, environment and human health. In this direction, although inorganic nanomaterials are used today to improve the properties of paint / varnish layers, scientific studies and applications on nanocellulose and its derivatives, which is an organic nanomaterial, have attracted attention in recent years.

These studies reveal that water-based systems with minimal impact on the environment and human health can be developed with organic nanomaterials. Nanocellulose and its derivatives have been shown to improve the optical, surface, physical and mechanical properties of water-based systems from the layer properties of wood materials, making them resistant to the effects of chemicals and aging (external effects).

The field of nanotechnology and wood science is impressive and has a bright future. What is presented in this paper is a very brief overview of what will happen in the near future and is of great importance for water-based systems.

In new studies to be carried out worldwide, it is recommended to carry out studies on the change in layer properties, development and durability of nanocellulose and its derivatives to be obtained from different sources, with different dispersions, in different wood materials and in different water-based systems for future generations, environment and human health.

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