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Preparation of nano-sized hydrophilic aluminum fins coating materials for air conditioner①

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[Abstract] Semicontinuous seeded emulsion copolymerization of acrylic acid, acrylamide and divinylbenzene was carried out at 80 ℃ with ammonium persulphate as the initiator and the polyether with comb configuration as the emulsifier to prepare approximately mono-dispersed nano-sized polymer particles with average diameter 90 nm. The particles were used to combine with special polyether and de-ionized water was added to obtain nano-sized hydrophilic aluminum fins coating materials with solid content of 10%. The aluminum fins were coated with the materials to get the film showing self-assembly properties in some degree. The obtained hydrophilic fins have contact angles < 5° with de-ionized water, minimum value 0°, after 4 cycles of wet and dry, contact angles < 10° with de-ionized water.

[Key words] nano-sized polymer; hydrophilic fins; polyether
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1 INTRODUCTION

In the heat exchangers used in air conditioners, the condensed water produced during air-cooling becomes waterdrops and forms a water bridge between the fins of heat exchangers when the intervals between two fins are lower than 2 mm, narrowing the air passages. As a result, various inconveniences arise such as increased resistance to airflow, waste of electric power, generation of noise, scattering of water drops etc. With the development of air conditioners becoming smaller and smaller, even 1.2 mm intervals between fins are required, more serious water bridge phenomena will come forth.

In order to prevent above mentioned phenomena, it is now conducted to impart hydrophilicity on the surfaces of aluminum-made fins to prevent the formation of waterdrops and water bridge. In the present, the most of related references are patents, among them three kinds can be classified as: 1) Polymer-nano-sized inorganic materials composite[1], the main disadvantage is that the polymerizable vinylsilane monomer containing hydrolyzable alkoxysilane is very expensive, obtained particles diameter is large and contact angles of coated hydrophilic fins with de-ionized water are merely 20°; 2) Nano-sized polymer particles/polymer composite[2], the main disadvantage is that most particle diameter is larger than 300 nm, and the particles are difficult to move to the very small aperture in the aluminum fins. Thus adhesive strength with fins is low and the fins need to be treated by chemical treatment with such as chromate in advance, which will result in serious environment problem; 3) Simplex polymer or polymer and organic hydrophilic materials composite[3~8]. The fins coated by that kind of materials have bad hydrophilicity retention and the mold used in press forming undergoes severe abrasion. Normally, contact angles of the fins coated by the hydrophilic materials are 30° after several dry and wet cycles and thus it is difficult to meet with the need of air conditioners miniaturization. Refs. [9~12] studied the hydrophilic fins materials similar with the third. In this work, we attempt to prepare nano-sized hydrophilic aluminum fins coating materials for air conditioner.

2 EXPERIMENTAL

2.1 Materials

Commercially obtained divinylbenzene(Wujing Fine Chemicals Co, China) and reagent ammonium persulphate and acrylamide(Shanghai Zhenxing Reagent Co, China) were chosen. The reagent acrylic acid was distilled under vacuum. The polyether with comb configuration was made according to Ref. [13]. The polyether DC-100 was provided by Dongchang Petroleum & Chemical Factory, represented by the following formula:

$$\begin{array}{l} \quad\quad O(XO)_{k_1}H \\ \quad\quad\quad | \\ CH_2\ CHCH_3 \\ | \\ O(XO)_{k_2}H \end{array}$$

where X —CH_2CH_2O and $CH(CH_3)CH_2O$; k_1 and k_2 are constants. The compositions of emulsion copolymerization were listed in Table 1.

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Table 1 Compositions emulsion copolymerization

Acrylic acid	Acrylamide	Divinyl-benzene	Ammonium persulphate	Comb polyether	DIW
6.0	12.0	2.0	0.15	14	80

Note: DIW-deionized water

2.2 Polymerization

Firstly, 6 g acrylic acid, 12 g acrylamide, 2 g divinylbenzene and 10 g polyether with comb configuration were placed in a flask with mechanical stirrer, then the stirrer ran at the speed of 350r/min to obtain monomers emulsion. Lastly 80 g DIW, 0.15 g ammonium persulphate, 4 g comb polyether and 8% monomers emulsion were placed in a flask provided a nitrogen inlet tube, an condenser, a dropping funnel and a mechanical stirrer, and heated to 80 ℃. Into the flask contents were dropwise added in 5 h. Thereafter, the flask contents were kept at same temperature for 1h to obtain a dispersion of nano-sized hydrophilic polymer particles with average diameter about 90 nm.

2.3 Preparation of nano-sized hydrophilic fins coating materials

30 g nano-sized polymer particles prepared by paragraph 2.2 and 10 g polyether DC-100 were mixed. The water was added to obtain a final nano-sized hydrophilization composition with a solid content of 10%.

2.4 Coating method

The nano-sized hydrophilic fins coating materials were coated on an aluminum plate with a thickness of 0.11 mm, which was subjected to degreasing using gasoline and an aqueous solution containing 5% sodium hydroxide, then drying. The coating materials were baked using hot air of 250 ℃ for 20 s.

2.5 Characterization

The microstructure of particle was observed by TEM. The microstructures of surface and section of coated hydrophilic fins were characterized by SEM. The contact angles of hydrophilic fins with water were determined by model JC-2000A measurement instrument of contact angle made by Shanghai Zhongchen digital Ltd. Co.

3 RESULTS AND DISCUSSION

3.1 TEM image of nano-sized polymer

TEM image of nano-sized polymer is shown in Fig. 1. It can be seen from Fig. 1 that nano-sized polymer particles are well distributed, which shows the film coated on the fins possess self-assembly properties in some extent. The capillary resulted in close and orderly arrangement of the polymer particles with same diameter with the evaporation of solvent when the polymer particles were rolled out on the surface of aluminum fins[14, 15].

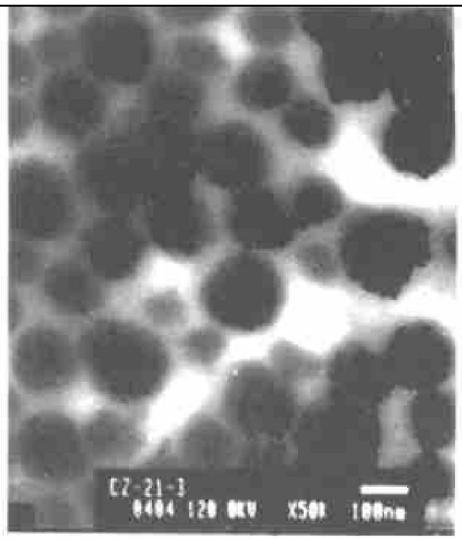

Fig. 1 TEM image of nano-sized polymer

3.2 Effect of mass ratio of nano-sized polymer to polyether DC-100 on hydrophilicity and its retention of coated fins

Nano-sized polymer particles and polyether DC-100 existed in different forms in the coated film. The nano-sized polymer particles acted as the knot of a network and the polyether acted as the link among the knots if the film was regarded as a network. The different mass ratios of nano-sized polymer to polyether DC-100 leaded to different densities of knots and links, which resulted in the difference of hydrophilicity of coated film. The experimental results were listed in Table 2.

Table 2 Effect of mass ratio of nano-sized polymer to polyether DC-100 on initial and lasting contact angle θ of coated film

Mass ratio	Contacting angle with water(θ)				
	Initial value	After one cycle	After two cycles	After three cycles	After four cycles
0.2	0	37.86	44.65	45.67	47.85
0.4	0.60	25.56	31.52	33.56	35.73
0.6	0	0	7.85	8.86	9.93
1.0	0	6.78	10.67	12.34	14.65
3.0	0	11.32	13.86	14.65	18.97

Note: the sample was placed in the water flowing at the speed of 15 $kg \cdot m^{-2} \cdot h^{-1}$ at room temperature for 8h, followed by drying at 80 ℃ for 16 h. The process described mentioned above was called as a cycle.

From Table 2, the initial contact angle of hydrophilic fins obtained by coating with de-ionized water had just less difference when mass ratio of nano-sized polymer to polyether DC-100 changed in certain range. But then the lasting contact angles had obvious differ-

ence. An optimum ratio 0.6 was determined according to our experiments and then the most sufficient retention of hydrophilicity could be achieved.

3.3 SEM image on section and surface of coated hydrophilic fins

To measure the film thickness of hydrophilic fins, the cross sections of the hydrophilic fins were measured under SEM. The image is shown in Fig. 2, apparently the thickness of the film is about 1 μm. To study the surface morphology of hydrophilic fins, its surface was scanned by SEM, as shown in Fig. 3. The painting of nano-sized hydrophilic fins coating materials was strictly carried through according to scheduled requirement and obvious self-assembly properties were displayed.

3.4 Effect of coating time on hydrophilicity of hydrophilic fins

Our experimental results showed that initial angles of hydrophilic fins with de-ionized water have less difference when coating time is different. The main reason is that diverse coating time results in variable film compact content. The fewer the coating time, the less compact the film, the easier the water permeating to the interface of aluminum bulk, which induced to swell partly and be brushed off and thus hydrophilicity becomes bad. The experimental results were listed in Table 3.

Fig. 2 SEM image on section of hydrophilic fins

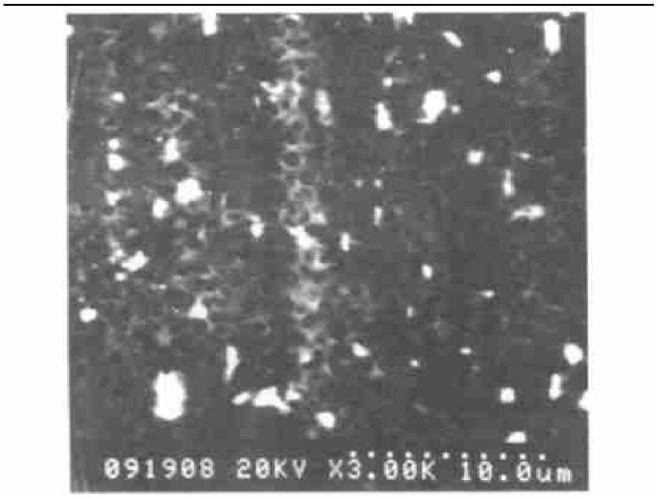

Fig. 3 SEM image on surface of hydrophilic fins

Table 3 Effect of coating number on hydrophilicity of hydrophilic fins

Coating number	Contact angle/(°)				
	Initial value	After one cycle	After two cycles	After three cycles	After four cycles
One time	0	4.85	46.50	48.60	50.45
Two times	0	0	7.85	8.86	9.93

4 CONCLUSION

Semicontinuous seeded emulsion copolymerization of acrylic acid, acrylamide and divinylbenzene is carried out at 80 ℃ with ammonium persulphate as the initiator in the presence of vast polyether with comb configuration as the emulsifier to prepare approximately mono-dispersed nano-sized polymer particles with diameter about 90 nm. The nano-sized polymer is combined with polyether DC-100 to obtain final products of nano-sized hydrophilic aluminum fins coating materials for air conditioner. The part of the polymer particles could embed into the gap among the aluminum materials. The functional group on the surfaces of the particles strictly combine with aluminum materials to make adhesion strength become high and lasting contact angles with water become low. Polyether DC-100 in the compositions has lubricative function, which is in favor of fast pressing of aluminum fins. In addition, the mold abrasion could be avoided because there was not organic materials in the composition.

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