Article

Effect of the Addition of Shellac Self-Healing and Discoloration Microcapsules on the Performance of Coatings Applied on Ebiara Solid Board

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Abstract: Self-made shellac microcapsules and discoloration microcapsules in different proportions were added to water-based coatings and the influence of different proportions of self-healing discoloration microcapsules on the coating performance for Ebiara solid boards was discussed. Through a three-factor, two-level orthogonal experiment, the effects of the content of the addition of discoloration microcapsules, shellac microcapsules, and microcapsules on the performance of the coating were explored; the most influential factor of microcapsules was the shellac microcapsule content. Through the coating repair experiment, after 5 days of repair, the coating without adding shellac microcapsules does not display the repair effect. When the shellac microcapsules and discoloration microcapsules were added simultaneously, the width of the coating decreased by 3–6 μm after 5 days of repair, displaying a good repair effect. The shellac microcapsules have a great influence on the surface roughness of coatings. After adding the shellac and discoloration microcapsules, the hardness of the coating was not significantly affected. It was found that there was no chemical reaction between the coating and microcapsules. The best comprehensive performance was obtained by adding 15.0% shellac microcapsules in primer and 20.0% discoloration microcapsules in topcoat. The results provided a reference for multifunctional wood coatings.

Keywords: hard broad-leaved wood; discoloration; self-repair; microcapsule; waterborne acrylic acid

1. Introduction

With the progress of society and science and technology, as wood is easy to process and nontoxic, it is widely used in various fields of life [1–5]. However, lignin, cellulose, and hemicellulose are easily decomposed, which means wood can easily rot and deteriorate, and shortens the service time of wood products [6–9]. Furniture surface coatings can effectively improve wood drying shrinkage such as wet bilge, playing the role of effective protection [10–15]. Compared with the previous traditional coating, water-based coatings are not harmful to human safety, have less taste, are resistant to chemical corrosion, and so on [16–18]. However, in daily life, the destruction of environmental and human factors leads to effects on its own structure and performance, thus a water-based coating film on the surface of the furniture will produce micro cracks. However, in daily life, owing to the destruction of the wood coating by effects from the environment and human activities, the performance of the coating itself will be affected, so cracks will occur on the surface of the furniture coating. The expansion of microcracks will eventually lead to the destruction of the overall structure of the coating, thereby reducing the protective function of the coating and its mechanical properties. In recent years, many researchers have imitated the self-healing function of organisms using repair technology, and micro cracks for coating
damage repair provide a novel and effective method [19–21]. Self-healing microcapsules are materials that repair from the outside. The microcapsule breaks when the coating is cracked by an external force, releasing the inner core material to repair the coating surface, which can improve the performance of wood products and furniture and thus extend their service life. The discoloration microcapsule is a kind of intelligent response material, whose colour can change with the change in the environmental temperature [22,23]. Temperature-sensitive reversible discoloration water-based coatings can be prepared by adding discoloration microcapsules to water-based coatings. It can change its color by increasing or decreasing the temperature [24]. The discoloration coating has a unique discoloration function and can not only be used for the measuring surface temperature, anti-counterfeiting recognition, and overtemperature warning, but also play a decorative role.

In this experiment, two functional microcapsules were prepared and applied to the coating to ensure that the coating has both good self-repair and discoloration properties. The two-level, three-factor orthogonal experiments and independent experiments were designed to prepare the coatings with the best self-healing and discoloration effects. Two functional microcapsules in the application of water-based wood coatings can enlarge the application range of microcapsules. It lays a foundation for future research and the development of multifunctional composite coatings.

2. Materials and Methods

2.1. Experimental Materials

The 37% (mass fraction) liquid formaldehyde solution, triethanolamine, and citric acid monohydrate were supplied by Deke Technology Co., Ltd., Shanghai, China. The urea was purchased from Henan Suke Chemical Technology Co., Ltd., Luoyang, China. The sodium dodecyl benzene sulfonate was purchased from Wuxi Yatai United Chemical Co., Ltd., Wuxi, China. The absolute ethanol was bought from Wuxi Yasheng Chemical Co., Ltd., Wuxi, China. The Dulux water-based coating (water-based acrylic copolymer dispersants, dimmers, additives, and water) with a solid content of 30.0% was purchased from Dulux Coatings Ltd., Slough, UK. The gum arabic powder was bought from Nanjing Jinyou Biotechnology Co., Ltd., Nanjing, China. The shellac tablets (Yunnan special grade 2) were purchased from Jinan Dahui Chemical Co., Ltd., Jinan, China. Ebiara solid wood boards (Berlinia sp., 100 mm × 100 mm × 10 mm) were supplied by Beijing Jinyu Temple of Heaven Furniture Co., Ltd., Beijing, China.

2.2. Coating Preparation

2.2.1. Preparation of Shellac Microcapsules

The schematic diagram in Figure 1 shows the two types of sphere microcapsules with a core and surface shell.

![Figure 1](image_url)

**Figure 1.** Two kinds of sphere microcapsules with a core and surface shell.

In this study, 20.00 g of urea was poured into a beaker, then 27.00 g of 37.0% liquid formaldehyde solution was slowly added to mix it completely. Triethanolamine was
slowly added and its pH was adjusted to about 8.5–9.0. Then, a slightly thick and transparent wall material solution was obtained by continuous stirring at 100 r/min for 60 min at a 70 °C constant temperature in a water bath. The mixture was cooled to the normal atmospheric temperature and set aside.

Then, 1.76 g of sodium dodecylbenzenesulfate white powder was added to 174.00 g of distilled water and stirred with a glass rod until completely dissolved. The obtained sodium dodecylbenzenesulfate aqueous solution was used as an emulsifier. Then, shellac tablets of 22.50 g were dissolved in 112.50 g of anhydrous ethanol, then impurities were separate, and a clear liquid was obtained. The emulsifier was added into the shellac solution, emulsified for 30 min in the mixer, and the core solution was obtained.

The solution of wall material was gradually dropped into the solution of core material, then the citric acid added was dropped, and it was stirred until it was completely dissolved. The pH of the mixture was adjusted to 3.0, slowly heated to 70 °C in the water bath, and reacted in a blender for 3 h. Then, the mixture was kept at a normal atmospheric temperature for 72 h, washed with distilled water and absolute ethanol, dried in an oven at 40 °C for 72 h, and finally the shellac microcapsule powder was obtained.

2.2.2. Preparation of Discoloration Microcapsules

Here, 3.00 g of urea was poured into a beaker and 4.05 g of a 37% liquid formaldehyde solution was added, followed by stirring until the urea was completely dissolved. Triethanolamine was dropped to adjust the pH to about 8.5–9.0, the temperature was raised to 70 °C, and the mixture was stirred for 60 min to obtain a slightly viscous transparent wall material solution for later use.

Then, 1.35 g of the gum arabic powder as the emulsifier was dissolved in 43.65 g of the distilled water and the chromotropic complex made of crystal violet lactone, bisphenol A, and tetraceol was added. The mass ratio of crystal violet lactone/bisphenol A/tetraceol was 1:3:60. The solution of core material was placed in a magnetic mixer and stirred at 65 °C for 60 min.

The wall solution was added to the core material solution, then citric acid crystals were added to adjust the pH value and the solution was stirred until it was just combined. After adjusting its pH to 3.0, the water bath was slowly heated to 70 °C and the mixture was placed into the agitator for 3 h. After stirring for 3 h, the precipitate was kept at a normal atmospheric temperature for 72 h. The product was filtered several times with distilled water and ethanol. Finally, the granular powder was dried in a 40 °C oven for 72 h and then dried at a normal atmospheric temperature for discoloration microcapsule powder.

2.2.3. Preparation of Coating

The coating preparation process was carried out by controlling factors such as the content of discoloration microcapsules, the content of shellac microcapsules, and the microcapsule addition method in order to obtain a variety of coatings with different structures and morphologies. An orthogonal test with three factors and two levels was used to analyze and determine the effect of process parameters on the performance of the coatings. The test factors and the levels are shown in Table 1. The parameter settings in Table 1 were designed according to the concentrations in [25,26].

The surface of the Ebiara solid boards was sanded first, then the sawdust on the surface of the Ebiara solid boards was wiped off with paper. Then, 1.8 g of primer and 0.2 g of discoloration microcapsules were weighed and placed into a beaker. The mixture was evenly stirred and the coating was coated on the Ebiara solid boards three times; each time, it needed to be placed in an oven, dried to the surface, and then coated with the second and third layers. The third layer was coated and then dried in an oven. The 1.9 g topcoat and 0.1 g shellac microcapsule were weighed and stirred evenly, and the above steps were repeated. Finally, the coated Ebiara solid boards were dried at 40 °C in an oven for 2 h and at normal atmospheric temperature for 24 h.
Table 1. Orthogonal test table.

| Sample   | Content of Discoloration Microcapsules (%) | Shellac Microcapsule Content (%) | Addition Method                                      |
|----------|-------------------------------------------|---------------------------------|-----------------------------------------------------|
| PD10TS5  | 10.0                                      | 5.0                             | Primer added with the discoloration microcapsules, topcoat added with the shellac microcapsules |
| PS15TD10 | 10.0                                      | 15.0                            | Topcoat added with the discoloration microcapsules, primer added with the shellac microcapsules |
| PS5TD20  | 20.0                                      | 5.0                             | Topcoat added with the discoloration microcapsules, primer added with the shellac microcapsules |
| PD20TS15 | 20.0                                      | 15.0                            | Primer added with the discoloration microcapsules, topcoat added with the shellac microcapsules |
| PS0TD20  | 20.0                                      | 0                               | Topcoat with discoloration microcapsules            |
| PS5TD20  | 20.0                                      | 5.0                             | Primer added with the shellac microcapsules, topcoat added with the discoloration microcapsules |
| PS10TD20 | 20.0                                      | 10.0                            | Primer added with the shellac microcapsules, topcoat added with the discoloration microcapsules |
| PS15TD20 | 20.0                                      | 15.0                            | Primer added with the shellac microcapsules, topcoat added with the discoloration microcapsules |
| PS20TD20 | 20.0                                      | 20.0                            | Primer added with the shellac microcapsules, topcoat added with the discoloration microcapsules |
| PS25TD20 | 20.0                                      | 25.0                            | Primer added with the shellac microcapsules, topcoat added with the discoloration microcapsules |
| PT       | 0                                         | 0                               | No microcapsules                                     |

According to the orthogonal experiment results, the other two factors were fixed and the biggest influencing factor was the shellac microcapsule content, as shown in Table 1. The content of discoloration microcapsules was fixed at 20.0%, the discoloration microcapsules were added in the topcoat, and the shellac microcapsules were added in the primer. The shellac microcapsule content in the primer was 0 g, 0.1 g, 0.2 g, 0.3 g, 0.4 g, and 0.5 g, respectively, that is, the content was 0%, 5.0%, 10.0%, 15.0%, 20.0%, and 25.0%, respectively. The experimental process and operation were the same as the previous orthogonal experiment.

2.3. Testing and Characterization

The SEGT-J portable colorimeter (Zhuhai Tianchuang Instrument Co., Ltd., Zhuhai, China) was used to measure the chromaticity value of the water-based coating film surface according to GB/T-1989-11186.3 [27]. The sample was heated to 26 °C in an oven, three points were selected for testing in the middle parts of the wood coating, and the average color of the coating film was calculated, denoted as $L$, $a$, and $b$, respectively. Then, the sample was heated to 40 °C and the above steps were repeated to calculate the color difference of the coating at 40 °C, which was denoted as $L'$, $a'$, and $b'$. $\Delta L$ represents the difference of lightness, $\Delta a$ represents the difference of red and green, and $\Delta b$ represents the difference of yellow and blue. The colour difference ($\Delta E$) of the water-based coating was calculated according to the CIELAB formula (1):

$$\Delta E = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{1/2}$$

The single Q/YSMMDE 3 blade (2 cm long and 100 m deep) was used to scratch the coating to observe the effect of microcapsule repair. The Zeiss Axio Scope A1 optical microscope (OM, Carl Zeiss AG, Ober Kochen, Germany) was used to observe the repair changes of coating scratches before and after 5 days.

The roughness of the coating was measured by a precision roughness tester JB-4C (Shanghai Teming Optical Instrument Co., Ltd., Shanghai, China).

The hardness of the coating film was characterized by pencil hardness tester. The hardness of the water-based coating was measured using a 6H-6B pencil according to national standard GB/T 6739-2006 [28].

The micromorphology of coatings and microcapsules was characterized by a Quanta-200 scanning electron microscope (SEM, FEI, Hillsboro, OR, USA). The sample tray was
prepared and glued with double-sided adhesive tape. The tested sample was stuck on the double-sided adhesive tape and then it was sprayed with gold, placed on the sample table, and observed after vacuuming. The SEM voltage was set at 200 V–30 kV, the magnification was 20–300,000 times, and the resolution was 3.5 nm.

The chemical composition was characterized by Fourier transform infrared spectrometer (FTIR, Shanghai Smio Analytical Instrument Co., Ltd., Shanghai, China). A small amount of the sample to be tested was put into the mortar mill and an appropriate amount of potassium bromide (KBr) was added, fully ground evenly, poured into the grinding tool, and then put into the hydraulic press to press it into a transparent sheet. The spectral test range was 4000–500 cm$^{-1}$ and the resolution was 0.2 cm$^{-1}$.

The test was repeated four times and the error was less than 5%.

3. Results and Discussion

3.1. Color Difference Analysis

The color difference values of coatings PD10TS5, PS15TD10, PS5TD20, and PD20TS15 at a normal atmospheric temperature of 26 °C and high temperature of 40 °C were measured by portable colorimeter, as shown in the following Table 2.

| Sample    | $L$  | $a$  | $b$  | $c$  | $h$  | $L'$ | $a'$ | $b'$ | $c'$ | $h'$ | $\Delta L$ | $\Delta a$ | $\Delta b$ | $\Delta E$ |
|-----------|------|------|------|------|------|------|------|------|------|------|------------|------------|------------|-----------|
| PD10TS5   | 52.8 | 8.7  | 24.5 | 26.0 | 70.3 | 51.6 | 9.7  | 23.7 | 25.6 | 67.6 | −1.2       | 1.0        | −0.8       | 1.8       |
| PS15TD10  | 62.6 | 11.9 | 29.0 | 31.4 | 67.6 | 58.6 | 11.1 | 23.8 | 26.2 | 64.9 | −4.0       | −0.8       | −5.2       | 6.6       |
| PS5TD20   | 69.2 | 7.3  | 15.1 | 16.8 | 64.1 | 64.8 | 8.4  | 13.3 | 15.8 | 57.5 | −4.4       | 1.1        | −1.8       | 4.9       |
| PD20TS15  | 55.3 | 11.6 | 16.4 | 20.2 | 54.9 | 63.6 | 8.5  | 13.0 | 15.5 | 56.7 | 8.3        | −3.1       | −3.4       | 9.5       |

In Table 3, the colour difference means difference between colour at 26 °C and 40 °C. The color difference of PD10TS5 and PS15TD10 with 10.0% discoloration microcapsules is 1.8 and 6.6, while that of PS5TD20 and PD20TS15 with 20.0% discoloration microcapsules is 4.9 and 9.5. In Table 3, mean 1 is the average of the first level, mean 2 is the average of the second level, and range is the difference between the two averages. The range for the content of discoloration microcapsules was 3.0, the range for the shellac microcapsule content was 4.7, and the range for microcapsule addition was 0.1. The results show that adding 20.0% discoloration microcapsule has a better discoloration effect. This is because with the increase in the number of discoloration microcapsules, the color change effect of the coating can be reflected [25]. The more obvious the color change, the greater the color difference. According to the data, the shellac microcapsule content on the discoloration effect is the largest. On the basis of orthogonal test, the discoloration effect was further optimized. Compared with the colour results at a normal temperature of 26 °C and high temperature of 40 °C, the calculated results are shown in Table 4.
Table 3. The result of orthogonal experiment analysis.

| Sample       | Content of Discoloration Microcapsules (%) | Shellac Microcapsule Content (%) | Microcapsule Addition                                      | The Color Difference |
|--------------|--------------------------------------------|----------------------------------|------------------------------------------------------------|----------------------|
| PD10TS5      | 10.0                                       | 5.0                              | Primer added with the discoloration microcapsules,         | 1.8                  |
|              |                                             |                                  | topcoat added with the shellac microcapsules               |                      |
| PS15TD10     | 10.0                                       | 15.0                             | Topcoat added with the discoloration microcapsules,        | 6.6                  |
|              |                                             |                                  | primer added with the shellac microcapsules                |                      |
| PS5TD20      | 20.0                                       | 5.0                              | Topcoat added with the discoloration microcapsules,        | 4.9                  |
|              |                                             |                                  | primer added with the shellac microcapsules                |                      |
| PD20TS15     | 20.0                                       | 15.0                             | Primer added with the discoloration microcapsules,         | 9.5                  |
| Mean 1       | 4.200                                      | 3.350                            | 5.650                                                      | -                    |
| Mean 2       | 7.200                                      | 8.050                            | 5.750                                                      | -                    |
| Range        | 3.000                                      | 4.700                            | 0.100                                                      | -                    |

Table 4. The values of chromatism (normal atmospheric temperature is 26 °C: L, a, b, c, and h and high temperature 40 °C: L', a', b', c', and h').

| Sample       | L   | a   | b   | c   | h   | L'  | a'  | b'  | c'  | h'  | ΔL  | Δa  | Δb  | Δh' |
|--------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| PS0TD20      | 57.7| 10.5| 20.7| 23.2| 63.0| 65.8| 11.5| 22.7| 25.4| 63.0| 8.1 | 1.0 | 2.0 | 8.4 |
| PS5TD20      | 67.0| 10.5| 19.5| 22.1| 61.6| 65.1| 8.7 | 16.5| 18.6| 62.0| −1.9| −1.8| −3.0| 4.9 |
| PS10TD20     | 67.4| 8.3 | 13.8| 16.1| 58.8| 70.7| 9.5 | 16.4| 19.0| 59.9| 3.3 | 1.2 | 2.6 | 4.4 |
| PS15TD20     | 65.6| 7.6 | 11.5| 13.8| 56.6| 71.8| 8.8 | 14.1| 16.7| 58.9| 6.2 | 1.2 | 2.6 | 6.8 |
| PS20TD20     | 71.0| 3.6 | 14.1| 14.6| 75.4| 76.5| 7.3 | 13.8| 15.6| 61.9| 5.5 | 3.7 | −0.3| 6.6 |
| PS25TD20     | 75.5| 5.8 | 11.9| 13.2| 64.0| 79.2| 6.1 | 12.3| 13.7| 63.3| 3.7 | 0.3 | 0.4 | 3.7 |
| PT           | 62.1| 10.2| 38.8| 40.1| 67.1| 62.0| 10.7| 34.9| 36.5| 72.8| −0.1| 0.5 | −3.9| 3.9 |

As can been in Table 4, the colour difference of sample PS0TD20 is 8.4, the colour difference of sample PS5TD20 is 4.9, the colour difference of sample PS10TD20 is 4.4, the colour difference of sample of PS15TD20 is 6.8, the colour difference of sample of PS20TD20 is 6.6, the colour difference of sample of PS25TD20 is 3.7, and the colour difference of sample of PT is 3.9. The color difference values of PS5TD20, PS10TD20, PS15TD20, PS20TD20, and PS25TD20 with both discoloration microcapsules and shellac microcapsules were smaller than that of sample PS0TD20 with only discoloration microcapsules. The analysis showed that discoloration microcapsules had a greater effect on the color and the shellac microcapsules had an inhibitory effect on discoloration microcapsules. For PS5TD20, PS10TD20, PS15TD20, PS20TD20, and PS25TD20, which added both discoloration microcapsules and shellac microcapsules, when the content of shellac microcapsules is 15.0% (PS15TD20), the colour difference of the coating is the largest, that is, in the case that shellac microcapsules can self-repair the coating, the discoloration effect is the largest when the content of shellac microcapsules is 15.0%. Therefore, when preparing coatings, the proportion of discoloration microcapsules and shellac microcapsules should be controlled to ensure the discoloration effect and the self-healing effect of the coating.

3.2. Self-Healing Experiment

The restoration effect of the coating on Ebiara solid boards with different contents of shellac microcapsules is shown in Figure 2. Figure 2A,C,E,G are images at the beginning of the scratch. The same scratches were observed under a microscope 5 days later and the coating scratches are shown in Figure 2B,D,F,H.
Figure 2. Coating scratch OM: (A,B) repair before and after PS0TD20; (C,D) repair before and after PS5TD20; (E,F) repair before and after PS15TD20; (G,H) repair before and after PS25TD20.

Five days after the surface coating of Ebiara solid boards was scratched, except for PS0TD20, the scratch width of PS5TD20, PS15TD20, and PS25TD20 was relatively small, varying from 3 to 6 μm (Table 5). The sample PS0TD20 does not contain shellac microcapsules and the scratch width is almost the same, showing that the self-healing is associated with the shellac microcapsules' content. The shellac microcapsules can provide a better repair effect. When the coating has cracks, the shellac core material in the microcapsules flows out and solidifies at room temperature at the crack location, which can effectively heal the microcracks. When the content of self-healing microcapsules is 15%, the coating can not only change color with the temperature (Table 4), but also have a self-healing function.
Table 5. Restorative effect on the surface coating of Ebiara solid boards.

| Sample   | Before the Repair (μm) | After the Repair (μm) | Difference (μm) |
|----------|------------------------|-----------------------|-----------------|
| PS0TD20  | 25.69                  | 25.08                 | 0.61            |
| PS5TD20  | 30.59                  | 24.92                 | 5.67            |
| PS15TD20 | 36.33                  | 33.23                 | 3.10            |
| PS25TD20 | 37.90                  | 33.12                 | 4.78            |

3.3. Roughness Analysis

The surface roughness of PS0TD20 and PS25TD20 was tested with a roughness measuring instrument, as shown in Figure 3 and Table 6. Based on the analysis in Table 6, PS15TD20 and PS25TD20 contained 15.0% and 25.0% shellac microcapsules, respectively, and the roughness was 4.963 μm and 4.263 μm, respectively. The samples PS0TD20 and PS5TD20 contained 0% and 5.0% shellac microcapsules, respectively, with a roughness of 2.437 μm and 2.078 μm, respectively. The roughness of samples PS15TD20 and PS25TD20 is greater than that of samples PS0TD20 and PS5TD20. The shellac microcapsules have a great influence on the roughness of the coating; when the content is more than 15.0%, the roughness is greater, which affects the smoothness of water-based coatings.

As can be seen from the Figure 3, the surface roughness of the four coatings is roughly on the rise. When the content of shellac microcapsules is low, the coating roughness is relatively low. When the content of shellac microcapsules is high, the coating roughness is relatively high. Therefore, it can be concluded that the surface roughness of the coating is related to the shellac microcapsules' content.
3.4. Hardness Analysis

The hardness properties of the coating on Ebiara wood with different amounts of microcapsules are shown in Table 7. In accordance with the data in Table 7, the PS0TD20 hardness of only adding discoloration microcapsules is 5H, the PS5TD20 hardness of adding 20.0% discoloration microcapsules and 5.0% shellac microcapsules is 5H, the PS15TD20 hardness of adding 20.0% discoloration microcapsules and 15.0% shellac microcapsules is 6H, and the PS25TD20 hardness of adding 20.0% discoloration microcapsules and 25.0% shellac microcapsules is 5H. Therefore, there is little influence on the hardness of coating with the microcapsules, and the coating can maintain high hardness.

Table 7. The hardness of the coating.

| Sample   | PS0TD20 | PS5TD20 | PS15TD20 | PS25TD20 |
|----------|---------|---------|----------|----------|
| Hardness | 5H      | 5H      | 6H       | 5H       |

3.5. Microstructure Analysis

Scanning electron microscopy of coatings PS0TD20, PS5TD20, PS15TD20, and PS25TD20 is shown in Figure 4A–D. The 20.0% discoloration microcapsules were added to PS0TD20, the 20.0% discoloration microcapsules and 5.0% shellac microcapsules were added to PS5TD20, the 20.0% discoloration microcapsules and 15.0% shellac microcapsules were added to PS15TD20, and the 20.0% discoloration microcapsules and 25.0% shellac microcapsules were added to PS25TD20. As can be seen from the Figure 4 and Table 7, the coating surface is rough. Figure 4E,F are SEM images of microcapsules. The distribution of shellac microcapsules was relatively uniform, with a diameter of about 9 μm. The discoloration microcapsules were easy to agglomerate and had agglomeration and precipitation phenomenon, and the distribution was not very uniform.
3.6. Infrared Spectroscopy

As shown in Figure 5, after adding shellac microcapsules, the coating shows the infrared absorption peak at 3360 cm\(^{-1}\) for the N–H group and at 2929 cm\(^{-1}\) and 2865 cm\(^{-1}\) for C–H stretching vibration peak, as well as 1639 cm\(^{-1}\) urea-formaldehyde resin as wall materials in the C=O stretching vibration peak. The characteristic peaks of shellac resin microcapsule were 1465 cm\(^{-1}\) and 1255 cm\(^{-1}\). The peak at 1465 cm\(^{-1}\) was the carbonyl negative ions COO– stretching vibration of carboxylic acid and the peak at 1255 cm\(^{-1}\) was the C=O–C stretching vibration of ester molecule. The infrared spectrum of the water-based coating showed that 2929 cm\(^{-1}\) and 2865 cm\(^{-1}\) were the stretching vibration peaks of -CH\(_2\) and 1730 cm\(^{-1}\) was the vibration absorption peak of C=O [26]. When the content of discoloration microcapsules in the topcoat was fixed to 20.0%, there is no excess peak disappearance or appearance between coating samples with different shellac microcapsule contents.
4. Conclusions

In this paper, water-based coatings with self-healing and discoloration properties were prepared for the Ebiara solid board. Orthogonal experiments showed that the content of shellac microcapsules had a great influence on the effect of discoloration. When the content of shellac microcapsules was 15.0% and the content of discoloration microcapsules was 20.0%, and when the shellac microcapsules were added to the primer and the discoloration microcapsules were added to the topcoat, the color difference of the coating was 6.8. After 5 days of repairing the scratched coating, the width of the scratch was correspondingly smaller, varying from 3 to 6 μm. The self-repair of the coating was related to the content of shellac microcapsules and the shellac microcapsules had an obvious effect on the self-repair of the coating. When the shellac microcapsules were added to the coating, the roughness of the coating increased obviously. When the shellac and discoloration microcapsules were added to the coating at the same time, the hardness of the coating changed little, which was 5H–6H. Adding 15.0% shellac microcapsules in the primer and 20.0% discoloration microcapsules in the topcoat, the water-based coating had good properties, which not only had certain healing properties, but also had good discoloration properties. The research results lay a foundation for the application of composite microcapsule in the water-based coatings on the wood surface.

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