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Research paper

Organic modification of bentonite and its effect on rheological properties of paper coating

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ABSTRACT

Objective: The effect of organic modified bentonite on rheological behavior of paper coating was studied to extend the use of bentonite in the paper industry.
Background: In the coating process, the paper coating was performed in various shear forces. Therefore, the rheological properties of the coating had profound effects on the quality of coated paper. In order to achieve the good rheology, paper coating required the addition of thickener or rheology modifiers. Organic bentonite was a kind of thixotropic ge1, which was extensively used in a number of applications as rheology modifier to modify the rheology and control the stability of systems.
Method: Na^{+}-bentonite was modified with diallyl dimethylammonium chloride and dodecyl trimethylammonium chloride, respectively. The organic bentonite was characterized by XRD and TGA and the rheological properties of paper coating containing organic bentonite were measured by rheometer.
Results: The XRD spectra showed that the 001 reflection of bentonite was shifted to a lower 2θ after the modification. Moreover, the modification with DTAC had more pronounced effect than with DADMAC. The TGA curve showed that one dehydration stage in the range of 30–155 °C was observed. For organic bentonite, thermal degradation took place in two stages. The first step was obtained in the temperature range of 250–600 °C and the second step took place between 600 and 900 °C. The addition of modified organic bentonite resulted in the increases of yield stress and viscosity of coating, and they increased when the amount of organic bentonite was increased. The flow characteristics fitted well with the Herschel–Bulkley model, and the rheological properties of paper coatings exhibited typical pseudoplastic behavior.
Conclusion: (1) The organic modifying agents were successfully inserted into the interlayer space of bentonite, the bonded amount of DADMAC and DTAC was 0.107 g/1 g Bent-DADMAC and 0.124 g/1 g Bent-DTAC, respectively; (2) organic bentonites had the thickening and promoting rheological function for paper coating; and (3) the paper coating containing organic bentonite exhibits the pseudoplastic fluid.

1. Introduction

Paper coating was mainly used to improve the appearance and printability of paper. The paper coating generally consisted of inorganic pigments such as kaolin and calcium carbonate, binder, soluble co-binders, dispersants, and other additives (Morsy et al., 2014). In the coating process, the paper coating was performed in various shear forces. Therefore, the rheological properties of the coating had profound effects on the quality of coated paper (El-Sadi et al, 2004). Better rheology of paper coating could result in the better surface quality of paper. In order to achieve the good rheology, paper coating required the addition of thickener or rheology modifiers. Carboxymethyl cellulose (CMC) was commonly used as a co-binder and thickener in paper coating (Kugge et al., 2004).

Bentonites were the layered aluminosilicate whose interlayer space was permeated with water and exchangeable cations (Liu et al., 2003). They met a wide range of application due to their layered structure, high cation exchange capacity, and swelling (Yeşilyurt et al., 2014). Organic surfactant cation (typically quaternary ammonium salt) could be intercalated into the bentonite to exchange inorganic cation via a cation exchange mechanism (zcan et al., 2007; Paiva et al., 2008), leading to the increase of basal spacing. Thus, this modification was termed as organic bentonite and the surface properties changed from hydrophilic to hydrophobic form (Groisman et al, 2004; Paiva et al., 2008).

Organic bentonite was a kind of thixotropic gel (Lei et al., 2006), which was extensively used in a number of applications, such as paints (Cinku et al., 2000), coatings (Choudalakis and Gotsis, 2014), ceramics,

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pesticides, pharmaceuticals, cosmetics, medicines (Jones, 1983; Murray, 2000), drilling fluids (Silva et al., 2014), and rheology modifiers (Cinku et al., 2000; Borah and Chaki, 2012; Bhatt et al., 2013) to modify the rheology and control the stability of systems.

So far no reports were made to study the effect of organic bentonite on rheological properties of paper coating. Thus, the main objective of this study was to investigate the effect of organic bentonite on rheological properties of paper coating as thickener. Herein, it was based on the color ink jet paper coating as sample, which was waterborne paint. On the other hand, the hydrophobicity of organic bentonite was increased with the basal spacing increase (Chen et al., 2000). Considering the organic bentonite dispersed in water system, diallyl dimethylammonium chloride and dodecyl trimethylammonium chloride, with short chain, were selected as the modifier agent for bentonite. The foundation of inexpensive bentonite broadened the use in the paper industry was expected.

2. Materials and methods

2.1. Preparation of organic bentonite

Na^+-bentonite (marked as Na^+-Bent, Zhejiang Fenghong Clay Chemicals Co. Ltd., cation exchange capacity (CEC) of 1.1 meq/g) was modified with diallyl dimethylammonium chloride (DADMAC) and dodecyl trimethylammonium chloride (DTAC) under conditions of 20% of modifier, reaction time 3 h, reaction temperature 80 °C and pH 9. The obtained sample was marked as Bent-DADMAC and Bent-DTAC, respectively.

2.2. Paper coating formulation

In color ink jet paper, traditionally, silica was used as pigment due to its high specific surface area (SSA) (Hladnik, 2004), therefore, the silica was used as pigment in here. In addition, the viscosity of a silica-based pigment increased rapidly with the amount of the silica added into a coating, limiting solid content of coating to further increase. Thus, the solid content of 14% was limited in this study. The coating formation of color ink jet paper consisted of silica (SiO_2)100 parts, polyvinyl alcohol (PVA) 30%(relative to mass of SiO_2, the same below), poly-diallyl dimethylammonium chloride (PDADMAC) 2%, defoamer 0.05%, and organic bentonite. According to the various organic bentonite amounts, the coating formulation was given in Table 1, the content of organic bentonite was also relative to mass of SiO_2. For evaluating the effect of organic bentonite, the coating containing 1% CMC was used as comparison.

2.3. XRD characterization

The structural changes in bentonite were examined using a Bruker D8X X-ray powder diffractometer (XRD) with 0.15418 nm Cu Kα radiation, operating at 40 mA and 40 kV. The scanning rate was 2° 2θ min^{-1}.

Table 1
Paper coating formulations and their solid content.

	CMC %	Bent-DADMAC %	Bent-DTAC %	Solid content %
1	1			14.1
2		1		14.8
3		3		14.5
4		5		14.7
5			1	14.6
6			3	13.9
7			5	14.0

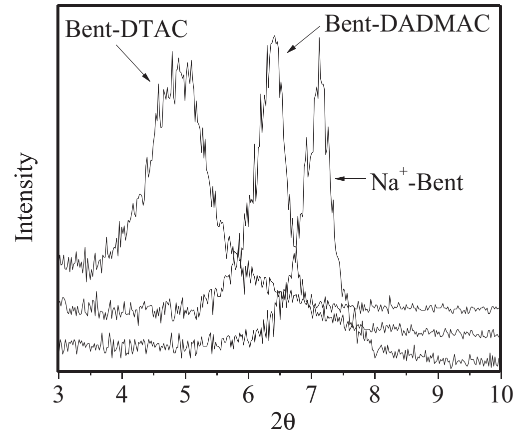

Fig. 1. The XRD curves of samples before and after modification.

2.4. TGA characterization

The content of modifier inserted into the bentonite was determined by thermogravimetric analysis (TGA) (TGA/SDTA851^e, Switzerland) between 30 °C and 900 °C.

2.5. Rheological measurements

The rheological properties of coating were measured using a rheometer AR 550 (TA Instruments, USA) equipped with parallel plate geometry 40 mm in diameter. All rheological measurements were conducted at 25 °C.

3. Results and discussion

3.1. XRD characterization

The XRD spectra of the bentonite samples before and after modification were shown in Fig. 1. The influences of organic treatment became evident when comparing the basal spacing of the original sample with those of the treated samples. Specifically, the 001 reflection was shifted to a lower 2θ after the modification. Moreover, the modification with DTAC had more pronounced effect than with DADMAC. According to the change of basal spacing derived from the Bragg's Law, the basal spacing was increased from 1.24 nm of the original sample to 1.37 nm for the Bent-DADMAC sample and 1.80 nm for the Bent-DTAC sample,

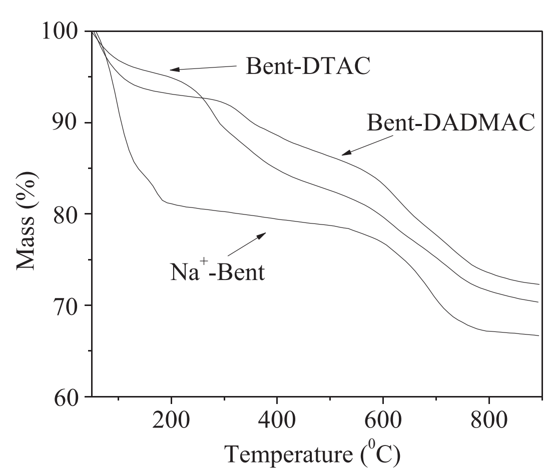

Fig. 2. The TGA curves of samples before and after modification.