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Short communication

Optimization of the rheological properties of yttria suspensions

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Abstract

To advance the rheological quality of yttria suspensions, the effects of three dispersants were evaluated and compared. It was found that after adding each of these dispersants, zeta potential moved toward negative direction and the pH_{IEP} shifted from basic to acidic. An increase of the pH could increase the absolute zeta potential. The fluidity and stability of yttria suspensions were examined by viscosity measurements and sedimentation tests.

Keywords: A. Slip casting; Yttria; Dispersant; Rheological properties

1. Introduction

Yttria ceramics have been developed in many practical and potential applications such as laser crystals [1], infrared-domes [2], nozzles [3], refractories [4] and components of semiconductor devices [5].

Generally, the forming methods for yttria ceramics are dry pressing and cold isostatic pressing (CIP) [1]. These methods are inconvenient to make complex-shaped ceramic bodies. Nevertheless, presently there are a few studies concerning wet forming methods of yttria slurries [6,7], which are successfully employed to form complex-shaped parts with several other ceramic materials. The possible reason is that it is difficult to prepare a suitable yttria suspension which is the prerequisite for wet forming.

To gain good aqueous yttria suspensions, three kinds of dispersants, i.e. Dolapix CE 64, Dispex A40 and Darvan C-N, were selected and evaluated. The effects of pH, dispersant type, and dispersant dosage on the dispersibility, stabilization and fluidity of the suspension were also studied.

2. Experimental procedure

The yttria powder was prepared by milling a commercial powder at 3000 rpm for 3 h and then calcined at 1000 °C for 2 h. Commercial yttria powder (Jiangyin Jiahua Advanced Material Resources Co., Ltd., China) consists of agglomerated platelet particles (Fig. 1) with a mean particle diameter of 2.0 μm and a BET surface area of 3.44 m^2/g. The morphology of the powders after milling is shown in Fig. 2. It consists of dispersed particles with a mean particle diameter of 0.92 μm.

Detailed characteristics of the dispersants are summarized in Table 1. Suspensions with 10–30 vol% were made by 2 h ball milling yttria powder, deionized water and dispersant. The dispersant dosage was based on the weight of yttria powder.

The zeta potential of the yttria particles in diluted suspension was directly measured by an electroacoustic method (Zeta Plus, Brookhaven Instruments Corp., USA). The rheological properties of suspensions were determined by a rotational rheometer (SR5, Rheometric Scientific, USA) at a shear rate ranging from 10 to 1000 s^{-1}. A sedimentation test was performed to evaluate the degree of particle dispersion in 10 vol% suspensions with different dispersants. Yttria suspensions were left standing for different times in 25 cm^3 cylinders, and then sedimentary height percent on the basis of the total suspension height was recorded with time.

3. Results and discussion

3.1. Zeta potential

The zeta potential of diluted yttria suspensions with and without dispersants are shown in Fig. 3. It can be seen that the addition of dispersant shifted zeta potential of the suspensions

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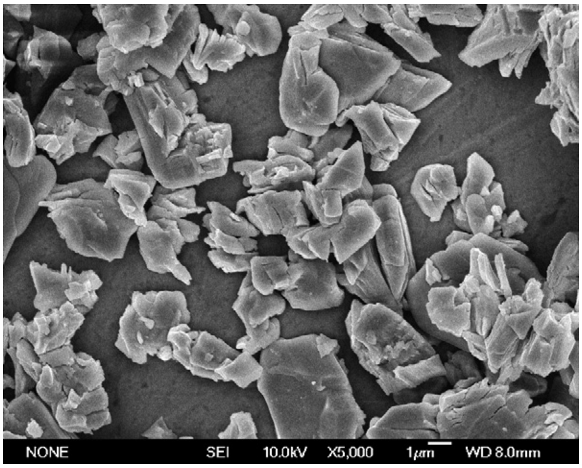

Fig. 1. SEM photograph of the commercial yttria powder.

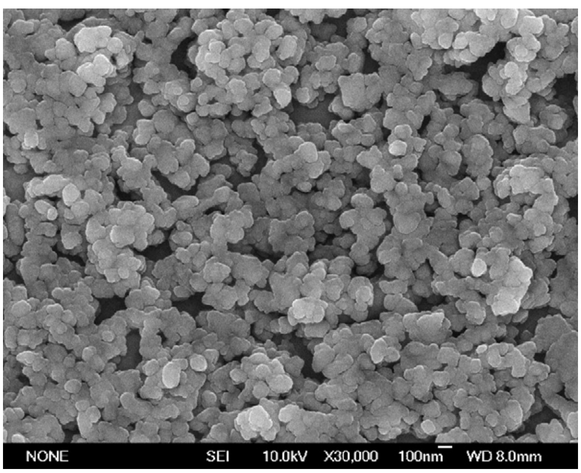

Fig. 2. SEM photograph of the yttria powder after attrition.

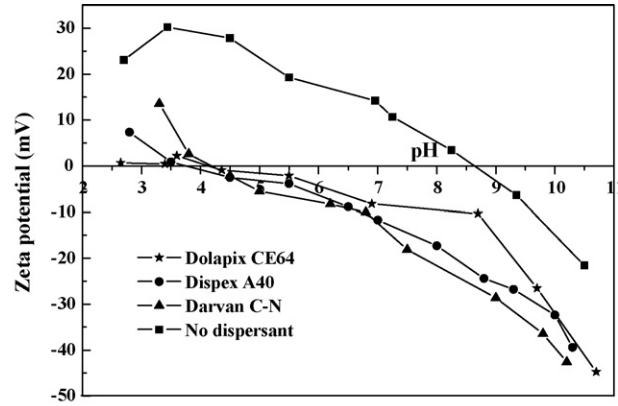

Fig. 3. Zeta potential of yttria as function of pH value with and without dispersants.

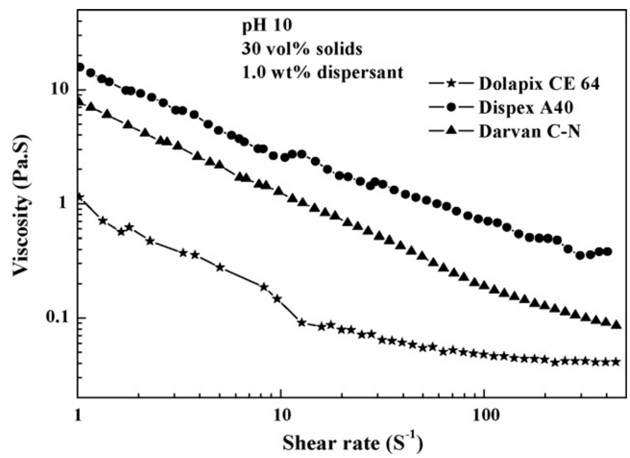

Fig. 4. Viscosity of 30 vol% yttria suspensions with the addition of various dispersants.

negatively and the isoelectric point (IEP) shifted from 8.7 to around 4. This IEP shift was attributed to the adsorption of the negatively charged dispersant on the positively charged surface of the yttria particles. Evidently, at pH 10, the absolute zeta potential values were about 40 mV, revealing that the presence of these dispersants made it possible to get stable suspensions. In a word, these three dispersants seemed to be efficient for the dispersion of yttria, and stable suspension with lower viscosity would result by adjusting the pH value to 10 [8–10].

3.2. Viscosity and stability

To compare the effects of dispersants on yttria suspensions, the viscosity and stability of suspensions with the three dispersants were examined. Fig. 4 shows the viscosity against shearing rate for 30 vol% suspensions at pH 10. It can be seen that the lowest viscosity happened when Dolapix CE 64 was added. However, for the suspension dispersed with Darvan C-N or Dispex A40, the viscosity was much higher than that with Dolapix CE 64.

Suspension stability was evaluated by sedimentation test. The effects of dispersants on sediment are shown in Fig. 5. It can be seen that the sedimentary height with Dolapix CE 64 was the lowest among the three dispersants, due to the formation of a flocculated network structure with Dolapix CE 64 which impedes particle sedimentation. So the suspension dispersed with Dolapix CE 64 exhibits the best performance in suspension fluidity and stability and can be easily handled and used successfully for casting.

Table 1
Properties of the aqueous solutions of the dispersants used

Dispersant	Dolapix CE 64	Dispex A40	Darvan C-N
Nomenclature	Polymethacrylate, ammonium salt	Polyacrylate, ammonium salt	Polymethacrylate, ammonium salt
Active matter (wt%)	70%	40%	25%
Density (g/cm^3)	1.10	1.16	1.10–1.12
pH	7	8.0	7.5–9.0
Molecular weight (g/mol)	300	4000	10,000–16,000

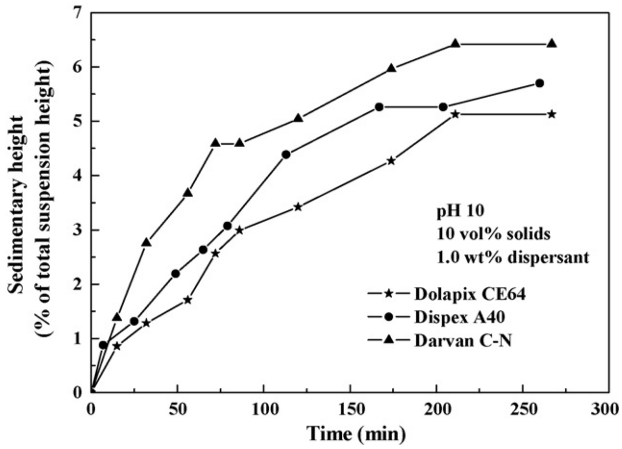

Fig. 5. Sediment behavior of yttria suspensions with the addition of various dispersants.

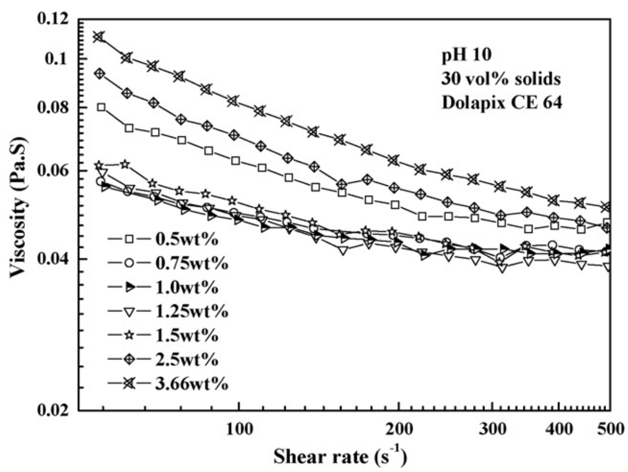

Fig. 6. Viscosity of 30 vol% yttria suspension as a function of Dolapix CE 64 dosage.

3.3. Dispersant dosage

To prepare excellent yttria suspensions, the effect of Dolapix CE 64 dosage on the viscosity of the 30 vol% yttria suspension at pH 10 is shown in Fig. 6. In the region of dispersant dosage 0.75–1.5 wt%, suspension viscosity was lower. Beyond this region, suspension viscosity had a significant increase. In general, low dispersant dosage is not sufficient to fully deflocculate the suspension and maintain the colloidal particles in dispersion. On the other hand, high dispersant dosage results in a significant shift in pH value, which would lead to higher ionic strength in the suspension and consequently affects its colloidal viscosity [11].

4. Conclusions

(1) Zeta-potential measurements showed that the addition of dispersant shifted the pH_{IEP} from 8.7 to 4.0. With increasing pH value, the absolute zeta potential became higher and higher in the presence of these dispersants.
(2) Dolapix CE 64 is a more effective dispersant compared with Dispex A40 and Darvan C-N via sediment test and rheological measurement.
(3) The optimum Dolapix CE 64 dosage was 1.0 wt% for suspensions with 30 vol% solid content.

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