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A new insulating coating with characteristics of sand texture and imitation ceramic

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HIGHLIGHTS

- The coating mainly consists of hollow microcapsule materials.
- The coating has a lower thermal conductivity and a imitation ceramic decorative effect.
- The coating has good adhesive, mildew and corrosion resistance, and good acid and alkali resistance.

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ABSTRACT

A new type of multi-functional and cost-effective insulating coating is prepared by mixing a class of hollow microcapsule powder and adhesive of melamine urea–formaldehyde resin of hollow microcapsule material. The new insulating coating shows great property of heat preservation, sand texture and decorative effect of imitation ceramic. The results show that the best formula of the insulating coating is one part of hollow microcapsule powder to three parts of adhesive. The coating has good adhesive, mildew and corrosion resistance, acid and alkali resistance. The coating's maximum degradation temperature rate T_p is up to 410 °C, which is higher than that of commercial coating (86 °C). Moreover, its density and thermal conductivity is 0.780 g/cm^3 and 0.055 W/(m K), respectively.

1. Introduction

The field of building energy conservation applications has attracted a great deal of scientific interest in the decades [1]. Many new types of building materials with heat-retaining properties were developed [2–5]. Among those technologies of building energy conservation, the insulating coating for simultaneously heat preservation and storage, is one of the hottest topics. Nowadays, the common insulating coatings [6,7] used for heat preservation are produced by adding solid heat preservation materials or hollow insulating materials like sepiolite and perlite with low thermal conductivity [8–10]. These materials have moderate price and excellent insulating effect. However, they are poor ornaments with low cost performances, and the raw materials for producing the coatings are limited.

Lately, microcapsule containing phase change material is used to prepare insulating coatings with good heat storage effect. This class of coating has received increasingly attention [11–15]. But the product has single function, high density and low performance-price ratio, which limits its utilization. In this study, a new imitation ceramic coating material with great heat preservation effect and good ornament was prepared [16–18]. Then, the characteristics of the coating were tested. In addition, and the optimal formula of the coating was investigated.

2. Materials and methods

2.1. Materials

All materials were presented in Table 1 and used as received without further treatment.

2.2. Preparation of hollow microcapsule powder

The hollow microcapsule powder was prepared using orificing method with the yeast extract and chitosan extracted from waste yeast and shrimp crab shell as raw materials.

A total of five different solutions, including sodium alginate solution, chitosan solution, yeast extract solution, polyvinyl alcohol solution and span-60 solution, were prepared from distilled water using the following formulas:

1. Sodium alginate solution: 1.2 g sodium alginate + 80 ml distilled water at 65 °C.
2. Chitosan solution: 1.2 g chitosan + 1.5 ml acetic acid + 50 ml distilled water at 65 °C.

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Table 1
Materials.

Code materials	Product description	Chemical identification	Commercial information
1. Water	Liquid	Single-distilled	Self-produce
2. Yeast extract	Paste	Technical pure	AYIC
3. Chitosan	Powder	Deacetylated degree of 80.0–95%	China PGCRCL
4. Span-60	Powder	AR	China PGCRCL
5. Glutaraldehyde	Liquid	AR	China PGCRCL
6. Formaldehyde	Liquid	AR	China PGCRCL
7. Sodium hydroxide	Powder	AR	China PGCRCL
8. Urea	Powder	CP	China PGCRCL
9. acetic acid	Liquid	36%, CP	China PGCRCL
10. Sodium alginate	Powder	PT	GGCPCL
11. Melamine	Powder	PT	LCHCCL
12. Glue 808	Liquid	PT	NJCP
13. Glue 606	Liquid	PT	NJCP
14. Butadiene Latex	Liquid	PT	BTCL
15. White cement	Powder	PT	GYBMCL
16. Emulsion coating	Liquid	PT	GYBMCL
17. Titanium dioxide	Powder	PT	GYBMCL

AYIC: Angel-Yeast incorporated company (Shanghai, China).
PGCRCL: Pharmaceutical group Chemical Reagent Co., Ltd. (China).
GGCPCL: Guangdong Guanghua Chemicals plant Co., Ltd. (Guangdong, China).
LCHCCL: Laiwu City Hongyuan Chemical Co., Ltd. (Laiwu, China).
NJCP: Nanhai Jiamei Chemical Plant (Foshan, China).
BTCL: Biyuan Technology Co., Ltd. (Tianjing, China).
GYBMCL: Guangzhou Youfa Building materials Co., Ltd. (Guangzhou, China).

3. Yeast extract solution: 5.9 g yeast extract + 40 ml distilled water in 24–26 °C.
4. Polyvinyl alcohol solution: 6.7 g polyvinyl alcohol + 1000 ml distilled water at 95 °C.
5. Span-60 solution: 0.32 g span-60 + 40 ml distilled water at 65 °C.

The hollow microcapsule powder was prepared by the following five-step procedure. First, span-60 solution was rapidly stirred for 45 min to get emulsifying micro air bubbles by orificing method. Next, the chitosan solution, polyvinyl alcohol solution, yeast extract solution and sodium alginate solution were in turn added into the emulsified span-60 solution, and the mixture was stirred constantly in ice bath for 40 min forming microscopic air sacs due to agglomeration. Then, the pH value of mixture was adjusted to about 7.0 by adding sodium hydroxide solution, and 3 ml glutaraldehyde was added to form stable micro air bubbles due to the cross-linking of chitosan and glutaraldehyde. Afterwards, the pH value of mixture was adjusted to about 8.0 using sodium hydroxide solution to form the microcapsule powder. Finally, the microcapsule powder was poured through 40-mesh screen, washed and dried. Subsequently, the hollow microcapsule powder was obtained.

Orificing method: When gas is passing though micropores under pressure, a mass of bubbles can be generated in the emulsifier. Then, microcapsules can be formed by coacervation reaction.

2.3. Preparation of hollow microcapsule emulsion

The prepolymer of melamine urea–formaldehyde resin was, in turn, prepared by mixing 90 ml of 36% formaldehyde, 9 g urea and 20 ml distilled water with 30 g melamine. Then, the pH value of mixture was adjusted to about 6.5–7.0 using 36% acetic acid, and the mixture was heated up slowly to 65 °C with constantly stirring to clarify the solution. Finally, the clear solution was added into 30 ml alcohol with constant stirring for another 10 min, and then the prepolymer of melamine urea–formaldehyde resin was obtained. The span-60 solution was prepared by adding 1.5 g span-60 into 45 ml distilled water at 65 °C and dissolving span-60 through heating the mixture up to 90 °C with constantly stirring. Then, the span-60 solution was kept at 60 °C.

The hollow microcapsule emulsion was prepared by the following three-step procedure. First, the span-60 solution was sparged in air or carbon dioxide and rapidly stirred for 45 min, and then 50 ml melamine urea–formaldehyde resin solution was added with constantly stirring for 30 min. Next, another 50 ml melamine urea–formaldehyde resin solution was added. After stirring for another 30 min with slowly heating up to 68 °C, the solution was bleached. Finally, the solution was gotten thickened by stirring, the emulsion of hollow microcapsule was obtained after stirring 30 min.

2.4. Preparation of insulating coatings

The insulating coatings with characteristics of sand texture and imitation ceramic were prepared by mixing the hollow microcapsule emulsion and hollow microcapsule powder according to a certain proportion. In order to find the appropriate proportion, six different proportions were investigated (Table 3g–l). Meanwhile, the control experiments were carried out as following: several other kinds of coatings were made by mixing hollow microcapsule powder or titanium pigment with adhesive like glue 808, glue 606, butyl benzene latex, white cement or hollow microcapsule emulsion according to a certain proportion (Table 2a–f).

2.5. Particle size

The morphologies of hollow microcapsule particles in emulsion were observed by a Nikon YS 100 digital biological microscope. A typical microphotograph is shown in Fig. 1. The coating dusts were spherical and had sizes of 5–50 μm.

2.6. Heat-insulating property

The thermal conductivity of the coating material was measured using a ZKY-BRDR thermal testing device (Manufacturer: Chengtu ZKY Instruments Co., Ltd. (Chengtu, China), Model: ZKY-BRDR). The coating was firstly painted 1.0 cm evenly on a plywood with 30 cm of the length. Then, the painting plate was peeled after dried completely, and was put into a thermal conductivity measuring apparatus to measure its temperature difference thermoelectric potential. The thermal conductivity was calculated according the following four formulas:

$$\lambda = \frac{q_c h}{2\Delta T} \tag{1}$$

$$q_c = \frac{V^2}{2SR} \tag{2}$$

$$S = A \times 0.30 \times 0.30 \tag{3}$$

Table 2
Formula and thermal conductivities of coating.

Code	Formula of coating (wt.%)			TCC (W/(m K))
	HMP	TD	Adhesive	
(a)	25.00	25.00	50.00 glue 808	–
(b)	25.00	25.00	50.00 glue 606	–
(c)	25.00	25.00	50.00 butyl benzene latex	–
(d)	25.00	25.00	50.00 white cement	0.182
(e)	25.00	25.00	50.00 hollow microcapsule emulsion	0.103
(f)	25.00	–	75.00 hollow microcapsule emulsion	0.055

TCC: Thermal conductivity of the coating.
HMP: Hollow microcapsule powder.
TD: Titanium dioxide.