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# Using Extension Materials to Improve Efficiency and Promote Environmental Protection and Sustainable Development in Contemporary Chinese Lacquer Arts

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## ABSTRACT

Industrial paints exacerbate air pollution by emitting volatile organic compounds during application and drying processes. This study seeks to enhance the efficiency of Chinese natural paints and increase their accessibility as bio-based alternatives, thereby mitigating the adverse effects of industrial paints on the environment. The researchers incorporated ten materials into the Chinese natural lacquer, with the formulations containing 5% titanium dioxide nanoparticles and 5% polyurethane demonstrating superior performance. These formulations reduced the drying time of the Chinese natural lacquer to 12 hours and 8 hours, respectively, under climatic conditions of 34 degrees Celsius and 64% humidity, while also improving the physical properties of the expanding materials. By experimenting with the materials and processes of contemporary lacquer art, modern lacquer material drying time test, scanning electron microscope (SEM), water droplet angle test, pencil hardness test, adhesion test and other tests, expanding the modern lacquer art materials; the researchers carried out comparative experiments of creative practice, using modern Chinese lacquer materials completely original 32 lacquer paintings, 20 of which were successful; the creation of lacquer paintings using the traditional methods The

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creation cycle of the works using the traditional method was around 2 months, as a control, the creation cycle of the lacquer paintings using the innovative method was between 2 weeks and 3 weeks, which is a drastic reduction in time. Expanded Chinese natural lacquer can contribute to the sustainable development of traditional Chinese lacquer art.
***Keywords:*** Natural Lacquer from China; Contemporary Expanded Materials; Sustainable Development

# 1. Introduction

As the economy progresses, the worldwide need for coatings is intensifying. The World Paint and Coatings Industry Association projects that the worldwide paint and coatings industry will attain sales of 179.7 billion US dollars by 2022, reflecting a year-on-year growth of 3.1%. Initial estimations indicate that the worldwide coatings industry is approximately 185.5 billion US dollars in 2023 [1]. Significant volumes of volatile organic compounds (VOCs) are released into the atmosphere during the manufacturing and assembly of industrial paints. Volatile chemicals are extremely reactive and rapidly interact with atmospheric particles, resulting in pollution through various physical and chemical reactions [2]. Increased concentrations of VOCs and NOx have resulted in an approximate doubling of oxygen in the lower troposphere during the last two centuries, positioning tropospheric ozone as the third most significant human greenhouse gas following carbon dioxide ($CO_2$) and methane [3]. Industrialization has significantly contributed to environmental pollution from VOCs, prompting consideration of the biological and natural characteristics of coatings in the pre-industrial period.

China was the inaugural nation globally to utilize natural lacquer [4]. The lacquer tree sap applied to artifacts can enhance their durability [5]. The antibacterial properties of lacquer tree sap were discovered serendipitously and then popularized, serving as the foundation to produce lacquerware by the Chinese ancestors. As recorded in *Han Fei Zi*, during the time of Yao and Shun, wood was used to make food utensils, with "the traces of cutting and sewing and repairing covered with lacquer and ink" [6]. Additionally, during the time of Dayu, "black lacquer was applied to the outside and vermilion was painted on the inside", indicating that lacquer was already used during the time of Yao, Shun, and Yu (legendary rulers of pre-dynastic China, traditionally dated to the 3rd millennium BCE). In 1978, Cinnabar lacquer wooden bowls unearthed from the Hemudu culture site, which have been carbon-14 dated [7], are considered by the industry to be the earliest lacquer ware in China [8] The use of raw lacquer in China dates back approximately 7,000–8,000 years, with lacquerware objects holding cultural significance predating the earliest known Chinese script. Chinese natural lacquer has consistently had significant importance in the historical progression of China. During the Qin and Han Dynasties, lacquerware was utilized by the nobility [9]. During the Tang Dynasty, Japanese monks and envoys introduced Chinese lacquerware to Japan, therefore advancing Japanese lacquer methods [10]. In the 17th century, European courts acquired Fujian lacquerware in substantial quantities [11]. Chinese natural lacquer, derived from tree sap, exhibits minimal artificial intervention, promotes ecological sustainability, and possesses remarkable anticorrosive characteristics. It enhances the aesthetics of antiques while serving as an environmentally benign paint. The expansion and promotion of current Chinese natural lacquer applications align with the 3R principle: REDUCE, REUSE, RECYCLE, and aim for balanced and sensible resource development [12].

Following the 20th century, the global wave of industrialization significantly affected China's natural lacquer sector, leading to a dramatic decline in the usage of traditional lacquer in daily life [13]. Following the 1990s, the industrialization of coatings intensified, scientific and technological advancements persisted, manufacturers commenced the development of diverse synthetic resins, and the coatings sector transitioned into a new era characterized by synthetic film-forming substances. The increasing utilization of coatings cannot overlook the environmental issues posed by solvents. Countries globally are implementing regulations to advance the sustainable development of coatings, with an emphasis on the creation of green, natural, bio-based coatings as a present necessity. In 2010, the European Union published a strategic paper titled "Knowledge-based European Bioeconomy: Achievements and Challenges [14]," emphasizing the necessity of integrating policy, research, and innovation, and advocating for the transformation of bio-based product systems and additional recommendations. In 2012, the

United States released the National Bioeconomy Blueprint to advance the bioeconomy [15]. In 2010, the State Council of China promulgated the "Guiding Opinions on Promoting Joint Prevention and Control of Air Pollution to Enhance Regional Air Quality" [16], which proposes the policy mandate of "implementing the prevention and control of volatile organic compounds (VOCs) pollution" at the national level. In 2022, China's Ministry of Ecology and Environment (MOE), National Development and Reform Commission (DRC), and Ministry of Industry and Information Technology (MIIT) published in 2022, the MOE, the DRC, the Ministry of Industry and Information Technology, and other agencies jointly released the "Implementation Plan for Pollution Reduction, Carbon Reduction, and Efficiency Synergy" [17], emphasizing synergistic control for air pollution prevention and optimization of treatment technology pathways technologies. Subsequently, in 2023, the State Council issued the Action Plan for Continuous Improvement of Air Quality [18], which sets explicit targets to reduce nitrogen oxides (NOx) and VOCs, aiming for a > 10% reduction in total emissions by 2025 (baseline: 2020).

Traditional Chinese natural lacquer satisfies the criteria for modern paint development, being a natural, renewable, and sustainable product. Nonetheless, it cannot attain the status of a common commodity in modern paint due to the laborious production process of traditional Chinese lacquer art, which renders traditional lacquerware costly [19]. The primary issue is that the drying duration of Chinese natural lacquer is prolonged, resulting in a laborious production process for traditional Chinese lacquer art due to its inherent properties.

The research assessed ten contemporary materials by integrating them with Chinese natural lacquer in different proportions to create an enhanced composite. Drying experiments contrasted pure Chinese natural lacquer with the modified versions, indicating that two additives, nano-titanium dioxide and polyurethane, could potentially decrease the drying time. Physical property testing indicated that the inclusion of 5% extender material improved the lacquer's properties. A controlled trial contrasted traditional Chinese lacquer art procedures with the novel extender material technology, revealing diminished production time when employing the modified lacquer.

The elevated cost of traditional Chinese lacquerware primarily stems from the extensive time and work required for its manufacture, leading to its declining practical significance an established fact [20]. Minimizing the drying time of Chinese natural lacquer can enhance production efficiency of contemporary Chinese lacquer artistry. It can also inherit and perpetuate the exquisite hues of traditional Chinese lacquer art and the classical Chinese aesthetic essence found in modernist paintings, which may be characterized as ancient Oriental. Simultaneously, it can investigate sustainable applications of Chinese natural lacquer as an eco-friendly bio-based coating in modern society.

# 2. Materials and Methods

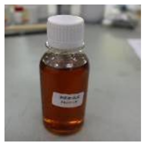
## 2.1. Laboratory Instruments and Equipment

(1) QHQ-A Pencil Hardness Tester (Aierpu Company).
(2) Hundred-grid test knife (Aierpu Company).
(3) Circular cantilever linear shaking table (SUNNE Corporation).
(4) Metallographic microscope CX40M (SEM) (SUNNY GROUP CO).
(5) Regulus 8100 Scanning Electron Microscope (SEM) (Hitachi Limited).
(6) Theta Flex optical contact angle measurement device, Biolin Scientific.
(7) Tinplate, frosted slides, horn scrapers, sandpaper, and polishing implements.
(8) A two-story building in Jimei District, Xiamen City, Fujian Province, China, designated as the lacquer painting studio.
(9) Traditional Chinese lacquer art production tools:
   - Electric mixer for lacquer powder preparation
   - Japanese thick plastic wrap (covering lacquer)
   - Painting brushes (tracing, oil painting)
   - Wooden backing boards
   - Cheesecloth (board leveling)
   - Lacquer containers (small buckets, porcelain bowls)
   - Lacquer mixing boards and glass backing boards

## 2.2. Materials

Chinese natural lacquer is derived from the sap of lacquer trees and is extensively found over 24 provinces and municipalities in southwestern China, including Shaanxi, Guizhou, Sichuan, Hubei, and Gansu[21]. In the study of the evolution and physical characteristics of modern materials and contemporary Chinese lacquer, the primary substance employed by the researcher was natural Chinese lacquer, which was combined with modern materials as additives to formulate extension materials for natural Chinese lacquer. **Table 1** enumerates the additions for natural Chinese lacquer extension materials.

**Table 1.** China Natural Paint Expansion Material Additives.

| No. | Name | Note | Producers | Photographs | No. | Name | Note | Producers | Photographs |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Cooked tung oil | Liquid | Hunan Xiangxi, China Origin |  | 3 | Cobalt trioxide | Powder | Xilong Chemical Co. |  |
| 2 | Organic perilla seed oil | Liquid | Liaoning Shengmai Industry Co. |  | 4 | Calcium carboxylate sodium salt | Powder | Bomei Biotechnology Co. |  |
| 5 | Pure C emulsion | Liquid | Uso Chemical Technology Co. |  | 6 | Ethylenedi-aminete-traacetic acid iron sodium salt | Powder | Pomeroy Biotechnology Co. |  |
| 7 | Nano titanium dioxide | Powder | Zhongye New Material Company |  | 8 | Phosphate buffer | Liquid | Pomeroy Biotechnology Co. |  |
| 9 | Sodium carboxylated cellulose | Powder | McLean Chemical Reagent Co. |  | 10 | Polyurethane | Liquid | Ancient Rhyme Company |  |

*Source: Yang Song (2024).*

## 2.3. Experimental Design

To evaluate the effects of combining modern materials with traditional Chinese lacquer, the researchers designed two experimental groups:

**Group 1: Material Property Testing (Experiments 1–5)**

Objective: Assess the physical and chemical properties of modified lacquer composites.

**Experiment 1: Drying Time Test**

To determine how modern additives influence drying time—a key cost factor—researchers prepared in two lacquer blends (5%, and 30% additive ratios). The mixtures were uniformly applied to tinplate sheets, labeled with mixing ratios and stored in a controlled environment. Drying progress was monitored hourly using cotton swab tests: surface drying was confirmed if no fibers adhered, while full drying required resistance to indentation (**Figure 1**).

**Experiment 2: Water Droplet Angle Test**

Waterproof performance was evaluated by applying the lacquer composites to glass slides. After full drying, 10 µL of deionized water was dropped onto the surface of each sample. A contact angle analyzer recorded values at room temperature, with five measurements per sample averaged for reliability.

**Experiment 3: Pencil Hardness Test**

Coating hardness, a critical durability indicator, was tested using a pencil hardness tester (6H–6B range). Samples were prepared on tinplate sheets and assessed after full drying.

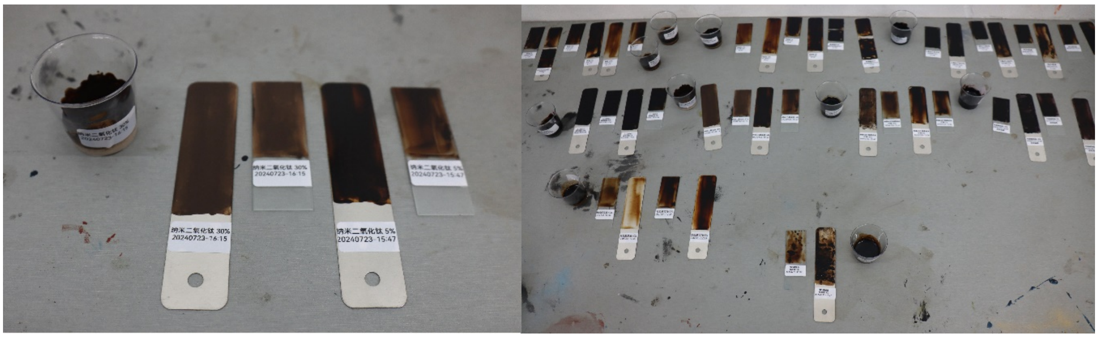



**Figure 1.** Natural Chinese lacquer was applied to the tinplate. Sample of additional materials.

*Source: Yang Song (2024).*

**Experiment 4: Adhesion Test**

Adhesion strength was measured by scoring cured samples with a right-angle film cutter. Three parallel tests are conducted per sample to ensure consistency.

**Experiment 5: Scanning Electron Microscopy (SEM)**

The microstructure of the composites was analyzed using SEM (50 μm–500 nm magnification). Samples were applied to glass slides, dried, and imaged to evaluate material compatibility with research objectives.

**Group 2: Artistic Application Comparison (Experiments 6–7)**

**Objective:** Compare traditional and modern lacquer techniques in creative practice.

**Experiment 6: Traditional Lacquer Methods**

Artists created original paintings using pure Chinese natural lacquer and conventional techniques. Environmental conditions (temperature, humidity) and time consumption were recorded.

**Experiment 7: Modified Lacquer with Innovative Techniques**

Identical artistic processes were repeated using modern lacquer composites and experimental methods. Outputs were compared with Experiment 6 (traditional methods) to evaluate advantages in workability, drying, and aesthetics.

## 2.4. Research on the Development and Physical Properties of Contemporary Chinese Lacquer

**(1) Drying time test of contemporary lacquer materials**

A significant concern in this study was the drying duration of Chinese natural lacquer. Researchers evaluated drying times by incorporating contemporary additives at 5% and 30% concentrations. The mixtures were homogenized using ultrasonic vibration and uniformly applied onto tinplate sheets with a bullhorn spatula. The samples of Chinese natural lacquer expansion materials applied to tinplate sheets can also serve as specimens for hardness and adhesion tests post-drying; hence, the researchers prepared five samples utilizing identical Chinese natural lacquer expansion materials. **Figure 2** displays the material samples: The samples of Chinese natural lacquer expansion materials applied to tinplate sheets. The test involved assessing the dryness of the surface expansion material on the tinplate sheet with a cotton swab at one-hour intervals, while documenting the time. The cotton swab was employed to assess the dryness of the surface and to determine the presence of sticky cotton fibers. Each sample was printed on label paper, indicating the manufacturing time, the sample material name, and the mixing ratio.


**Figure 2.** The samples of Chinese natural lacquer expansion materials applied to tinplate sheets.

*Source: Yang Song (2024).*

**(2) Microscopic morphology testing (SEM)**

The researchers used an electron microscope (SEM) to observe the microscopic morphological characteristics of the sample. First, the CX40M microscope with a maximum magnification of 1000x was used for observation. Morphological features on the scale of 50 μm could be observed. The researchers observed the dried samples. After the drying time test experiment was completed, the researchers further observed three types of samples: pure Chinese natural lacquer, Chinese natural lacquer expanded material with the addition of polyurethane, and Chinese natural lacquer expanded material with the addition of nano-titanium dioxide. The observation instrument was replaced with an electron microscope that could see a scale of 500 nm.

**(3) Pencil hardness test**

The pencil hardness test sample and tool are shown in **Figure 3**. A mechanical instrument made of metal with a weight of 750 grams and three-point contact with the measured surface is used. The two sides are made of nylon, and the point is the lead. The pencil is inserted into the hole nest of the machine to always ensure that the measured coating forms a 45-degree angle. The movement of the instrument is manually pushed horizontally to determine the ability of the coating to resist deformation. Use a pencil sharpener to remove the pencil well, leaving an unmarked smooth cylindrical pencil lead. Place the painted sample on a level and stable surface. Insert the pencil into the pencil hardness tester, keeping the instrument level, and place the tip of the pencil on the surface of the paint film. When the tip of the pencil just touches the coating, push the sample tinplate coated with expansion material, pushing at least 3 cm or more. If the pencil does not scratch the surface of the paint film, replace it with a harder pencil and test until the surface of the paint is scratched.

**(4) Adhesion test**

The test tools, including paint scratchers, are shown in **Figure 4**. To perform the test, place the blade edge of the paint film scoring instrument against the handle side and tighten the screw. The blade spacing is 2+0.01 mm and the blade has 11 teeth. Place the sample tinplate on a flat surface with sufficient hardness. Hold the handle of the paint film scoring gauge so that the multi-blade cutter is perpendicular to the plane of the test piece and cut slowly with even pressure and a steady hand. Then rotate the sample tinplate by 90 degrees and repeat the above operation on the scored cut to evaluate the adhesion of the paint sample coating to the substrate of the tinplate.

**Figure 3.** Pencil hardness test sample and tool.

*Source: Yang Song (2024).*

**English translation of Chinese characters in Figure 4**

| No. | English translation of Chinese characters | Timecode |
|---|---|---|
| 1 | Dicobalt trioxide 30% | 20240723-11: 25 |
| 2 | Dicobalt trioxide 5% | 20240723-11: 16 |
| 3 | Dicobalt trioxide 30% | 20240723-11: 25 |
| 4 | Dicobalt trioxide 5% | 20240723-11: 16 |
| 5 | Organic Perilla Oil 5% | 240723-17: 49 |
| 6 | Tung oil 5% | 240723-21: 01 |
| 7 | Pure Natural Chinese Lacquer | 240723-17: 13 |
| 8 | Nano Titanium Dioxide 30% | 240723-16: 15 |
| 9 | Nano Titanium Dioxide 5% | 240723-15: 47 |
| 10 | Ethylenediaminetetraacetic acid iron sodium salt 30% | 240723-17: 37 |
| 11 | Ethylenediaminetetraacetic acid iron sodium salt 5% | 240723-17: 26 |
| 12 | Carboxycellulose nanofibers 30% | 240723-15: 47 |
| 13 | Carboxycellulose nanofibers 5% | 240723-15: 34 |
| 14 | Polyurethane 5% | 240723-20: 38 |
| 15 | Polyurethane 30% | 240723-20: 45 |

**Figure 4.** Adhesion test sample and tool.

*Source: Yang Song (2024).*

**(5) Water droplet angle test**

The researchers selected three samples of Chinese natural paint with added polyurethane and nano-titanium dioxide for the water droplet angle test. These samples were evenly applied to glass slides. After complete drying, a drop of 10 μL deionized water was placed on the surface of each sample. The contact angle was measured at room temperature using a contact angle analyzer. Each sample was tested in five different areas, with five measurements taken per area, and the average value was calculated. The water drop angle test apparatus is shown in **Figure 5**.

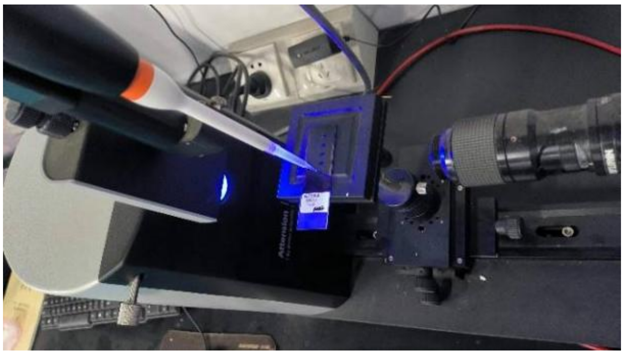


**Figure 5.** The water droplet angle test.

*Source: Yang Song (2024).*

## 2.5. A Comparative Study of Artistic Creations That Expand upon Contemporary Chinese Lacquer Techniques and Traditional Techniques

The researchers designed two experiments: one to restore traditional Chinese lacquer techniques and the other to create artistic creations that expand upon Chinese lacquer. In these experiments, natural Chinese lacquer and traditional Chinese lacquer techniques were used in one experiment, and the materials and innovative experimental methods used in the study to expand upon contemporary lacquer were used in the other, to conduct comparative experimental research. The bottom plate of the wooden tire in the experiment is shown in **Figure 6**.

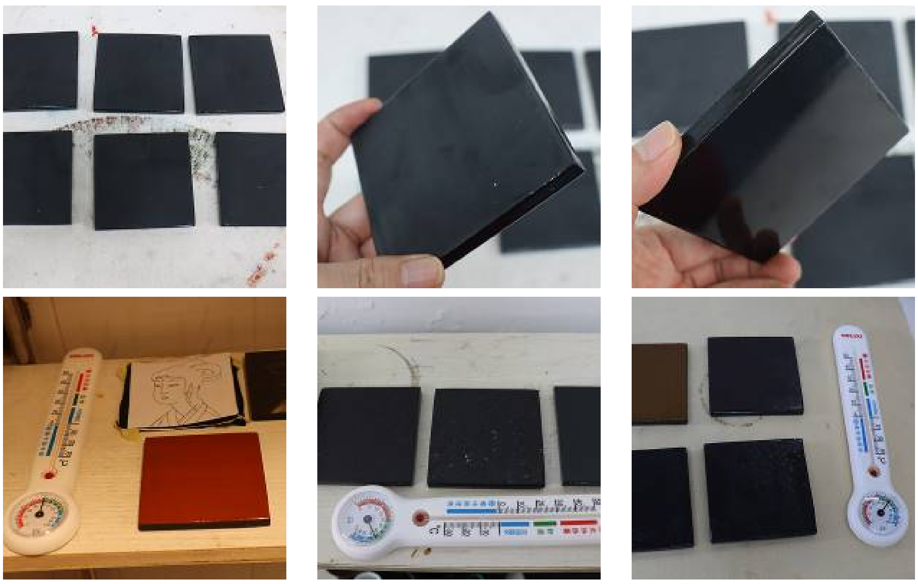


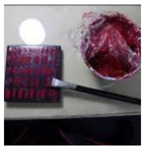
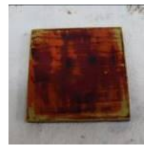
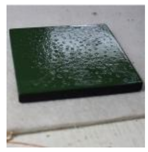
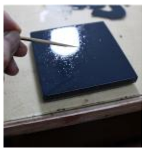
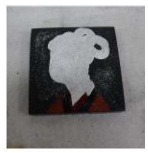
**Figure 6.** Wooden tray and temperature and humidity monitoring.

*Source: Yang Song (2024).*

**(1) An experiment to restore traditional Chinese lacquer techniques**

The researchers selected a 10 cm × 10 cm wooden base board, painted with black primer all over and one side sanded flat. After making the base plate, the researchers used high-purity Chinese natural lacquer to experiment with techniques from traditional Chinese lacquer art, such as bian tu (applying multiple coats of lacquer to create different lacquer layers, and then polishing to reveal a rich effect), zhang tu (using beans to create different textures), and inlaid (inlaying different materials, such as mother-of-pearl powder inlaid on a base plate, with multiple coats of lacquer and then polished), etc. Each technique was only tested on one base plate, and the process, time, and number of coats of lacquer were used as research data. Since temperature and humidity affect the drying of Chinese natural lacquer, the experimenters recorded the data of the experiment location, temperature, and humidity during the experiment. The wooden base plate in the experiment is shown in **Figure 6**. The researchers designed original line drawings and color sketches for the experiments with the two techniques, because this kind of technique experiment has a figurative character, and the other four technique experiments have abstract and random textural effects, so no specific shape sketches were designed. **Table 2** demonstrates the process of traditional Chinese natural lacquer creation methods.

**Table 2.** Experimental process of making Chinese natural lacquer by traditional method.

| Experiment Name | Process | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Change in coating experiment |  |  |  |  |  |  |
| Particle wrinkling experiment |  |  |  |  |  |  |
| Snow mountain effect experiment |  |  |  |  |  |  |
| Silver powder figure experiment |  |  |  |  |  |  |
| Sprinkling fine mother-of-pearl powder experiment |  |  |  |  |  |  |
| Plastic film wrinkling experiment |  |  |  |  |  |  |

*Source: Yang Song (2024).*

Polishing and displaying, or "polishing out", refers to the regular part of traditional lacquer art techniques, which involves polishing to reveal the patterns and base colors buried under the lacquer[22]. It is also a form of varied process combination that is particularly rich in content but is mainly composed of three parts: pre-embedded grain, overpainting, and sanding and polishing. Sanding and polishing are an important technique in traditional Chinese lacquer art. The researchers followed the traditional Chinese lacquer art process of sanding and polishing until the work was complete.

The researchers used the following methods in their experiments:

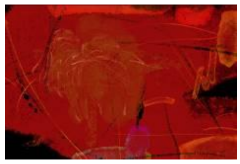
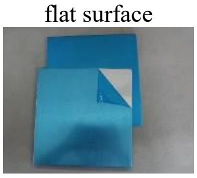
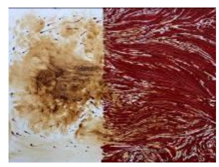
a. **Variable coating experiment:** Unevenness during lacquering creates different textural effects. The creation is completed through multiple coats of lacquer and polishing, resulting in an abstract work.
b. **Particle wrinkling experiment:** Sprinkle beans on the primer while it is still wet to create an uneven surface. The surface of the lacquered board is smoothed out during the multiple painting and sanding process to create an abstract work.

c. **Snow mountain effect experiment:** Use eggshell inlay and a wrinkled texture to create original artwork, a figurative work.
d. **Silver powder figure experiment:** Use silver powder to create original artwork, a figurative work.
e. **Sprinkle fine mother-of-pearl powder experiment:** Sprinkle mother-of-pearl powder to create an abstract work.
f. **Plastic film wrinkling experiment:** Use plastic film to create wrinkles while the primer is still wet, and reveal the texture during sanding, a figurative work.

**(2) Chinese natural lacquer art creation experiments with expanded materials**

Among the Chinese natural lacquer expanded materials prepared by adding contemporary materials, select materials with good performance as experimental expanded materials for artistic creation experiments. At the same time, the base material and creative methods for creating lacquer paintings have also been expanded, completing 32 distinct artworks. **Table 3** details the selected baseboard materials and the creation processes employed.

**Table 3.** Baseboard material selection and creation process for innovative lacquer paintings.

| Baseboard Materials | Selection of Bottom Material and Production | Process | | |
|---|---|---|---|---|
| | | 1 Concept | 2 Process | 3 Finished |
| Wooden Board |  20*30 cm, flat surface |  |  |  |
| Aluminum board |  20*20 cm, flat surface |  |  |  |
| Eco-Board |  30*40 cm, flat surface |  |  |  |

*Source: Yang Song (2024).*

# 3. Results

## 3.1. Experimental Results of Contemporary Materials Expanding Traditional Chinese Natural Lacquer

After adding different proportions of mixed materials, the experimental results for drying time are shown in **Table 4**.

Experimental test results show that adding polyurethane and nano-titanium dioxide can shorten the drying time of Chinese natural lacquer while adding cobalt (III) oxide and ferric sodium ethylenediamine tetraacetate will prolong the drying time of Chinese natural lacquer. Oily materials such as ripe tung oil and organic perilla seed oil will prolong the drying time by about 60% when added in small proportions, and when the proportion of addition reaches 30%, it will cause the lacquer to remain undried for a long time (more than 100 hours). Adding sodium carboxymethyl cellulose will also cause the Chinese natural lacquer to remain wet for a long time (more than 100 hours). Pure acrylic emulsion, as it is a water-based emulsion, will react with the Chinese natural lacquer to form a clot, which from another perspective shows that the Chinese natural lacquer will quickly form a film when in contact with water. As the researcher's experimental site was in Xiamen City, Fujian Province, China, where the air humidity is over 50%, adding sodium carboxymethyl cellulose and phosphate buffer will both cause the material to absorb water and remain wet.

**Table 4.** Drying times of expansion material.

| No. | Name | Mixing Ratio | Surface Drying Time (h) | Complete Drying Time (h) | Clarification |
|---|---|---|---|---|---|
| 01 | Pure natural Chinese lacquer | – | 10 | 14 | |
| 02 | Polyurethane | 5% | 6 | 8 | |
| 03 | Polyurethane | 30% | 5 | 7 | |
| 04 | Nano Titanium Dioxide | 5% | 11 | 13 | |
| 05 | Nano Titanium Dioxide | 30% | 9 | 12 | |
| 06 | Dicobalt trioxide | 5% | 20 | 24 | |
| 07 | Dicobalt trioxide | 30% | 24 | 30 | |
| 08 | Ethylenediaminetetraacetic acid iron sodium salt | 5% | 15 | 17 | |
| 09 | Ethylenediaminetetraacetic acid iron sodium salt | 30% | 25 | 30 | |
| 10 | Cooked Tung Oil | 5% | 16 | 19 | |
| 11 | Cooked tung oil | 30% | 100+ | 100+ | |
| 12 | Organic Perilla Seed Oil | 5% | 17 | 20 | |
| 13 | Organic Perilla Seed Oil | 30% | 100+ | 100+ | |
| 14 | Sodium Rice Carboxycellulose | 5% | 100+ | 100+ | |
| 15 | Sodium Rice Carboxycellulose | 30% | 100+ | 100+ | |
| 16 | Pure C Emulsion | 5% | F | F | agglomeration |
| 17 | Pure C Emulsion | 30% | F | F | Caking |
| 18 | Calcium carboxylic acid sodium salt | 5% | F | F | Absorbent but not dry |
| 19 | Sodium calcium carboxylate | 30% | F | F | Absorbent but not dry |
| 20 | Phosphate buffer | 5% | F | F | Absorbent but not dry |
| 21 | Phosphate buffer | 30% | F | F | Absorbent but not dry |

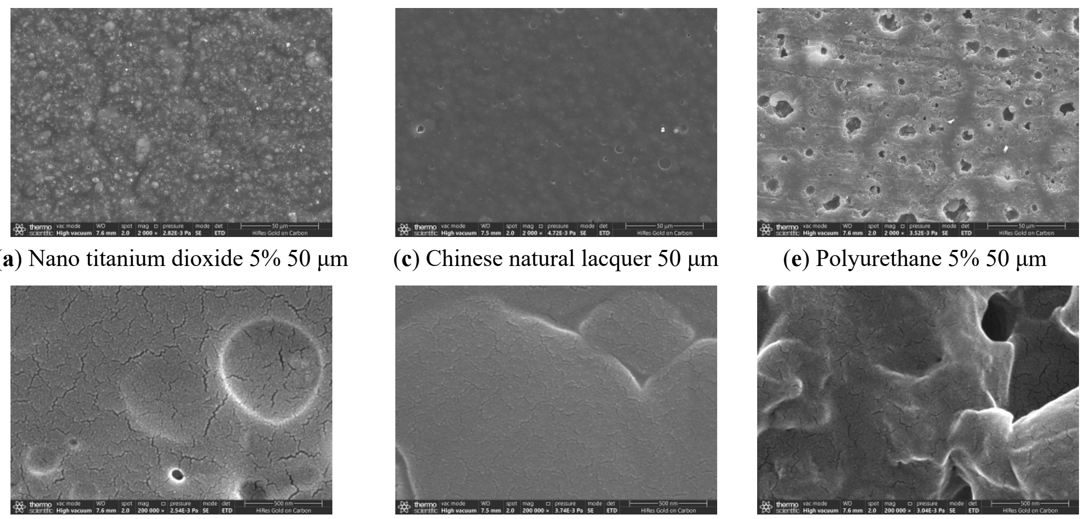
*Source: Yang Song (2024).*

## 3.2. Morphology

The researchers analyzed the following lacquer samples to compare drying times and microstructural properties:

(1) Pure Chinese natural lacquer
(2) Modified lacquer mixtures with accelerated drying times:
- Chinese natural lacquer blended with 5% polyurethane
- Chinese natural lacquer blended with 5% nano-titanium dioxide

Surface morphology was characterized using a scanning electron microscope (SEM) at high magnifications (50 μm to 500 nm). Results are presented in **Figure 7**.



(**a**) Nano titanium dioxide 5% 50 μm (**c**) Chinese natural lacquer 50 μm (**e**) Polyurethane 5% 50 μm

(**b**) Nano titanium dioxide 5% 500 nm (**d**) Chinese natural lacquer 500 nm (**f**) Polyurethane 5% 500 nm

**Figure 7.** SEM micrographs of the three materials.

*Source: Yang Song (2024).*

From the SEM characterization observations, it can be seen that the film-forming surfaces of the pure Chinese natural paint and the Chinese natural paint with added titanium dioxide nanoparticles are relatively smooth and flat after drying, and the Chinese natural paint with added titanium dioxide nanoparticles is characterized as shown in **Figure 7a** and **Figure 7b**, while the pure Chinese natural paint is characterized as shown in **Figure 7c** and **Figure 7d**. The Chinese natural lacquer with added polyurethane has more holes on the surface, showing uneven hollow rock-like characterization, as shown in **Figure 7e** and **Figure 7f**. This indicates that the addition of polyurethane accelerates the water loss of the Chinese natural paint, which is either the reason for the accelerated drying of the Chinese natural paint after the addition of polyurethane. The Chinese natural paint expansion material with added titanium dioxide nanoparticles can better maintain the surface properties of the Chinese natural paint.

## 3.3. Analysis of the Physical Properties of Expansion Materials

The experimenters evaluated three key properties of modified lacquers: pencil hardness, adhesion, and water droplet angle. The test results of hardness and adhesion are shown in **Table 5**.

**Table 6** presents grading criteria for adhesion.

The test results for the angle of the water drop are shown in **Figures 8–10**. The test data of water droplet angle is shown in **Table 7**.

**Table 5.** Test results for pencil hardness and adhesion test.

| No. | Name | Scale | Pencil Hardness | Adhesion | |
|---|---|---|---|---|---|
| | | | | ISO Grade | ASTM Classification |
| 1 | Pure natural Chinese lacquer | | 5B | 0 | 5B |
| 2 | Organic perilla oil | 5% | 6B | 1 | 4B |
| 3 | Cobalt(II) oxide | 5% | 5B | 0 | 5B |
| 4 | Cobalt(II) oxide | 30% | 6B | 0 | 5B |
| 5 | Tung oil | 5% | 6B | 0 | 5B |
| 6 | Carboxymethyl cellulose sodium microfiber | 5% | 3B | 3 | 2B |
| 7 | Carboxymethyl cellulose sodium microfiber | 30% | 5B | 0 | 1B |
| 8 | Disodium Edetate | 5% | 3B | 4 | 1B |
| 9 | Disodium Edetate | 30% | 4B | 3 | 2B |
| 10 | Polyurethane | 5% | B | 0 | 5B |
| 11 | Polyurethane | 30% | 2B | 0 | 5B |
| 12 | Nano titanium dioxide | 5% | B | 0 | 5B |
| 13 | Nano titanium dioxide | 30% | 2B | 2 | 3B |

*Source: Yang Song (2024).*

**Table 6.** Adhesion test grading criteria according to ISO/ASTM standards.

| ISO Grade | ASTM Classification | Performance Characteristics |
|---|---|---|
| 0 | 5B | The edges of the cut are completely smooth, and there is no flaking at the edges of the lattice. |
| 1 | 4B | There is small flaking at the intersection of the cut, and the actual breakage in the lattice area does not exceed 5%. |
| 2 | 3B | There is flaking at the edges and/or intersections of the cut, which is larger than 5% but less than 15%. |
| 3 | 2B | There is partial flaking along the edge of the cut or complete flaking, or some of the lattice is completely flaked. The area of flaking is more than 15% but less than 35%. |
| 4 | 1B | Large pieces of the cut edge are peeled off or some squares are partially or completely peeled off, covering an area of more than 35% but no more than 65% of the grid area. |
| 5 | 0B | Exceeds the previous level. |

*Source: Yang Song (2024).*

The results of the pencil hardness test showed that the pencil hardness of pure Chinese natural lacquer was 5B. The hardness of lacquers with added materials that were harder than pure Chinese natural lacquer was as follows: 5% carboxylated cellulose nanofiber mixed with Chinese natural lacquer, ferric sodium ethylenediamine tetraacetate mixed with Chinese natural lacquer, and polyurethane and nano-titanium dioxide mixed with Chinese natural lacquer had the highest hardness, reaching the B level (**Table 5**). The adhesion test results show that the adhesion of Chinese natural lacquer to tinplate is not high. Carboxylated sodium cellulose nanofibers, ferric sodium ethylenediaminetetraacetate, and nanometer titanium dioxide mixed with Chinese natural lacquer can all effectively improve the adhesion of Chinese natural lacquer (**Table 6**). The results of the water droplet angle test show that the hydrophobicity of pure Chinese natural lacquer is relatively strong, approaching 90°. The hydrophobicity of Chinese natural lacquer with added polyurethane and Chinese natural lacquer with added nano-titanium dioxide is stronger than that of pure Chinese natural lacquer. The hydrophobicity of Chinese natural lacquer with added nano-titanium dioxide is the strongest, reaching 97.33° (**Table 7**).

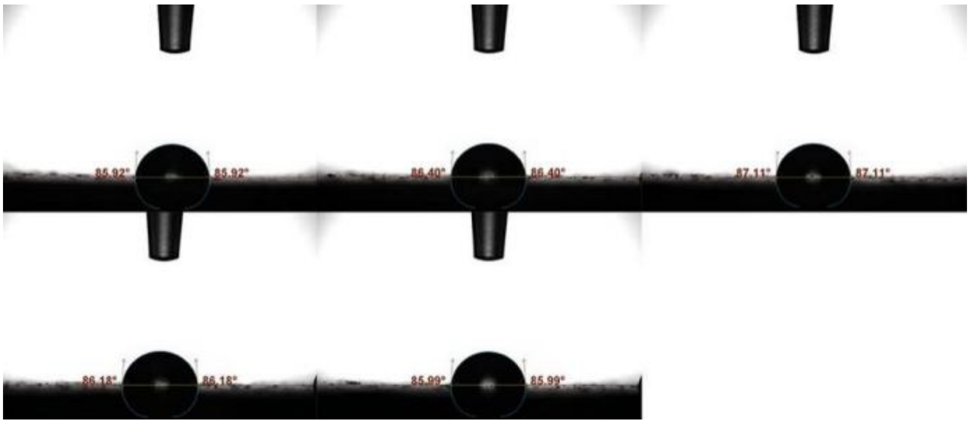



**Figure 8.** Test results of the pure Chinese natural lacquer water droplet angle test.

*Source: Yang Song (2024).*

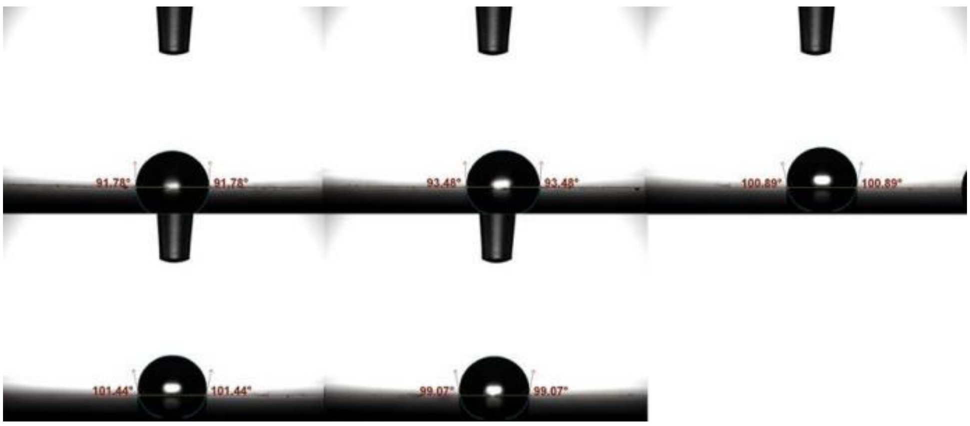



**Figure 9.** Test results of the Chinese natural paint water droplet angle test with added titanium dioxide.

*Source: Yang Song (2024).*

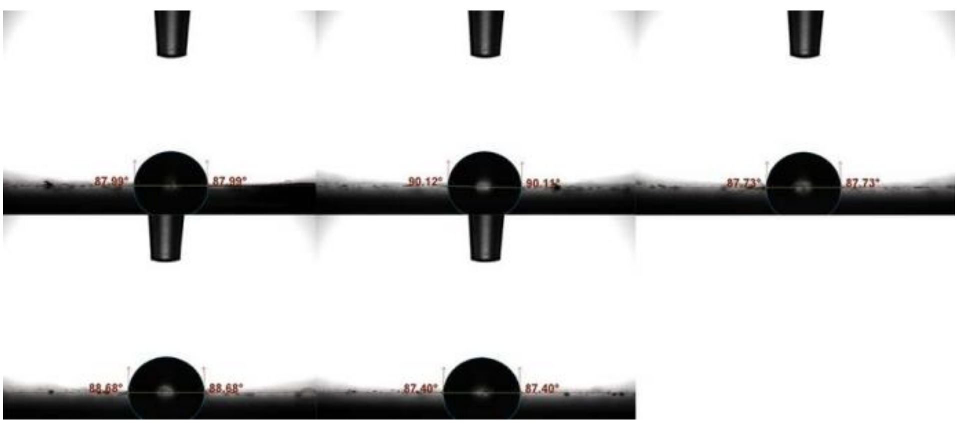



**Figure 10.** Test results of the Chinese natural lacquer water droplet angle test with the addition of polyurethane.

*Source: Yang Song (2024).*

**Table 7.** Test results for the water droplet angle test.

| Sample Name | Pure Chinese Natural Lacquer | Chinese Natural Lacquer with Added Polyurethane | Chinese Natural Lacquer with Added Nano Titanium Dioxide |
|---|---|---|---|
| Angle1 | 85.92 | 87.99 | 91.78 |
| Angle2 | 86.4 | 90.12 | 93.48 |
| Angle3 | 87.11 | 87.73 | 100.89 |
| Angle4 | 86.18 | 88.68 | 101.44 |
| Angle5 | 85.99 | 87.40 | 99.07 |
| Angle Mean Value | 86.32 | 88.38 | 97.33 |

*Source: Yang Song (2024).*

## 3.4. Comparative Analysis of Traditional and Experimental Methods of Creating Chinese Natural Lacquer

The researchers used traditional Chinese lacquer art methods and experimental expansion methods to create lacquer art, and compared and analyzed the two methods, The comparison results are shown in **Table 8** and an example of the creative work is shown in **Figure 11**.

Examples of works created using experimental and expanded methods of lacquer art are given in **Figures 11** and **12**.

**Table 8.** Comparison of traditional and innovative development methods.

| Method of Creation | Base Material | Base Preparation Method | Number of Successes | Number of Failures | Dimensions (cm) | Average Number of Coats | Average Number of Sandings | Average Drying Time per Coat (hours) | Average Temperature | Average Humidity | Average Total Time per Work |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pure Chinese natural lacquer and traditional Chinese lacquer art creation methods | Wood | Linen and plaster | 6 | 0 | 10 long, 10 wide | 12 | 7 | 16 | 32 | 64% | 207 |
| Chinese natural lacquer expansion materials and innovative creation methods | Aluminum | Sanded | 2 | 1 | 20 long, 20 wide | 8 | 5 | 7 | 31.5 | 60% | 45 |
| | Silicone | Sanded | 2 | 2 | 20 long, 20 wide | 6 | 5 | 6 | 34 | 65% | 38 |
| | PVC | Sanded | 3 | 2 | 20 long, 30 wide | 7 | 5 | 5 | 32 | 59% | 33 |
| | Ecological laminate | Sanded | 1 | 3 | 30 long, 40 wide | 5 | 3 | 6 | 29 | 68% | 29 |
| | Wood | Linen and plaster | 14 | 2 | 20 long, 30 wide | 12 | 8 | 5 | 34 | 69% | 51 |

*Source: Yang Song (2024).*

**Figure 11.** Lacquer painting created using Chinese natural lacquer to expand material creation.

*Source: Yang Song (2024).*

**Figure 12.** Lacquer painting created using Chinese natural lacquer to expand material creation.

*Source: Yang Song (2024).*

### 3.5. Focus Group to Evaluate the Potential Application of the Extended Material

To examine the experimental results of the contemporary materials for Chinese natural lacquer, the researchers conducted a structured focus group with three experts (two university professors and one lacquer art artist), to collect qualitative data [23].

On December 27, 2024, from 3:00 p.m. to 6:00 p.m., the focus group addressed the quality and application of contemporary Chinese natural lacquer for expanding lacquer materials. The discussion took place in the discussion room of the Fuzhou University Jinjiang Campus Library. During the three-hour session, the researchers asked open-ended questions, actively listened to avoid leading, and took detailed notes.

The data was analyzed, conclusions were drawn, and the experts were invited to review the findings. The conclusion was as follows: The modern expanded material with added nano-titanium dioxide and polyurethane has better physical properties such as strength and water resistance. These qualities make it suitable for use in contemporary lacquer painting. However, due to the inherent characteristics of lacquer materials, specific color performance and other material properties need to be continuously monitored for over three years. The experts believe that the expanded lacquer materials, derived from contemporary Chinese natural lacquer, hold the potential for development and can be applied in the creation of traditional Chinese lacquer art.

## 4. Discussion

The study boosted the qualities of Chinese natural lacquers using modern material tests and approaches for expanding artistic production. The drying time of the two expansion materials, Chinese natural lacquer with 5% nano titanium dioxide and 5% polyurethane, applied to tinplate, was greatly reduced (**Table 4**), and both hardness and adhesion were enhanced (**Tables 5** and **6**) in comparison to pure Chinese natural lacquer. In creative practice, the two Chinese natural lacquer expansion materials can save production time by over 50% compared to traditional Chinese lacquer techniques through the application of new approaches (**Table 8**).

China has a long history of using Chinese natural lacquer [24], with evidence of mature production processes dating back to the Spring and Autumn Periods [25]. In recent years, ancient Chinese lacquerware unearthed still has bright lacquer film [26], which is sufficient to prove that Chinese natural lacquer has good anticorrosive and retention properties as paint. Chinese natural lacquer is essentially the sap of the lacquer tree [27], which is a natural green product that is more in line with environmental protection in contrast to contemporary industrialized paints. Over millennia, Chinese lacquer painters have developed a complex traditional Chinese lacquer painting process to meet the aesthetic requirements of the aristocracy, creating complex decorative effects through multiple painting and sanding displays, which has led to the long time-consuming and expensive traditional Chinese lacquer techniques while improving the exquisiteness of traditional Chinese lacquer crafts [28]. By the 20th century, the global rise of industrialization marginalized traditional lacquerware, as mass-produced, synthetic paints offered cheaper alternatives. Chinese natural lacquer—a purely natural and green paint—deserves renewed attention. To revive its relevance, challenges such as drying time and production efficiency should be addressed through modern innovation.

Among the ten added materials, which are categorized into two types, powder and liquid, tung oil was an auxiliary material that had been added to Chinese natural lacquer in ancient China [29], so Chinese natural lacquer with tung oil added can be regarded as a reference. The drying time of all materials except titanium dioxide nanoparticles and polyurethane exceeded the drying time of pure Chinese natural lacquer. Since drying time is an important part of the product production process to reduce cost, reducing the drying time of Chinese natural lacquers is important for the application of contemporary Chinese natural lacquers. In terms of physical properties, the hardness and adhesion of the Chinese natural paint extensions with titanium dioxide nanoparticles and polyurethane were improved, and in terms of waterproofing properties, the Chinese natural paint extensions with titanium dioxide nanoparticles performed even better (**Table 8**).

In the context of environmental issues that cause global concern, sustainable development has become the focus of research in the academic world, and the study of bio-based coatings has attracted much attention. Bio-based refers to the use of renewable biological materials combined with contemporary technology to create new materials [30], and the products made from bio-based materials are bio-based products, which are now widely used in all aspects of people's lives. Since contemporary applications of Chinese natural lacquer are more in handicraft making and art creation, researchers conducted experiments comparing the traditional creation methods of Chinese natural lacquer with the innovative methods of expanded Chinese natural lacquer materials. Expanded Chinese natural lacquer materials and innovative creation methods can enhance the production efficiency of traditional Chinese lacquer art. On the one hand, the new expanded materials and innovative creation methods have commercial development potential; on the other hand, the expanded materials are still based on Chinese natural lacquer as the main material, with contemporary materials such as nano-dioxide as the additives, which improves the performance of the materials while maintaining the bio-based properties and traditional cultural attributes of Chinese natural lacquer, which is beneficial for the inheritance of the traditional Chinese culture and the sustainable development of the Chinese culture. This study suggests that by expanding the materials, the production efficiency of lacquer can be improved, the production time of lacquer can be reduced, and a new source of income can be created for the craftsmen [31], thus better controlling the production cost of lacquer products.

## 5. Conclusions

This paper studies the impact of contemporary material development on Chinese natural lacquer. Among the ten types of added materials, the Chinese natural lacquer development material with 5% nano-titanium dioxide and the Chinese natural lacquer development material with 5% polyurethane have better performance. The drying time is reduced to eight hours and 12 hours, and the hardness and adhesion are improved to a certain extent. The average angle of the Chinese natural lacquer with 5% nano-titanium dioxide added in the water droplet angle test reached 97.33, and the average angle of the Chinese natural lacquer with 5% polyurethane added reached 88.38. The better physical properties, faster drying time, and excellent hydrophobic properties indicate that the expanded materials of Chinese natural lacquer are superior to pure Chinese natural lacquer in terms of performance. Since the expanded materials are still based on Chinese natural lacquer, they can inherit the long-lasting properties of Chinese natural lacquer.

The researchers used a control group experiment to compare traditional Chinese lacquer creation methods with innovative creation methods using Chinese natural lacquer expanded materials. In the pure Chinese natural lacquer and traditional Chinese creation methods, six methods were used, with a wooden baseboard of 10 cm in length and 10 cm in width, and a single traditional Chinese lacquer technique was used on each baseboard, with an average of 12 paintings, an average drying time of 12 hours, and an average of 185 hours for a single piece of artwork. In the innovative creation method of expanding materials of Chinese natural lacquer, the researchers used different baseboard materials such as wood, aluminum, silicone, polyvinyl chloride, ecological board, etc. The minimum size of the baseboards was 20 cm in length and 20 cm in width, the average number of lacquering times was 7.6 times, the average drying time was 5.8 hours, and the average total time spent for a single piece of artwork was 39.2 hours (**Table 8**). The expanded material of Chinese natural lacquer can substantially reduce the time consumption in the comparison experiment. Less time consumption can enhance the market competitiveness of Chinese natural lacquer products, which is conducive to Chinese natural lacquer gaining wider attention as a green bio-based paint and increasing the market share of Chinese natural lacquer, thus reducing the negative impact of the paint industry on the natural environment, and promoting the sustainable development of Chinese lacquer art.

## Author Contributions

Conceptualization, methodology development, experimental design, conducting experiments, creative practice, original manuscript, writing, Y.S.; review and inspection, C.D.; review, M.K. All authors have read and agreed to the published version of the manuscript.

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## Data Availability Statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author(s).

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## Conflicts of Interest

The authors confirm that there are no conflicts of interest pertaining to this work.

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