Research Article
Araştırma Makalesi
DOI: 10.24011/barofd.442707

Bartın Orman Fakultesi Dergisi,
20 (3): 503-508,
15 Aralık/December, 2018

Journal of Bartin Faculty of Forestry
p-ISSN :1302-0943
e-ISSN :1308-5875

Distribution of Nano Particles in the Wood Impregnated with Nano Scale Boron Nitride

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Abstract

Thermal stability is the one of the most important properties of wood and wood based materials. Many papers have been done to rise the thermal stability. Nanotechnology offers an important opportunity to improve the thermal stability that cannot be obtained with previous techniques. Homogenously distribution of nano fillers on the surface of the wood can provide an improvement on the thermal stability of wood. In this study, wood was impregnated with nano-sized boron nitride (BN) with a solution of 3% in a vessel which can be controlled the ratio of vacuum and pressure. SEM/EDX analysis of the impregnated samples was conducted to determine the distribution of nano particles. SEM images showed that some deposits of BN on the pits and the cell wall were found, but the BN deposits were only viewed until 10 mm deeply (samples are 30 mm thickness) under the surface.

Keywords: Boron nitride, wood materials, nano fillers, Impregnation, morphological analysis.

Nano ölçekte Bor Nitrürle Emprenyelenmiş Ahşapta Nano Partiküllerin Dağılımları

Öz

Termal kararlılık, ahşap ve ahşap esaslı materyallerin en önemli özelliklerinden biridir. Birçok çalışma termal kararlılığı iyileştirmek için yürütülmektedir. Nanoteknoloji, eski tekniklerle sağlanamayan termal kararlılığı artırmak için önemli bir fırsat sunmaktadır. Odun yüzeyinde nano partiküllerin homojen olarak dağılımları odunun termal kararlılığında iyileşme sağlayabilmektedir. Bu çalışmada; odun, vakum ve basınç oranları kontrol edilebilen bir kabin içerisinde %3lük bir nano boyutta bor nitrür (BN) çözeltiyle emprenye edilmiştir. Elde edilen emprenyelenmiş numunelerin SEM/EDX analizi nanopartiküllerin dağılımını belirlemek için yürütülmüştür. SEM resimleri, geçit ve hücre duvarları üzerinde bazı BN kalıntılarına rastlandığını göstermiştir. Fakat bu BN kalıntıları yüzeyin (örnekler 30 mm kalınlığındadır) 10 mm derinliğine kadar görüntülenebilmiştir.

Anahtar Kelimeler: Bor nitrür, ahşap materyal, Nano partikül, Emprenye, morfolojik analizi

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Geliş (Received) : 11.07.2018
Kabul (Accepted) : 19.07.2018
Basım (Published) : 15.12.2018

1. Introduction

The bio-based materials have many attractive features such as renewable, sustainable, environmentally friendly and. The shortage of petroleum and environmental concern has resulted in a considerable increase in the usage of renewable natural resources in recent years. The many technology for the lignocellulosic materials have been used to improve the material performance. Nanotechnology, which is the one of benefited technologies, is explained as the development that differ significantly from larger particles of application of materials using the same material, such as their interaction with particles under the size range of 100 nanometers (Afrouzi et al. 2013; Clausen 2007; Xia et al. 2008; Sozen et al., 2018).

In recent years, nanocomposites have attracted the attention of many researchers because of the significant enhancements in many features at low loadings (Aydemir et al. 2016). The new functions and properties can be provided with various nano particles such as ZnO, nanoclays, Nano-TiO_2, etc (Chang and Leung, 2008; Aydemir et al. 2016). Nano-particles of various materials such as ZnO, TiO_2, silver, etc. may possess the unique characteristics in the wood protection. But the dispersion of the particles on the wood surface must be homogenously provided (Habibzade et al. 2016; Aydemir et al. 2016). Some studies have conducted with various nano-particles, which is an effective and convenient way to increase material performance of wood. In one of the studies, Afrouzi et al. (2013) worked on outdoor performance with artificial weathering of the wood impregnated with nano-ZnO. The results showed that nano zinc oxide can be used as an important material, separated or combined with other materials in wood preservation in the external environment. Similar results were obtained by Can and Sivrikaya (2014). In another study, Akhtari and Arefkhani (2013) worked about characterization of wood treated with nano particle-impregnation solution after fungal treatment, and they provided some evidence that the treatment with nanoparticles such as nano-silver, nano-copper and nano-zinc oxide have positive effects on bio-resistance of Paulownia wood after fungal treatment. Akhtari et al. (2012) studied on characterization of Paulownia wood treated with nano particles such as silver, copper and zinc oxide. According to the results, the treatment with nano particles of the wood had no negative effect on flexural strength, flexural modulus and compressive strength. Generally, treatment with nano-particles such as copper resulted in the highest increase of mechanical properties. Only hardness was decreased by impregnation of nano-fluid. In another study, Habibade et al. (2016) studied on effects of treatment with fillers such as nano-ZnO and styrene on some properties of poplar wood. The results showed that nano-ZnO improved some thermal properties such as fire-retarding in the treated poplar wood. Kookandeh et al. (2014) studied on effects of the treatment with nano-ZnO on the some properties of heat-treated beech wood. The obtained results showed that treatment with ZnO resulted in a slight and significant increase in weight loss and biological resistance after fungal degradation, and the treatment of the nano-ZnO slightly improved the wood-water relationship of the treated wood. The treatment with nano-ZnO of wood showed an important effect on the properties of wood compared to that of un-treated wood. In a study, Aydemir et al. (2016) studied the changes in some properties of wood materials after nano-boron nitride (BN) impregnation of some wood materials. According to the results, the flexural strength and flexural modulus were found to generally increase with the impregnation of wood with BN. However, the treatment with BN of wood species generally decreased the compression strength. The results also showed that the changes in density and color properties after impregnation process were statistically important. Some white deposits of BN around the cell wall and the pits were viewed with scanning electron microscopy and EDAX. Degradation temperature in weight loss at 10% wt and 50% wt for BN-treated wood was determined to increase with the impregnation with BN. As results, some studies about the topic were conducted, but the studies on the dispersion of nano-particles inside wood material aren't enough. So, this paper was conducted on the dispersion of nanoboron nitride inside the wood materials with help scanning electron microscopy.

2. Material and Methods

Materials

In this study, three wood species such as Ash (*Fraxinus exelsior*), Iroco (*Chlorophora excelsa*), and Scots pine (*Pinus sylvestrist* L.) were used to better compare the changes in the properties of the woods. The wood materials were supplied from a firm operated on heat-treated wood products (NovaWood, Turkey). The obtained heat-treated and un-treated woods were dimensioned and conditioned with related Turkish Standards. The test samples were prepared as 2x2x3 cm for analysis of the scanning electron microscopy. Nano scale boron nitride (BN) used in the study was supplied from Boron Technologies (BOR-TEK, Turkey). The BN is a compound with boron and nitrogen. It has a hexagonal structure and a specific gravity of 2.27 g/cm^3. Average diameter and thickness of BN used was 200 nm and 80 nm (Ayrilmis et al. 2014).

Impregnation of Nanoboron nitride to Wood

The test samples were condition for a month at relative humidity of 60% and temperature of 20°C before impregnation process. The impregnation processes were conducted on the faultless test samples. The impregnation process was made in a cabin to be controlled all test conditions water according to the ASTM D-1413 (1976) standards. The impregnation solution was prepared with 3% wt. BN and distilled water. The test samples were impregnated in the cabin at 600 mm-Hg vacuum for 30 min and at a pressure of 0.6 MPa for 60 min according to Taghiyari et al. (2013)

Determination of the Dispersion of BN

The morphological characterization was conducted with scanning electron microscopy (SEM-EDX). The all surface of test samples were sputter-coated with gold (75%)-palladium (25%) blends using a Denton sputter coater for enhancedconductivity with coating machine. The distribution of BN nano particles in the wood materials were observed under nitrogen with scanning electronmicroscope with an accelerating voltage of 5 kV (Phillips Electroscan 2020). EDX analysis was conducted on the surface and inside of the woods to prove the presence of BN in the wood treated with nano particle. The obtained SEM pictures were preceded with software programs such as photo shop, etc., and the distribution of the BN particles in the wood were showed on the SEM images.

3. Results and Discussion

In this study, it was investigated the dispersion of nanoboron nitride in the Scots Pine, Ash, and Iroco wood with help a scanning electron microscopy. After impregnation of woods, the samples were divided in the middle, and the dispersion of the nano-particle was tracked with SEM pictures, and EDAX analysis also were conducted to prove the presence of BN in the wood. Fig. 1 (a) and (b, c) shows the particle dispersion on the surface and inside wood after cutting of the middle of the samples.

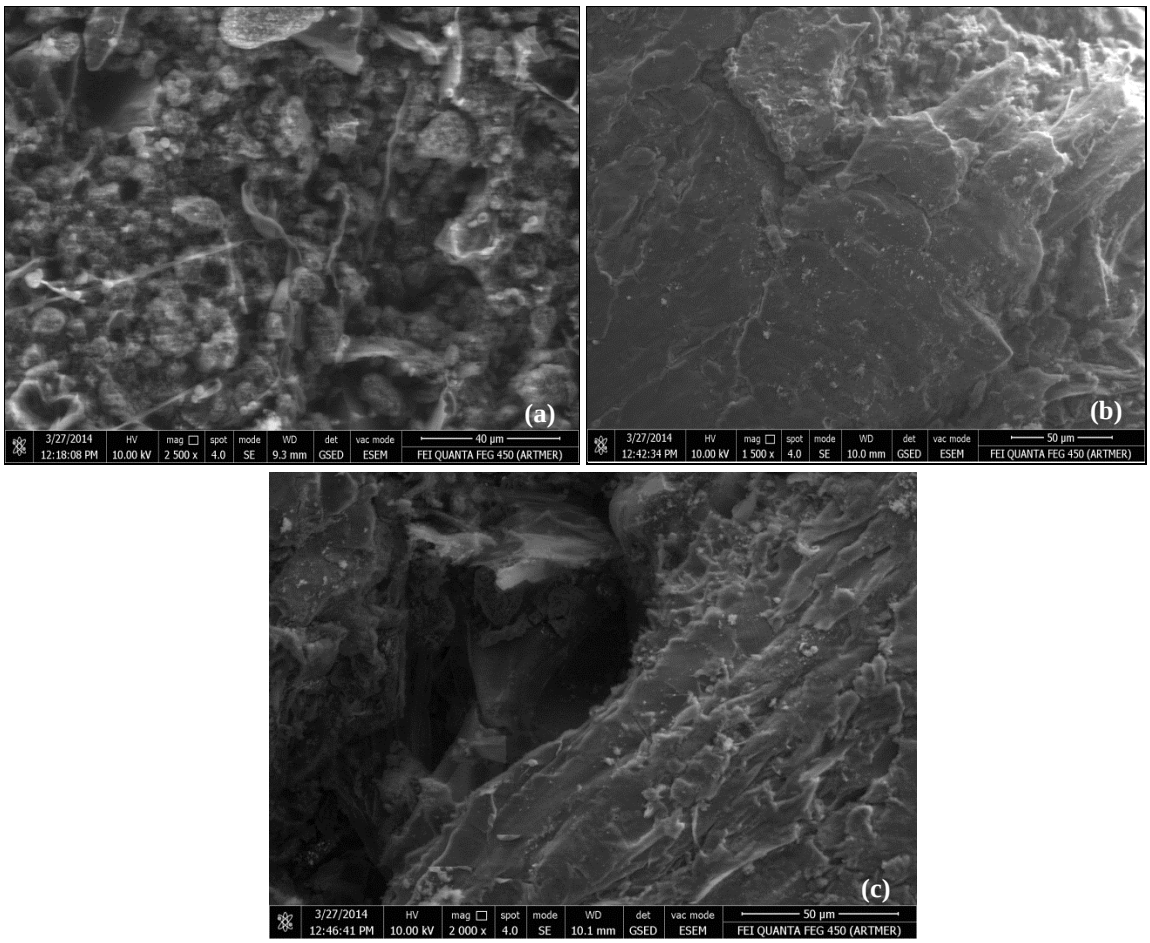

Figure 1. The dispersion of the nanoboron nitride on the inside of the samples.

When the surface of the samples was analyzed, many particles of the BN were viewed to adhere to the surface of the wood. Therefore, the surface of the wood appears to be a layer with white and black dots. The BN was found to have aggregated in cell lumens and inside part of the wood. The BN particles appeared as the white dots in the inert surface of cells. The similar pictures were determined to all wood species.

SEM analysis was conducted in the pits and cell wall of the wood, and the obtained images with white deposits on the fractured surface were given Fig. 2. According to SEM images, the BN nano particles appeared as the white dots were found inside the surface of the vessel and cells. The white dots generally were determined the BN nano particles on or around the pits, and they were also viewed as aggregated particles inside the cell lumen of wood. The BN particles around the pits weren't generally penetrated into the inside of the pits. Same images were obtained to the wood samples. As a result, the distribution of BN with various sizes and shapes in the inside of wood was determined with SEM, but it was found not to able to penetrate into the pits. In a study done a the distribution of nano particles in the wood impregnated with nano-TiO_2 by using the full-cell process, it was found that the nanoparticles had more uniform distribution in the wood, and the presence of the nano particles was clearly visible at 1.5% concentration (Afrouzi et al., 2015). In a study, Matsunaga et al. (2009) researched the positons of the dispersed fillers in cell walls of wood. According to the results, it was found that fillers dispersed around the pits, but they cannot penetrate into the pits. The nano fillers also aggregated in the bordered pits that connect the fibers, and the nano fillers also appeared to be able to pass through the bordered pits. In different study, many deposits were seen around the wood cells such as the vessel and rays. They were found strongly with the walls of the wood's cells (Akhtari et al. 2012). As seen the results of the literatures, the results of the paper can be said to be similar to the literature.

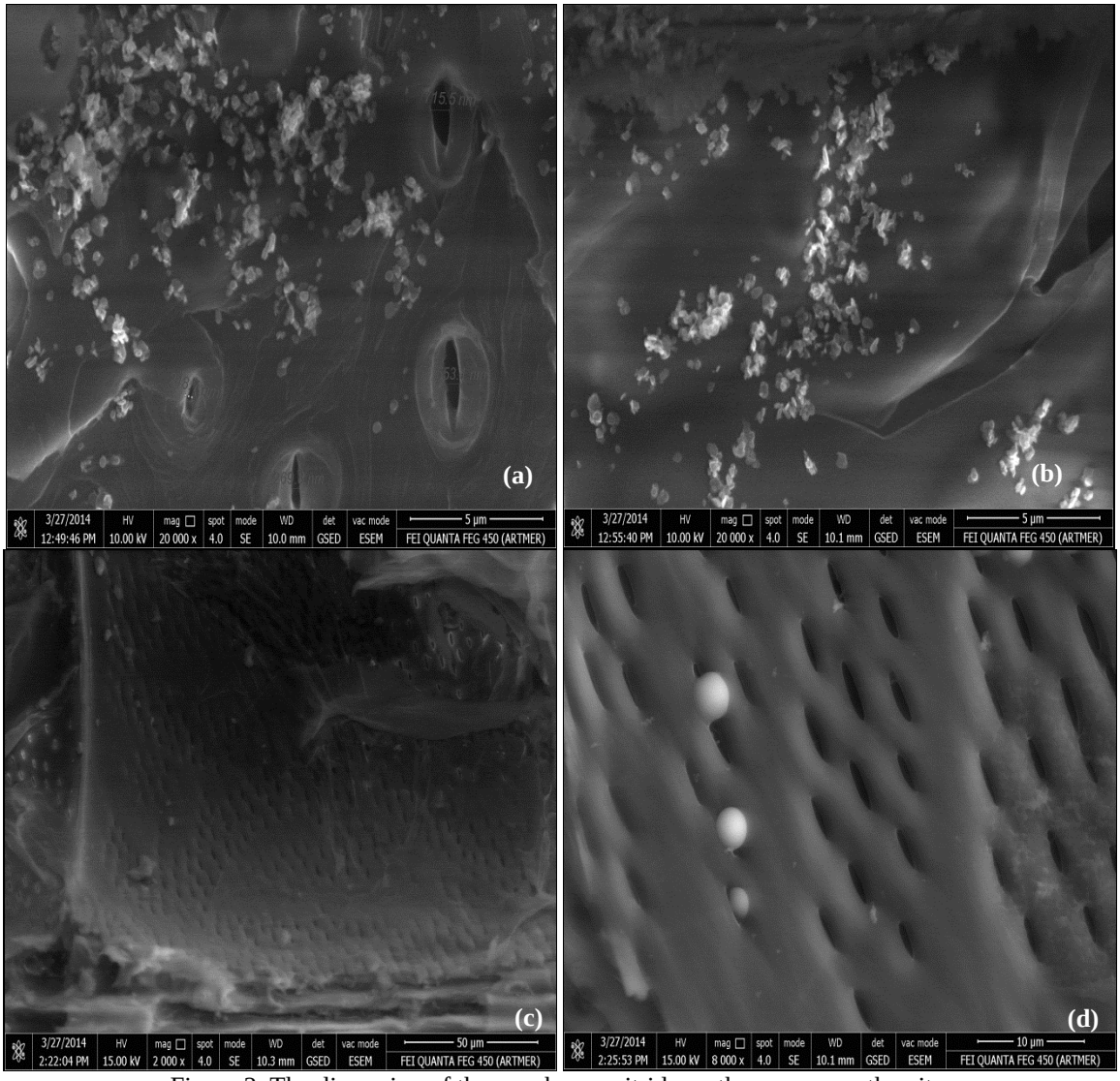

Figure 2. The dispersion of the nanoboron nitride on the near or on the pits.

Fig. 3 shows EDAX analysis (elemental analysis) on the perforation table of the nanoboron impregnated woods. The SEM-EDAX analysis was conducted to determine the identity of the deposits placed on cell wall and around the pits. The elemental composition of the white deposits in the wood cells were detected as an of 5% B; and 15% N, and the results showed that the deposits were the hexagonal boron nitride (hBNs).

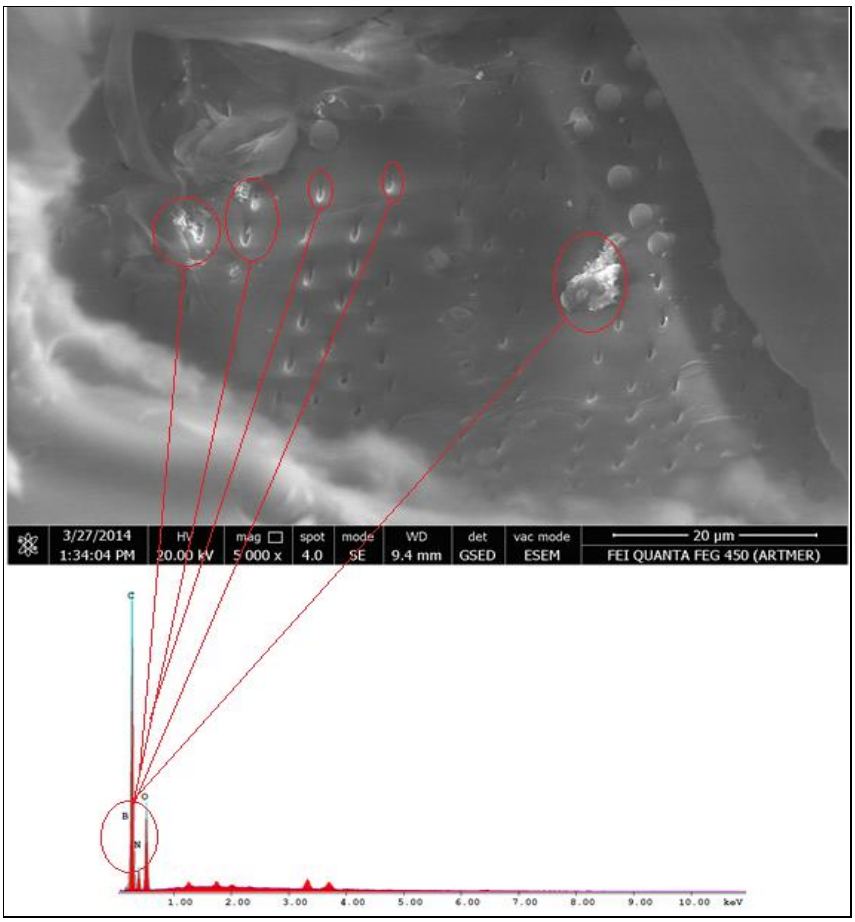

Figure 4. EDAX analysis on the perforation table of the nanoboron impregnated woods.

4. Conclusions

The dispersion of boron nitride nanoparticles in the wood was investigated in this study. According to the obtained results, the impregnation of scots pine, ash, and irocco woods with BNs can be provided, and BN nanoparticles were found to be in the fractured surface with white deposits, which also were found inside the surface of the vessel and cells. They were determined to have aggregated the white deposits on or around the pits. The white deposits can clearly be seen inside the cell lumen and on the pits in the SEM pictures, and EDAX analysis proved the present of the BN nanoparticles (the white dots) in the wood. The dispersion of BNs in the wood should be studied in further researches to find out wood material performance. Because, BNs nanoparticles can be provided better thermal performance to wood if its dispersion is well homogenously.

Acknowledgement

The Abstract of the studies was published electronically in the Proceeding Book of International Conference on Agriculture, Forest, Food Science and Technologies organized at 15-17.05.2018 in Cappadocia, Nevsehir-Turkey.

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