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The Characteristics of Lacquer Product Added with Woodceramics Powder

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ABSTRACT

In order to improve the functional components such as deformation prevention due to friction and scratches, discoloration prevention, and improved durability of the lacquer known as eco-friendly paints, to produce the woodceramic powder, known as a porous carbon material in a variety of conditions, and then added to the lacquer and cross cut test, scratch resistance and far-infrared emissivity was measured. A cross cut test was excellent as 1 class when the lacquer was added 5%–10% woodceramic powders made from resin content of 40%–50% and carbonization temperature of 600℃–800℃. When the lacquer was added 5%–10% woodceramic powders made from resin content of 50% and carbonization temperature of 600℃–800℃ showed the highest value of scratch resistance of 2 N. When the lacquer was added 5%–10% woodceramic powders made from resin content of 50% and carbonization temperature of 600℃ showed the highest value of far-infrared emissivity of 0.917. The result shows lacquer when added to the woodceramics powder known as the porous carbon material is found to be effective and increased the performance of lacquer.

Keywords: woodceramic powder, lacquer product, scratch resistance

1. INTRODUCTION

The lacquer tree (*Rhus verniciflua* Stokes), belonging to the family Anacardiaceae, is a deciduous tree native to the highlands of Central Asia, such as Tibet and the Himalayas. Its sap, known as lacquer, has been widely used across East Asia—including Korea, China, and Japan—for both industrial and medicinal purposes (Jo *et al.*, 2007; Kim *et al.*, 1998, 1999).

Lacquer coatings are particularly valued for their excellent durability, providing properties such as heat resistance, corrosion resistance, preservation, water repellency, insect deterrence, and electrical insulation. These qualities have contributed to the widespread use of lacquer in artworks and lacquerware over thousands of years, significantly influencing the development of lacquer culture in East Asia. Today, lacquer is recognized as a high-quality natural coating material and is used in applications ranging from automobiles and aircraft to marine vessels (Jo *et al.*, 2007). In recent years, lacquer has gained increasing research attention for its beneficial properties, particularly as an environ-

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mentally friendly natural material (Jeong and Oh, 2008; Kim, 2003). However, although lacquer has been widely used in traditional furniture and woodworking, its usage has declined in part due to allergic reactions triggered by urushiol, a major component of lacquer sap. This has led to ongoing studies into the causes and mechanisms underlying lacquer-induced allergies (Kim *et al.*, 2011; Shim *et al.*, 2011).

More recently, the lacquer industry has begun evolving beyond traditional applications, spurred by changes in modern lifestyles. There is growing interest in applying lacquer to a wider range of craft and household items designed to engage multiple senses. Among these, lacquered tableware offers notable advantages such as antibacterial and chemical resistance. However, it faces limitations in everyday use due to susceptibility to scratching and discoloration.

To address these challenges, this study examined the durability of lacquer-coated products by incorporating woodceramic powder—known as a porous carbon material (Hwang and Oh, 2022, 2023; Iizuka *et al.*, 1999; Oh *et al.*, 2000; Okabe *et al.*, 1996)—into lacquer and applying it using traditional lacquering techniques, rather than relying solely on conventional film formation.

2. MATERIALS and METHODS

2.1. Experimental materials

2.1.1. Lacquer

The lacquer used in this study was raw Chinese lacquer, purchased and refined by Mokwoon Craft Workshop. Following refinement, it was stored under refrigeration at temperatures below 5℃ until use. The wood substrate used was alder, which had been properly dried prior to its use.

2.1.2. Preparation of woodceramic powder

Sawdust from the woody tissue of paper mulberry (*Broussonetia kazinoki*) was screened to particles smaller than 1 mm and dried to a moisture content below 6%. It was then mixed thoroughly with 10% by weight of powdered phenol resin (KMB-100PL, Kolon Industries, Seoul, Korea), and hot-pressed into boards. The fabricated boards were subsequently impregnated with liquid phenol resin (KPD-L777, Kolon Industries), adjusting the resin impregnation rate as needed. The impregnated boards were then dried and cured in a drying oven. Following this, the cured boards were carbonized using a vacuum carbonization furnace under varying carbonization temperatures and resin impregnation rates (heating rate: 4°C/min; peak temperature holding time: 2 hours) to produce woodceramic. The resulting material was then ground to a particle size of less than 120 mesh for experimental use.

2.2. Experimental methods

2.2.1. Preparation of woodceramic-modified lacquer and specimen fabrication

Lacquer mixed with woodceramic powder was prepared under the conditions outlined in Table 1. The formulated lacquer was then applied to alder wood panels using a traditional lacquering technique, with a total of seven coating layers to fabricate the test specimens. Specimens with a lacquer film thickness of 60.0 ± 1.0 μm were selected for testing.

2.2.2. Functional property measurements

For the coating adhesion test, two specimens measuring 75 × 75 mm were prepared in accordance with the KS F 3111 testing method. Scratch resistance (scratch hardness) was assessed following the KS M 3332 method, using three 50 × 50 mm specimens. The performance was evaluated based on the measured scratch hardness, expressed in newtons (N).

Far-infrared emissivity was measured using two specimens with dimensions of 40 × 40 × 30 mm,

Table 1. Manufacturing condition of lacquer with woodceramic powder

Manufacturing condition	Resin content of woodceramics (%)	Carbonization temperature of woodceramics (℃)	Addition amount of woodceramics (%)
Lacquer mixed woodceramic powder according to the resin content	40 50 60 70	600	10
Lacquer mixed woodceramic powder according to the carbonization temperature	50	600 800 100 1,200	10
Lacquer mixed woodceramic powder according to the addition amount of ceramics	50	600	5 10 15 20

following the KICM-FIR-1005 testing protocol provided by the Korea Institute of Construction & Living Environment (KICM). For each experimental condition, the grade and results were determined based on the average values.

3. RESULTS and DISCUSSION

3.1. Properties of woodceramic according to carbonization temperature

The properties of lacquer-coated specimens containing woodceramic produced at different carbonization temperatures are presented in Table 2.

Coating adhesion was classified as Grade 1 when lacquer formulated with woodceramic produced at 600℃ and 800℃ was used, whereas the use of woodceramic produced at 1,000℃ and 1,200℃ resulted in a Grade 2 rating. In the Grade 1 specimens (600℃ and 800℃), no delamination was observed during the adhesion test. In contrast, the Grade 2 specimens (1,000℃ and 1,200℃) exhibited surface delamination over less than 5% of the tested area.

Scratch resistance reached its highest value of 2 N when lacquer was applied with woodceramic produced at 600℃ and 800℃. This trend closely aligns with the coating adhesion results of specimens containing woodceramic powders produced at the same temperatures, suggesting a likely correlation between improved adhesion and enhanced scratch resistance. It is generally recognized that increased material density contributes to improved mechanical performance. According to a

Table 2. Properties of lacguered wood mixed woodceramic powder according to the carbonization temperature

Carbonization temperature (℃)	Adhesion of painting layer (grade)	Scratch resistance (N)	Far-infrared emissivity
600	1	2	0.917
800	1	2	0.915
1,000	2	1	0.907
1,200	2	1	0.902

previous study (Byeon *et al.*, 2004), the density of woodceramic increases with carbonization temperature up to 1,000℃, after which it declines—indicating that the high scratch resistance observed in these specimens may be attributed to the higher density of powders produced at 600℃ and 800℃. Far-infrared emissivity recorded its peak value of 0.917 when lacquer was mixed with woodceramic powder carbonized at 600℃. As the carbonization temperature increased, emissivity showed a decreasing trend. This result is consistent with previous findings regarding the effect of carbonization temperature on the far-infrared emissivity of woodceramic (Oh and Byeon, 2006).

3.2. Properties of woodceramic-based lacquer according to resin impregnation rate

The properties of lacquer-coated specimens containing woodceramic powders produced at different resin impregnation rates are summarized in Table 3.

Coating adhesion was classified as Grade 1 when lacquer was mixed with woodceramic powders prepared at resin impregnation rates of 40% and 50%. In contrast, specimens using powders with 60% and 70% impregnation levels exhibited Grade 2 adhesion. In the Grade 1 specimens formulated with powders containing 40% and 50% resin, no surface delamination was observed during the adhesion test. For the Grade 2 specimens mixed with powders produced at 60% and 70% resin content, delamination was observed on less than 5% of the tested area.

Scratch resistance was lowest, with a value of 1 N, in specimens using woodceramic powder with a 40% impregnation rate, while those using powders with 50%, 60%, and 70% impregnation levels exhibited values of 2 N. This improvement in scratch resistance aligns with previous studies suggesting that higher resin content during carbonization promotes the formation of glassy carbon, which enhances the strength of woodceramic (Oh, 2005; Oh *et al.*, 2005).

Far-infrared emissivity reached its highest value of 0.917 when woodceramic powder with a 50% resin impregnation rate was used. However, no clear trend in emissivity was observed among specimens coated with lacquer containing woodceramic powders produced at varying resin impregnation levels. This result is consistent with previous findings on the effect of resin impregnation on the far-infrared emissivity of woodceramic (Oh and Byeon, 2006).

3.3. Properties based on woodceramic powder addition level

The properties of lacquer-coated specimens prepared with varying amounts of woodceramic powder are presented in Table 4.

Coating adhesion was rated as Grade 1 in specimens where 5% and 10% woodceramic powder were added to the lacquer. In contrast, specimens containing 15% and 20% powder exhibited Grade 2 adhesion. These results indicate that coatings with 5% and 10% woodceramic

Table 3. Properties of lacguered wood mixed woodceramic powder according to the resin content

Resin content (%)	Adhesion of painting layer (grade)	Scratch resistance (N)	Far-infrared emissivity
40	1	1	0.909
50	1	2	0.917
60	2	2	0.913
70	2	2	0.912

Table 4. Properties of lacguered wood mixed woodceramic powder according to the addition amount of ceramics

Addition amount of woodceramics (%)	Adhesion of painting layer (grade)	Scratch resistance (N)	Far-infrared emissivity
Non-addition	2	1	0.905
5	1	2	0.914
10	1	2	0.917
15	2	1	0.910
20	2	1	0.913

additions demonstrated better adhesion performance than either the powder-free formulation or those with 15% and 20% powder content. This may be attributed to a reduced binding force between particles at higher powder concentrations, which appears to negatively affect coating adhesion.

Scratch resistance was measured at 2 N in specimens containing 5% and 10% woodceramic powder, whereas specimens without powder and those with 15% and 20% additions showed a value of 1 N. These findings suggest that coating adhesion may influence scratch resistance, as higher powder contents appear to reduce adhesion quality, thereby negatively impacting scratch resistance.

Far-infrared emissivity reached its highest value of 0.917 in the specimen containing 10% woodceramic powder. However, no consistent trend in emissivity was observed with respect to powder content. Nevertheless, all specimens with added woodceramic powder exhibited higher emissivity than the powder-free specimen, which recorded a value of 0.905. These results indicate that the addition of woodceramic powder is effective in enhancing far-infrared emissivity.

4. CONCLUSIONS

This study aimed to improve the durability of lacquer-coated products by incorporating woodceramic powders—produced at various carbonization temperatures and resin impregnation rates—into lacquer using a traditional application method. The resulting specimens were evaluated for coating adhesion, scratch resistance, and far-infrared emissivity, and the results are summarized as follows:

1. Coating adhesion was rated as Grade 1 when the carbonization temperature was 600℃ or 800°℃, the resin impregnation rate was 40% or 50%, and the powder content was 5% or 10%. Under these conditions, cross-cut tests confirmed the absence of delamination on the specimen surfaces.
2. Scratch resistance was measured at 2 N under the conditions of 600℃ and 800℃ carbonization temperatures, 50%, 60%, and 70% resin impregnation rates, and 5% and 10% powder contents, indicating enhanced performance. In addition, scratch resistance in specimens lacquered with different carbonization temperatures and powder contents appeared to be influenced by coating adhesion.
3. Far-infrared emissivity was highest at a value of 0.917 in the specimen prepared with a 600℃ carbonization temperature, 50% resin impregnation rate, and 10% powder addition. While emissivity generally decreased with increasing carbonization temperature, no clear trend was observed in relation to resin impregnation rate or powder content.
4. Specimens without added woodceramic powder exhibited lower performance compared to those with powder additions. Among all tested conditions, the specimen produced at 600℃ with 50%

resin impregnation and 10% powder content demonstrated the best overall performance.

CONFLICT of INTEREST

No potential conflict of interest relevant to this article was reported.

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Not applicable.

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