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Stabilized dispersion of nano-ceramic coating①

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Abstract: The mechanism and effects of sodium carboxymethyl cellulose (CMC) as a dispersant on nano-ceramic aqueous suspension were examined by the measurements of ζ potential and the sedimentation test. The results show that proper addition of CMC to nano-ceramic coating exhibits an enhanced dispersity and stability compared to the coating without CMC; the stably dispersed nano-ceramic coating with excellent preformance was obtained with addition of 0.10% CMC to it in pH 7 to 8.

Key words: stability; dispersity; nano-ceramic coating
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1 INTRODUCTION

For many applications in ceramic coatings it is desirable to sinter at relatively low temperature. One method by which this goal can be accomplished was using submicrometer particles, such as nano-particles. But the agglomeration caused by the high surface energy of the nano-particles made it impossible to show the advantage of them, so homodispersed coating is necessary. On the other hand, in order to achieve a coating with uniform thickness, it was also advantageous to use homodispersed colloidal suspensions[1-4].

In general, suspensions can be dispersed by electrostatic, steric or electrosteric stabilization mechanisms[5-7]. Electrostatic stabilization is accomplished by generating a common surface charge on the particles. Steric stabilization, on the other hand, is achieved by adsorption of polymeric additives which serves to form protective colloids. Electrosteric stabilization requires the presence of adsorbed polymer or polyelectrolyte and a significant electrical double-layer repulsion. In general, nano-ceramic coating can be stabilized electrostatically, but improvement of the suspensions to better meet the requirements necessary for ceramic coating is possible by incorporating polymeric additives.

The coating examined in this paper contains a certain amounts of nano-particles. In order to obtain fully dispersed and stabilized suspension coating, sodium carboxymethyl cellulose (CMC) as a dispersant on nano-ceramic aqueous suspension is added, the mechanism and effects of CMC on the coating are investigated.

2 EXPERIMENTAL

2.1 Materials

The mixed oxide ceramic coating containing certain amounts of nano-particles was used in this experiment, which contains 25% (mass fraction) solids, and analytical-grade CMC was used as dispersant.

The water used was distilled and deionized. The pH value was adjusted with standardized analytical-grade HCl and NaOH solutions.

2.2 Evaluation of dispersion by sedimentation method

10 mL coating and various amounts of CMC were mixed together under an ultrasonic processor in six cylinders, and then the suspensions were allowed to stand for 72 h, and the states of precipitation were observed every 24 h, the volume percents of stabilized suspension, which was trepresented by the height of the stabilized suspension over the original height of the 10 mL coating in the same mixing vessel were noted.

2.3 Measurement of ζ-potential

The sample without CMC and the sample with 0.1% CMC that showed the best stability in all samples in the sedimentation test, were chosen for the measurement of ζ-potential for each particle in the suspensions. The ζ-potential versus pH for the coating was measured using zeta plus instrument made in America Brookhaven Company. The pH value was adjusted with HCl and NaOH solutions.

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3 RESULTS AND DISCUSSION

3.1 Observation of effects of CMC on nano-ceramic coating by sedimentation method

Table 1 shows the results of the sedimentation test for the coating with or without various amounts of CMC, i. e. the data of stabilized volume percents indicates the state of dispersion or precipitation of the nano-ceramic particles.

Table 1 Data of stabilized volume percents of each coating at different times

Sample No	w(CMC)/%	Stabilized volume fraction/%		
		24 h	48 h	72 h
1	0.05	91.8	88.8	85.7
2	0.10	92.0	90.0	88.0
3	0.15	91.8	89.8	85.7
4	0.20	91.8	89.8	83.7
5	0.25	81.6	72.5	66.3
6	0	84.0	80.0	70.0

Table 1 shows that the coating with 0.10% CMC (mass fraction) has the best stability. From Table 1, the following results can be reached: the stability of the coating becomes better and better when CMC changes from 0 to 0.10%, and the best stability is reached with 0.10% CMC. Furthermore, the stability shows decreasing trend when CMC increases further. A plausible explanation for this is as follows: when the content of CMC changes from 0 to 0.10%, CMC adsorbed on the particles in coating and made the particles present negative charge because of the ionization of CMC, thus effect of electrostatic stabilization is obtained. With the increase of CMC, the anchor group adsorbed on the particles more and more, and the saturated adsorption was reached at 0.10% CMC in the coating. Here, the adsorbed polyelectrolyte and a significant electrical double-layer were simultaneously presented, and electrosteric stabilization mechanism was achieved. Fig. 1 shows the conventional diagram for potential of electrosteric stabilization[8]. It shows that the main dispersing function is electrostatic stabilization when the particles are in near distance because of the electrostatic repulsion, and it is steric stabilization when the particles are in far distance. When more CMC was added into the coating, however, the super saturated adsorption shown in Fig. 2 happened[9, 10]. This will help to form bridging structure and reduce the hydrophile, which is of no advantage for wetting and dispersion.

3.2 Dependence of ζ-potential on pH of nano-ceramic coating with or without CMC

Fig. 3 shows the variation of the ζ-potential of each sample as function of pH. The ζ-potential of the sample in the absence of CMC exceeded − 35 mV only in the highly alkaline pH range of 9 to 11. On the other hand, the ζ-potential of the sample in the presence of 0.10% CMC retained a high negative value above − 35mV over a wider pH range of 6.5 to 11 than those in the absence of CMC. On addition of

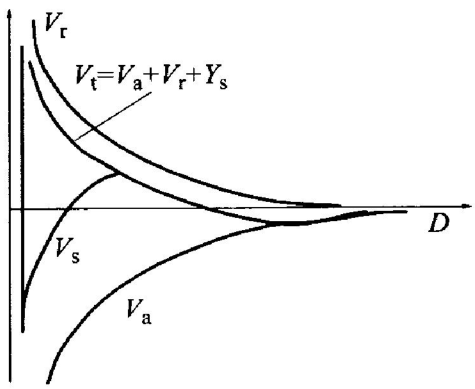

Fig. 1 Conventional diagram for potential of electrosteric stabilization
V_s —steric repulsion potential;
V_a —van der waals gravitation potential;
V_r —electrical double-layer repulsion potential;
V_t —total potential

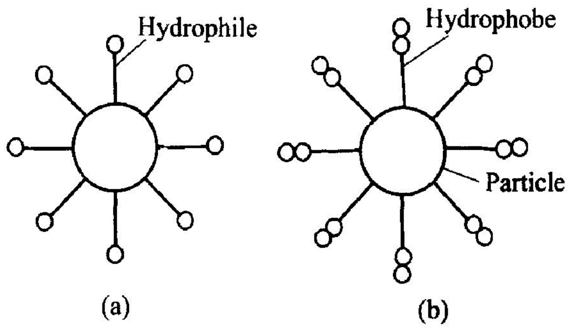

Fig. 2 Conventional diagram for adsorption of polyelectrolyte on particles in coating with CMC
(a) —Saturated adsorption;
(b) —Super saturated adsorption

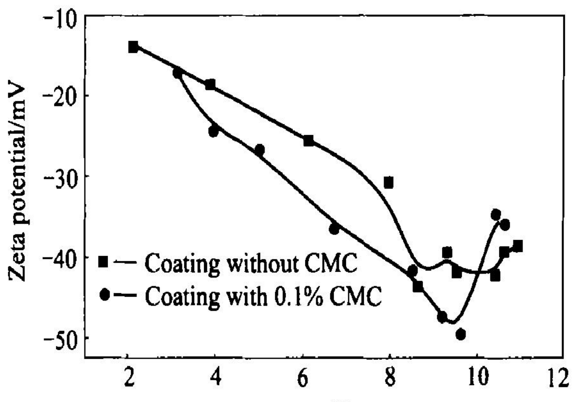

Fig. 3 ζ-potential of each coating as function of pH

CMC, the range of pH where ζ-potential exceeded −35mV was shifted to lower values of pH and extended to a wider pH range.

A high negative ζ-potential was obtained in a highly alkaline medium (pH = 9.5) with CMC. An alkaline coating, however, caused low value of viscosity as reported in Refs. [11, 12], which reduced the adhesive property of the coating on the substrate. Furthermore, alkaline coating exhibited corrosivity to the substrate, thus a neutral or weak alkaline coating is preferable for application. The coating including 0.10% CMC exhibited a higher ζ-potential around neutral or in the weak alkaline pH range of 7−8.

Fig. 4 shows the contrast of the coating with 0.10% CMC and the coating without CMC, the dispersion effect of the coating with CMC is better than that of the coating without CMC.

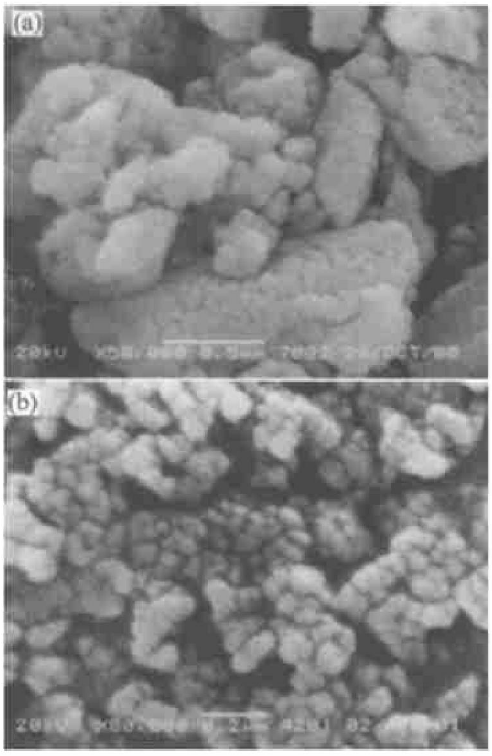

Fig. 4 SEM morphology of coating before and after dispersion

(a) —Before dispersion (without CMC);
(b) —After dispersion (with 0.10% CMC)

4 CONCLUSIONS

1) Proper addition of CMC to nano-ceramic coating exhibits an enhanced dispersity and stability compared to the coating without CMC.

2) The stably dispersed and excellent performance nano-ceramic coating is obtained with addition of 0.10% CMC to it in pH values range of 7 to 8.

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