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Effect of Urea–Formaldehyde Resin–Coated Colour–Change Powder Microcapsules on Performance of Waterborne Coatings for Wood Surfaces

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Abstract: Microcapsules have received a great deal of attention from researchers due to their excellent properties, and are commonly prepared by interfacial and in situ polymerisation methods. In situ polymerisation is an important method of microcapsule preparation, which has a number of advantages such as low cost and suitability for industrial production. Microencapsulation is used to modify the state of the material in order to improve its practical usability and mechanical and optical properties. In this paper, urea–formaldehyde resin–coated colour–changing powder microcapsules were prepared and their properties were used to study the colour–changing properties of wood surface coatings, and the mechanical and optical properties of waterborne paint films incorporating colour–changing powder microcapsules were tested. The results show that as the microcapsule content increases, the colour–change effect of the coating gradually becomes obvious and the amount of change in the b–value representing the yellow hue gradually increases. As the microcapsule content increased from 1.0% to 13.0%, the b–value increased from 0.7 to 2.6. The gloss of the film decreased significantly with the increase in the microcapsule content of the colour–change powder, with the highest gloss at 1.0%. The impact resistance of the film was also influenced by the content of microcapsules in the waterborne topcoat, with the best impact resistance at 5.0%, level 2 of adhesion at 1.0%–5.0% and 11.0%–13.0%, and level 1 of adhesion at 7.0% and 9.0%. In terms of mechanical and optical properties, the 5.0% content of colour–changing powder microcapsules is the best for the overall performance of waterborne topcoats. In practical furniture applications, the microcapsules prepared in this paper can change the colour in appearance according to the actual temperature and play a decorative role.

Keywords: urea–formaldehyde resin; colour–changing powder; microencapsulation; in situ polymerisation

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1. Introduction

A microcapsule is a miniature container made of natural or synthetic polymers. Microencapsulation refers to the encapsulation of tiny solid particles, droplets, or bubbles with a coated film. Microcapsules have received a lot of attention from researchers due to their excellent properties. Common preparation methods include spray drying, phase separation, interfacial polymerisation, in situ polymerisation, etc. [1–8]. Among the microencapsulation techniques, the spray drying is the most widely used and practical. It involves pre–dispersing the core material in a liquefied wall material to form an emulsified dispersion and then atomising the mixture in a high–temperature air stream [9–12]. The phase separation, also known as coalescence, is a method of microencapsulation of water–insoluble or poorly water–soluble solids or liquids called aqueous phase separation, and a method of microencapsulation of water–soluble solids or liquids called oil phase separation [13–15]. Interfacial polymerisation has been proposed since the 1950s. It is suitable for the preparation of microcapsules with water–soluble cores as well as oil–soluble cores [16,17]. In situ polymerisation is an important method for the preparation of microcapsules, and has many advantages such as low cost and suitability for industrial production. Microencapsulation is used in the fields of energy saving in construction, medicine and health, military camouflage, etc., due to its significant role in changing the state of materials to improve their performance, protecting and isolating special functional materials, and controlling the release of core materials [18–20].

Most thermochromic materials use organic thermochromic dyes, which are mainly used in crafts, fibres, films, and other products that need to change colour with temperature. With the development of oil refining and aerospace technology, thermochromic materials have gradually come into the limelight, and most of the thermochromic materials used in the oil refining and aerospace industries are inorganic metallic thermochromic materials that can measure temperatures in excess of 1200 °C. These materials are mainly used as over–temperature alarm devices in oil refineries and to measure the temperature of some high–temperature surfaces in aerospace devices. In recent years, with the rapid development of research into low–temperature reversible organic thermochromic materials and the popularisation and development of microencapsulation technology, many new varieties of thermochromic materials have emerged and their applications have gradually expanded from a single aerospace technology material to various areas of life. In the industrial sector, organic thermochromic materials are used to indicate temperature, to control temperature rise and fall during chemical reaction experiments and to detect and record changes in the temperature of experimental reactions, to monitor and alert real–time temperature in warehouses where dangerous chemicals are stored to ensure storage safety and personal safety, and to warn of high temperatures in electrical cables and other electrical high–risk environments to ensure timely maintenance and servicing [21–24].

The research on reversible organic thermochromic materials started relatively late due to various methods, so it has not yet reached a large area in life where it can be seen everywhere and is readily available. Microencapsulated reversible organic thermochromic material is a multifunctional material, the preparation of which is mainly the preparation of colour–changing microcapsules. The good sealing and optical properties of microcapsules make them well–suited for use as colour–changing microcapsules. Microencapsulation provides stability to the product. The protection of the core material from external influences by the wall material enhances the resistance to oxidation and contamination, reduces the volatility of the core material, etc. [25–28].

The coating not only protects the wood substrate, but also increases the aesthetics, and has a colour–changing function through modification. Water–based coatings use water as solvent, which is green and environmentally friendly. The water–based coating can show transparent effect, and the colour–changing microcapsules can show better colour–changing effect after modification [29–35].

In this experiment, urea–formaldehyde resin–coated colour–changing powder microcapsules were prepared and the mechanical and optical properties of the waterborne paint films were tested. A comparative study was carried out to analyse the content of colour–changing powder microcapsules in waterborne topcoats when the impact resistance of the film is optimal, the content of colour–changing powder microcapsules in waterborne topcoats when the gloss of the film is optimal, and the grade of adhesion of the film at different levels of colour–changing powder microcapsules. The purpose of this study is to investigate the performance and improvement of wood materials.

2. Experimental Materials and Methods

2.1. Experimental Materials

A lime wood plate (100 mm × 100 mm × 12 mm) and collector type thermostatic magnetic stirrer (DF–101S standard) were supplied by Lichen Technology Co., Ltd., Shanghai, China. A circulating water type multi–purpose vacuum pump (SHZ–D) was supplied by Yuhua Instruments Co., Ltd., Gongyi, China. An organic microporous filter membrane mixer (diameter 50 mm, aperture 0.45 μm) was supplied by Yu Yang Glass Instrument Co., Ltd., Yancheng, China.

The colour–changing powder was supplied by Oriental Colour Changing Technology Co., Ltd., Shenzhen, China. The main components are 19.0%–27.2% polymethanol melamine, 5.8%–7.2% styrene maleic anhydride monomethyl, 18.2%–19.0% maleate polymer, 42.6%–44.3% methyl palmitate, 2.3%–4.9% ethyl stearate. Dulux pure odour waterborne wood paint topcoat and primer were supplied by Kegaki Co., Ltd., Shanghai, China.

2.2. Experimental Methods

The in situ polymerisation method was used to prepare urea–formaldehyde resin–coated discolouring powder microcapsules: (1) Preparation of wall material urea–formaldehyde resin prepolymer: a 20.0 g measure of urea and 27.0 g of 37% formaldehyde solution were weighed and added to a beaker at a mass ratio of 1:1.35. After the beaker had been clarified with no visible fine urea crystals, a disposable plastic dropper was used to draw in the triethanolamine reagent, the triethanolamine was added slowly into the plastic film with a small opening to make the pH of the solution between 8.0 and 9.0, then the setting temperature of the stirrer was adjusted to 70 °C, and stirred for 90 min in a constant temperature water bath at 70 °C, keeping the beaker sealed throughout the process. The solution was clarified and the wall material solution was produced as urea–formaldehyde resin wall material, and the beaker was sealed and left to cool naturally at room temperature after the reaction. (2) Preparation of core material temperature sensitive colour–change powder: a 99.0 g measure of distilled water and 1.0 g of sodium dodecylbenzene sulfonate white powder were weighed and put into the stirrer to stir and dissolve, and stirred for 30 min until completely dissolved to obtain 1.0% concentration of sodium dodecylbenzene sulfonate aqueous solution. A 1.0 g measure of thermochromic powder was weighed and 100 g of 1.0% aqueous sodium dodecylbenzene sulfonate solution was added, stirred, and emulsified for 30 min at 40 rpm and room temperature in a water bath to obtain a stable core emulsion. The above steps were repeated according to the ratios in Table 1 to prepare 6 core material solutions with different colour–change content, respectively. (3) Microencapsulation: After the urea–formaldehyde resin wall solution had cooled naturally at room temperature, the stirrer speed was adjusted to 30 rpm, and stirred for 3 h at room temperature. (4) After stirring, the product was slowly poured into a 250 mL plastic bottle and left to age in a cabinet for several days. After the bottle had been clearly stratified, the product was filtered and distilled water was added to rinse the excess emulsifier. The resulting powder was the urea–formaldehyde resin–covered colour–change powder microcapsules.

Table 1. Experimental raw material proportioning table.

Sample Number	Urea (g)	Formaldehyde (g)	Urea–Formaldehyde Resin (g)	Temperature–Sensitive Colour–Change Powder (g)	Water (g)	Dodecylbenzene Sulfonic Acid by (g)	Core–to–Wall Ratio
1	20.0	27.0	30.0	1.0	99.0	1.0	0.033
2	20.0	27.0	30.0	2.0	99.0	1.0	0.067
3	20.0	27.0	30.0	3.0	99.0	1.0	0.100
4	20.0	27.0	30.0	4.0	99.0	1.0	0.133
5	20.0	27.0	30.0	5.0	99.0	1.0	0.167
6	20.0	27.0	30.0	6.0	99.0	1.0	0.200

The microcapsules were added to the water–based paint, using the water–based topcoat as the paint base (Table 2). A 3.0 g measure of each of the eight reversible colour–changing water–based paints containing 0, 1.0%, 3.0%, 5.0%, 7.0%, 9.0%, 11.0%, and 13.0% of colour–changing powder microcapsules was prepared (see Table 1 for composition): a 3.0 g measure of the primer was weighed on an electronic scale and applied to the surface of the board in two even layers, waiting for it to dry naturally at room temperature. Measures of 3.00 g, 2.97 g, 2.91 g, 2.85 g, 2.79 g, 2.73 g, 2.67 g, and 2.61 g of topcoat were weighed and 0 g, 0.03 g, 0.09 g, 0.15 g, 0.21 g, 0.27 g, 0.33 g, and 0.39 g of urea–formaldehyde resin–coated colour–changing powder microcapsules were added to them, respectively. In order to dissolve the colour–change powder microcapsules in the topcoat, a small amount of ethanol was added to the topcoat to change the microcapsules from powder to viscous form, and then added to the topcoat to obtain seven types of microcapsules topcoat with 1.0%, 3.0%, 5.0%, 7.0%, 9.0%, 11.0%, and 13.0% content. Each board was evenly coated with topcoat two times and allowed to dry naturally at room temperature.

Table 2. Table of ingredients for paint films with microcapsules of colour–changing powder.

Sample	Colour–Changing Powder Microcapsule Content 0	1.0%	3.0%	5.0%	7.0%	9.0%	11.0%	13.0%
Weight of discolouring powder microcapsules (g)	0	0.03	0.09	0.15	0.21	0.27	0.33	0.39
Weight of water–based topcoat (g)	3.00	2.97	2.91	2.85	2.79	2.73	2.67	2.61
Temperature–sensitive reversible colour–changing water–based paint weight (g)	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00

2.3. Testing and Characterisation

The microstructure of the paint film was tested by an environmental scanning electron microscope. The chemical composition of the paint film was tested by VERTEX 80v infrared spectrometer.

The SEGT–J portable colourimeter was used to measure the chromaticity of the paint film from 18 °C to 40 °C and to calculate the colour difference. An HG268 intelligent gloss meter was used to test the gloss of the coating.

The QFH–HG600 adhesion tester, designed and manufactured in accordance with ISO 2409–1992, was used to test the adhesion of the paint film. The board coated with microencapsulated finish was placed on the table, and the handle of the scriber was held so that the tool was perpendicular to the surface of the board. The surface was then cut with uniform force and at a constant speed, after which the board was rotated 90 degrees, and the previous operation was repeated at the previously cut incisions to create a web–like pattern on the surface of the board. All cuts in this operation should penetrate the coating, but not too deep into the substrate. If the coating is too thick and hard for the scriber to penetrate the substrate, the experiment will be invalid. The tape was then applied to the entire grid and torn off at the smallest possible angle. The test results were compared by observing the degree of peeling of the paint from the surface of the tape.

The impact resistance of the paint film was tested using the QCJ–50 paint film impact tester, designed in accordance with GB1732–79. Testing the impact resistance of a paint film shows the elasticity and adhesion of the paint film and is an important step in mechanical property testing.

3. Results and Discussion

3.1. Microstructural Analysis

Figure 1 shows the SEM images of microcapsules with core–to–wall mass ratios of 0.033, 0.100, and 0.167. The in situ composite method successfully produced spherical microcapsules with relatively uniform particle size and high yield. Comparing the three SEM images, it is obvious that microcapsules with a core–to–wall ratio of 0.033 had the best morphology, with a spherical shape, size around 3–7 μm, less breakage, no serious agglomeration, and a smoother surface. The microcapsules with a core–to–wall ratio of 0.167 were probably not covered, with more amorphous form and surface breakage.

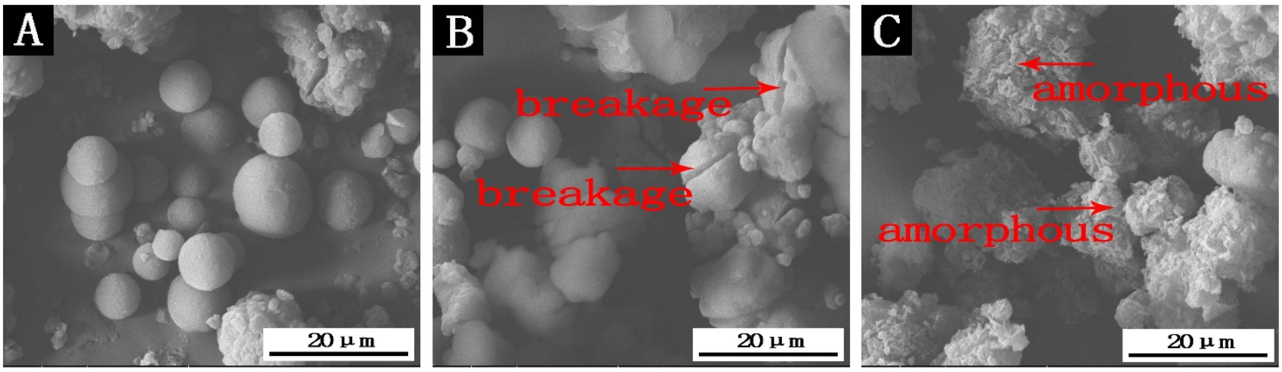

Figure 1. SEM images of microcapsules with different core to wall ratios: (**A**) 0.033, (**B**) 0.100, and (**C**) 0.167.

The microcapsules were added to the waterborne paint topcoat and SEM analysis was carried out to determine the distribution pattern of the discolouring powder microcapsules in the coating film. As can be seen in Figure 2, the waterborne coating topcoat with microcapsules increased as the microcapsule powder content increased, the coating became rough on the surface, particulate matter was evident, and the microcapsules were easily agglomerated in the coating.

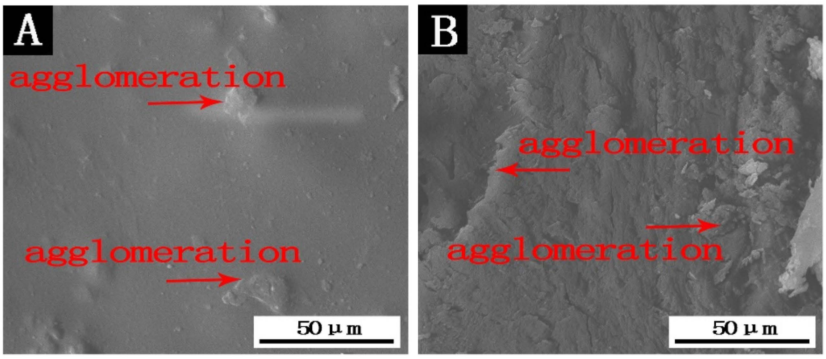

Figure 2. SEM diagrams of topcoat films with different discolouring powder microcapsule content: (**A**) 1.0% and (**B**) 13.0%.

3.2. Infrared Spectrum Analysis

The use of infrared spectral resolution can provide much information about functional groups and can help to determine some or even all molecular types of substances and their structures [36]. The infrared spectrograms (Figure 3) of microcapsules of varying levels of colour–changing powders coated with urea–formaldehyde resins show the presence of –OH and –NH stretching vibrations in the range 3300–3500 cm^{-1}. All urea–formaldehyde resins contain hydroxymethyl and ether bonds, which have broad strong absorptions in 1110–1000 cm^{-1} and 1600–1500 cm^{-1} (strong absorptions in phthalamide bands I and II). By these characteristic absorption peaks, it can be basically determined that the microencapsulation is successful. In the pure colour–changing powder infrared spectrum, 3431cm^{-1} is the –OH stretching vibration peak of melamine, and 2930 cm^{-1} and 2853 cm^{-1} are the stretching vibration peaks of melamine alkane C–H. By comparing the characteristic absorption peaks in the graph, it can be basically determined that the microcapsules contain colour–changing powder.

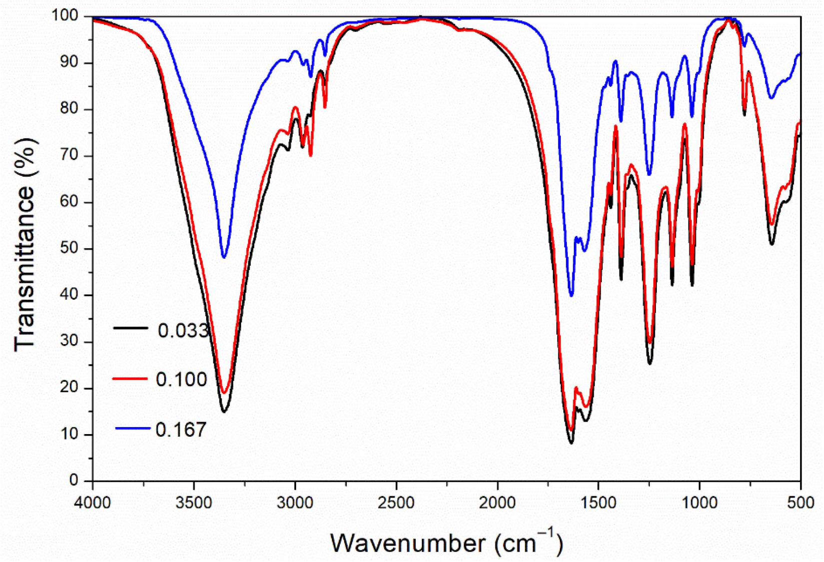

Figure 3. Infrared spectroscopy of microcapsules with different core–to–wall ratios.

The change in the molecular structure of the compound causes a change in the colour of the system. The gain or loss of electrons with temperature is reversible and therefore the colour change of the compound is also reversible. From infrared spectroscopy of microcapsules with different discolouring powder contents covered with urea–formaldehyde resin and infrared spectroscopy (Figure 4) of waterborne coatings with different microcapsule contents, it can be concluded that the microcapsules contain urea–formaldehyde resin and discolouring powder substances.

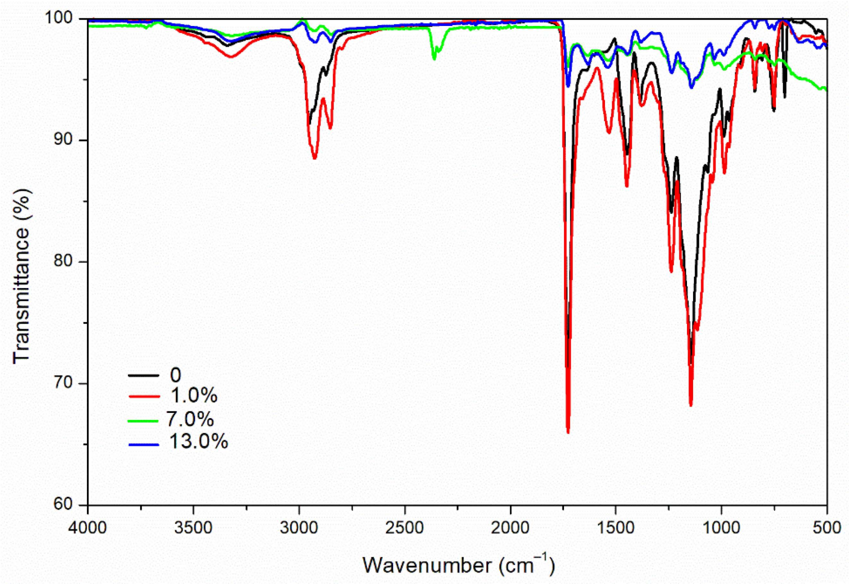

Figure 4. Infrared spectroscopy of microencapsulated incorporated waterborne coatings with different discolouring powder microcapsule contents.

3.3. Influence of the Microcapsule Content of Colour–Changing Powder on the Optical Properties of Waterborne Topcoat Films on Linden Wood Surfaces

3.3.1. Influence of the Microcapsule Content of Colour–Changing Powders on the Colour Difference in Waterborne Topcoats on Linden Wood Surfaces

The colour change is recorded in units of 1 °C by heating a topcoat film with different levels of colour–changing powder microcapsules from room temperature (25 °C) to 35 °C and stopping the heating to bring it slowly down to room temperature (Table 3). A positive value indicates a brighter surface colour and a negative value indicates a darker surface colour. a indicates a change in colour from red to green, with a positive value indicating a reddish colour and a negative value a greenish colour. b indicates a change in colour from yellow to blue, with a positive value indicating a yellowish surface colour and a negative value a blueish colour. c indicates colour saturation, and H indicates hue. ΔL (difference in lightness) = L_1 _ L_2, Δa (difference in red–green) = $a_1 - a_2$, Δb (difference in yellow–blue) = $b_1 - b_2$. The colour difference is calculated according to the following formula (1):

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

Table 3. Colour value of the coating with the core wall ratio 0.033 colour–changing powder microcapsules from room temperature 25 °C to 35 °C.

Colour–Changing Powder Microcapsule Content (%)	Colour	25 °C	26 °C	27 °C	28 °C	29 °C	30 °C	31 °C	32 °C	33 °C	34 °C	35 °C
1.0	L	+58.0	+58.0	+56.7	+56.3	+56.3	+56.1	+56.5	+56.2	+56.2	+56.2	+57.0
	a	+19.9	+19.9	+20.1	+20.7	+20.7	+20.5	+20.4	+20.8	+21.0	+21.0	+21.2
	b	+33.1	+33.1	+33.4	+32.4	+32.4	+32.7	+32.9	+33.6	+32.8	+32.8	+32.6
	c	38.6	38.6	39.0	38.5	38.5	38.6	38.7	38.8	39.0	39.0	38.9
	H	58.9	58.9	58.9	57.4	57.4	57.8	58.2	58.2	58.3	57.3	56.9
3.0	L	+68.8	+68.4	+67.0	+67.5	+67.4	+62.4	+66.9	+66.1	+68.4	+69.0	+67.8
	a	+14.6	+14.9	+14.8	+14.9	+15.3	+14.3	+15.4	+15.3	+14.8	+14.1	+14.9
	b	+29.2	+27.9	+28.3	+27.7	+27.4	+27.4	+27.5	+27.5	+27.9	+28.1	+28.0
	c	32.7	31.7	32.0	31.5	31.4	30.9	31.5	32.0	31.6	31.4	31.7
	H	63.4	62.7	62.3	61.7	60.8	62.4	60.6	62.0	62.1	63.3	61.9
5.0	L	+66.0	+63.0	+62.8	+62.5	+62.9	+62.6	+63.2	+62.8	63.3	+62.8	+62.8
	a	+17.9	+18.3	+18.3	+18.4	+18.5	+18.8	+18.6	+17.8	+18.1	+18.7	+18.2
	b	+28.1	+28.0	+27.5	+27.9	+27.4	+27.2	+26.5	+26.0	+26.3	+26.2	+26.1
	c	35.8	33.4	33.1	33.4	33.1	33.1	32.4	32.5	32.4	32.9	31.8
	H	56.6	56.7	56.3	56.5	55.3	55.5	54.9	56.7	55.9	55.2	55.0
7.0	L	+65.4	+64.4	+64.2	+63.7	+63.5	+63.7	+64.0	+65.0	+63.3	+65.2	+64.9
	a	+15.8	+15.6	+15.4	+15.3	+15.8	+15.1	+15.4	+15.2	+15.4	+15.2	+15.5
	b	+26.1	+25.1	+25.2	+25.8	+24.9	+24.6	+24.3	+24.0	+24.3	+24.5	+24.4
	c	30.5	29.6	29.6	30.0	29.5	29.2	29.0	29.3	29.3	29.7	30.2
	H	58.7	58.1	58.5	59.2	57.6	58.8	56.9	58.6	58.3	59.1	59.0
9.0	L	+65.0	+66.1	+66.0	+66.6	+66.2	+65.9	+67.0	+66.3	+67.0	+66.0	+67.0
	a	+14.2	+13.4	+13.6	+13.6	+14.1	+14.0	+13.3	+16.3	+15.3	+14.3	+13.3
	b	+22.6	+22.5	+22.5	+21.6	+21.0	+21.0	+21.2	+21.2	+21.1	+20.6	+20.7
	c	26.7	26.2	26.5	25.5	25.3	26.2	25.5	26.8	25.5	25.1	25.5
	H	57.9	59.2	59.0	57.7	56.1	55.5	58.3	52.4	58.3	55.3	58.3
11.0	L	+70.5	+70.1	+70.3	+70.4	+70.3	+70.2	+70.4	+70.5	+69.1	+70.1	+70.2
	a	+14.3	+14.0	+14.2	+14.1	+14.1	+14.1	+14.2	+13.9	+14.4	+14.2	+14.0
	b	+24.4	+24.6	+24.0	+23.3	+23.0	+22.8	+22.7	+22.6	+22.2	+22.0	+22.5
	c	28.3	28.4	28.3	28.2	28.1	27.5	27.0	27.0	27.4	26.5	27.2
	H	59.5	60.2	60.1	59.3	59.5	59.0	58.0	59.0	53.3	56.9	58.9
13.0	L	+66.1	+66.1	+66.3	+66.3	+66.2	+66.3	+65.2	+65.7	+66.9	+65.5	+66.7
	a	+14.1	+14.1	+13.9	+13.8	+13.8	+13.8	+13.2	+14.5	+14.6	+15.1	+14.4
	b	+21.7	+21.7	+21.1	+21.0	+21.0	+20.8	+20.0	+20.3	+19.5	+19.1	+19.3
	c	25.9	25.9	26.2	26.2	26.2	25.8	25.2	25.1	24.4	24.4	25.7
	H	56.8	56.8	57.3	56.8	56.8	57.0	55.6	54.5	53.1	51.6	55.8

From Tables 3–5 and Figure 5 analysis, based on the analysis of the range of colour difference values, by the temperature–sensitive colour–change powder warming colour difference change in the folding line graph can be seen. The colour–change powder content of 5.0% of the paint film heated to a 31 °C colour gap, a difference value of 2.1; colour–change powder content of 11% of the paint film heated to a 32 °C difference value of 2.4. Therefore, the preliminary view is that with colour–change powder content of 5.0%–10.0%, the paint film has a better colour change and the colour change is reversible [37].

Table 4. Colour difference value of the coating with the core wall ratio 0.033 colour–changing powder microcapsules.

Colour–Change Powder Microcapsule Content (%)	b–Value (25 °C)	Minimum b–Value	Variation of b–Value
1.0	33.1	32.4	0.7
3.0	29.2	27.4	1.8
5.0	28.1	26.0	2.1
7.0	26.1	24.0	2.1
9.0	22.6	20.6	2.0
11.0	24.4	22.0	2.4
13.0	21.7	19.1	2.6

Table 5. Analysis table of colour difference value range.

Scope	Colour Difference
0–0.25	Very small or none
0.25–0.5	Tiny
0.5–1.0	Tiny to medium
1.0–2.0	Moderate
2.0–4.0	There is a gap
4.0 and above	Very large

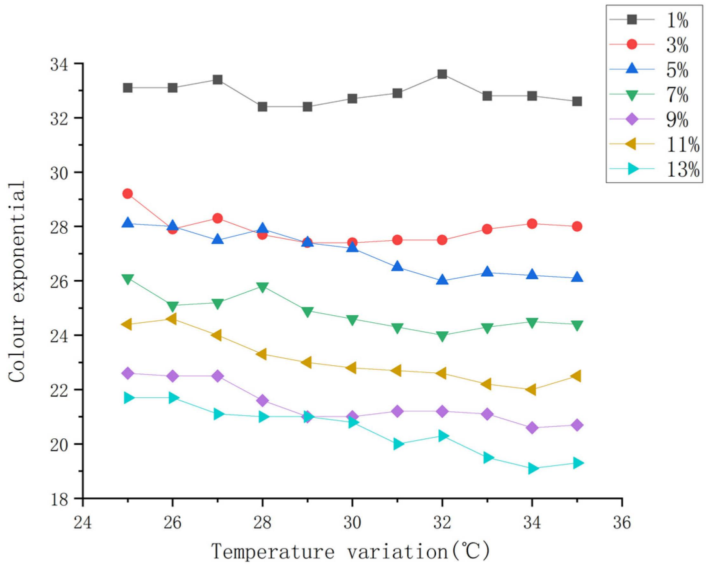

Figure 5. Colour–change diagram of water–based coating microcapsule with core wall ratio of 0.033 colour–changing powder b–value when heating up.

3.3.2. Influence of the Microcapsule Content of Colour–Changing Powder on the Gloss of Waterborne Topcoats on Linden Wood Surfaces

The effect of different levels of colour–changing powder microcapsules on the change in gloss of the paint film was observed by irradiating the colour–changing paint film with different light incidence angles. The change in the gloss of the film is reflected by irradiating the film with the same intensity of light at different angles of incidence. The three angles of incidence of light used in this study were 20°, 60°, and 85°, as shown in Table 6. As can be seen from Table 6, the gloss of the paint film decreased significantly as the microcapsule content of the colour–changing powder increased. The gloss of the paint film increased as the angle of incidence increased with the addition of the same microcapsule content of the colour–changing powder. This is due to the fact that the increase in microcapsules increases the roughness of the film and makes the incident light more susceptible to diffuse reflection. The highest gloss level was achieved when the microcapsule content was 1.0%. As the core–to–wall ratio increases, the gloss of waterborne coatings with the same microcapsule content gradually decreases.

Table 6. Analysis table of colour difference value range.

Colour–Change Powder Microcapsule Content (%)	20° Gloss (%)	60° Gloss (%)	80° Gloss (%)
0	7.7	31.5	48.5
1.0	3.4	15.6	14.9
3.0	2.5	13.7	12.4
5.0	2.4	11.7	6.7
7.0	2.2	10.5	4.3
9.0	1.8	5.0	2.0
11.0	1.4	4.1	1.6

3.4. Influence of the Microcapsule Content of Colour–Changing Powder on the Mechanical Properties of Waterborne Topcoats on Linden Wood Surfaces

Under good lighting conditions, the peeling of the coating on the cutting surface (with a magnifying glass) was visually checked. The correct scribing interval (choice of tool) should be chosen according to the actual substrate used and the thickness of the coating, while the peeling tape should not be adhered to the board for too long, and the peeling needs to be fast and smooth to ensure that the pattern on the tape is clear and easy to observe. This is achieved by observing the degree of peeling of the paint from the surface of the test tape. The adhesion can be divided into six levels according to the degree of shedding, from levels 0 to 5 of coating adhesion in decreasing order, with level 5 being the worst. The 1.0% microcapsule content of the board: level 2. The 3.0% microcapsule content of the board: level 2. The 5.0% microcapsule content of the board: level 2. The 7.0% microcapsule content of the board: level 1. The 9.0% microcapsule content of the board: level 1. The 11.0% microcapsule content of the board: level 2. The 13.0% microcapsule content of the boards: level 2. Based on the experimental data, the best adhesion performance was achieved at 7.0% and 9.0% microencapsulation. The higher the core–to–wall ratio, the better the adhesion when the same microcapsule content is added to the waterborne coating.

Impact resistance refers to the ability of the coating applied to wood to withstand rapid deformation at high rates of gravity without cracking. If the coating cannot withstand the impact, it will easily peel off from the surface of the object and lose its decorative and protective effect. The painted board is placed flat on the iron drill at the bottom of the apparatus, with the film side facing upwards, and the hammer is lifted with both hands to the desired height, then the hands are naturally released to allow the hammer to fall freely and impact the board. The test is repeated with a maximum height that does not cause damage to the paint film to indicate the impact resistance of the paint film. The board should be kept close to the surface of the iron drill during the measurement so that the results are not affected by the bouncing of the board during the impact of the hammer. The result is expressed in centimetres (cm) as the maximum height at which the film can be deformed without causing damage. It was found that the colour–change powder microcapsules had an effect on the impact resistance of the waterborne paint film. Table 7 shows that the maximum impact resistance of the paint film is the highest when the colour–changing powder microcapsules are 5.0% and the coating has the best impact resistance.

Table 7. Effect of the content of colour–changing powder microcapsules on the impact resistance of topcoat paint film.

Performance	Microencapsulated Content 1.0%	3.0%	5.0%	7.0%	9.0%	11.0%	13.0%
Impact resistance (kg·cm)	7.0	8.0	10.0	9.0	8.0	8.0	7.0

4. Conclusions

In this study, linden wood is used as the base material, and the wood water–based topcoat is used as the paint base. Optical property, mechanical property, electron microscope scanning, and infrared spectroscopy tests are conducted to investigate the content of colour–changing powder microcapsules for the best overall performance of the paint film. The purpose of this study is to investigate the performance of the wood material and its improvement effect, so as to extend the service life of the wood material. Comparing the microcapsules with three different core–to–wall ratios of 0.033, 0.100, and 0.167, the 0.033 core–to–wall ratio microcapsules were prepared more successfully. When the temperature was gradually increased from 25 °C to 35 °C, the colour of the coating changed significantly and the amount of change in the b–value of the coating colour increased with increasing microcapsule content. When the microcapsule content was 13.0%, the amount of change in b–value was as high as 2.6. As the microcapsule content increases, the gloss of the coating gradually decreases, with the best gloss of 15.6% at 1.0% microcapsule content. The coating adhesion is level 2 at 1.0%–5.0% and 11.0%–13.0%, and level 1 at 7.0% and 9.0%. The impact resistance of the waterborne topcoat is influenced by the microcapsule content of the colour–changing powder, with the best impact resistance of 10 kg·cm at 5.0%. In terms of combined mechanical and optical properties, 5.0% is the best overall performance of the waterborne topcoat film in terms of colour–changing powder microcapsules. The colour change of the microcapsules of the colour–changing powder incorporated in the water–based finish is reversible under heating and cooling conditions. In practical furniture applications, the microcapsules prepared by this experiment can change colour in appearance according to the actual temperature and play a decorative role.

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