Applied Clay Science 42 (2009) 553–558

Contents lists available at ScienceDirect

Applied Clay Science

journal homepage: www.elsevier.com/locate/clay

Synthesis and characterization of synthetic mica-bionanocomposites

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ARTICLE INFO

Article history:
Received 23 September 2007
Received in revised form 13 March 2008
Accepted 18 March 2008
Available online 1 April 2008

Keywords:
Bionanocomposites
Synthetic mica
Intercalation

ABSTRACT

Bionanocomposites of low charge swelling mica with several functional organic moieties have been synthesized under mild hydrothermal conditions at 120 °C and characterized by powder X-ray diffraction (XRD), scanning electron microscopy and ultraviolet, infrared and energy dispersive spectroscopies. The low charge mica showed affinity for the intercalation of a range of organic guest molecules including cellulose and fructose. All nanocomposites retained the parent mica layered structure with guest molecules occupying the mica interlamellar space.

1. Introduction

In the last decade the research field encompassing the nanocomposites has grown significantly (Komarneni, 1992; Pinnavaia and Beall, 2000; Ruiz-Hitzky et al., 2004). The recent research in this area was triggered by the use of clay nylon nanocomposite as a cover for timing belt in cars by Toyota Co (Okada et al., 1990). Nanocomposites have an edge over conventional microcomposites as the intermixing of the two phases is at the nano level which results in improved physical and chemical properties such as tensile strengths (Lee and Jang, 1996), conductivity (Aranda et al., 2006), barrier properties (Triantafyllidis and LeBaron, 2006) and thermal stability (Brown et al., 2000). Moreover structure and properties of nanocomposites can be tailored in desired manner by selectively choosing organic and inorganic phases (Giannelis, 1996; White, 2004). The reinforcement of inorganic matrix with biomolecules such as polysaccharides: starch (Park et al., 2002, 2003), chitosan (Darder et al., 2006) and cellulose (Kumar and Singh, 2007), peptides and proteins (Ikoma et al., 2001; Coradin and Livage, 2001; Kikuchi et al., 2001; Bigi et al., 2002; Coradin et al., 2002; Itoh et al., 2004; Wang et al., 2004), enzymes (Carrasco et al., 1995; De Fuentes et al., 2001; Rahman et al., 2004;) and DNA (Choy et al., 1999, 2000) have been explored quite extensively. These composites are referred to as "bionanocomposites" which exhibit improved properties in addition to being biodegradable and body compatible (Ruiz-Hitzky et al., 2005). Bionanocomposites are versatile materials which could be employed in tissue engineering, artificial bones, gene therapy, biosensors, slow drug delivery systems and food packaging materials (Olmo et al., 1987; Bautista et al., 2001; Tartaj et al., 2003; Ruiz-Hitzky et al., 2005).

So far mainly smectite clays, layered double hydroxides and hydroxyapatite are employed as the inorganic matrix for the synthesis of bionanocomposites as they are environmentally benign and biocompatible. However, swelling synthetic micas, a close member of the clay family has received little attention and has been explored in a few studies (Hata et al., 2007a,b). We have been investigating the synthesis and structure of synthetic swelling micas in our research group and we have reported the synthesis of several swelling micas by various routes (Paulus et al., 1992; Komarneni et al., 1998, 2001; Kodama and Komarneni, 1999a,b; Komarneni et al., 2005). Herein we report the intercalation properties of low charged swelling mica with organic species under hydrothermal conditions. This study is also relevant to understand the mechanisms of the interactions of organic pollutants such as pesticides, herbicides with soil clays and can be useful in the environmental soil pollution control.

2. Materials and methods

Sodium fluoride, silicic acid, aluminum nitrate, magnesium carbonate, fructose, cellulose, cholesterol, gelatin and proline were obtained from Aldrich and used without any further purification.

2.1. Synthesis

2.1.1. Synthesis of low charge swelling mica

A low charge swelling mica ($Na_{0.125}Si_{7.875}Al_{0.125}Mg_6O_{20}F_4{\cdot}{\times}H_2O$), referred to as Na mica hereinafter was synthesized following our previous methods (Komarneni et al., 2005; Ravella and Komarneni, 2008). Sodium fluoride, silicic acid, aluminum chloride and magnesium chloride were mixed in the stoichiometric ratio in a platinum crucible and were heated at 850 °C for 5 h before being cooled down to room temperature. The final white colored product was washed several times with deionized water using centrifugation and dried before using it as a host for intercalation.

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doi:10.1016/j.clay.2008.03.006

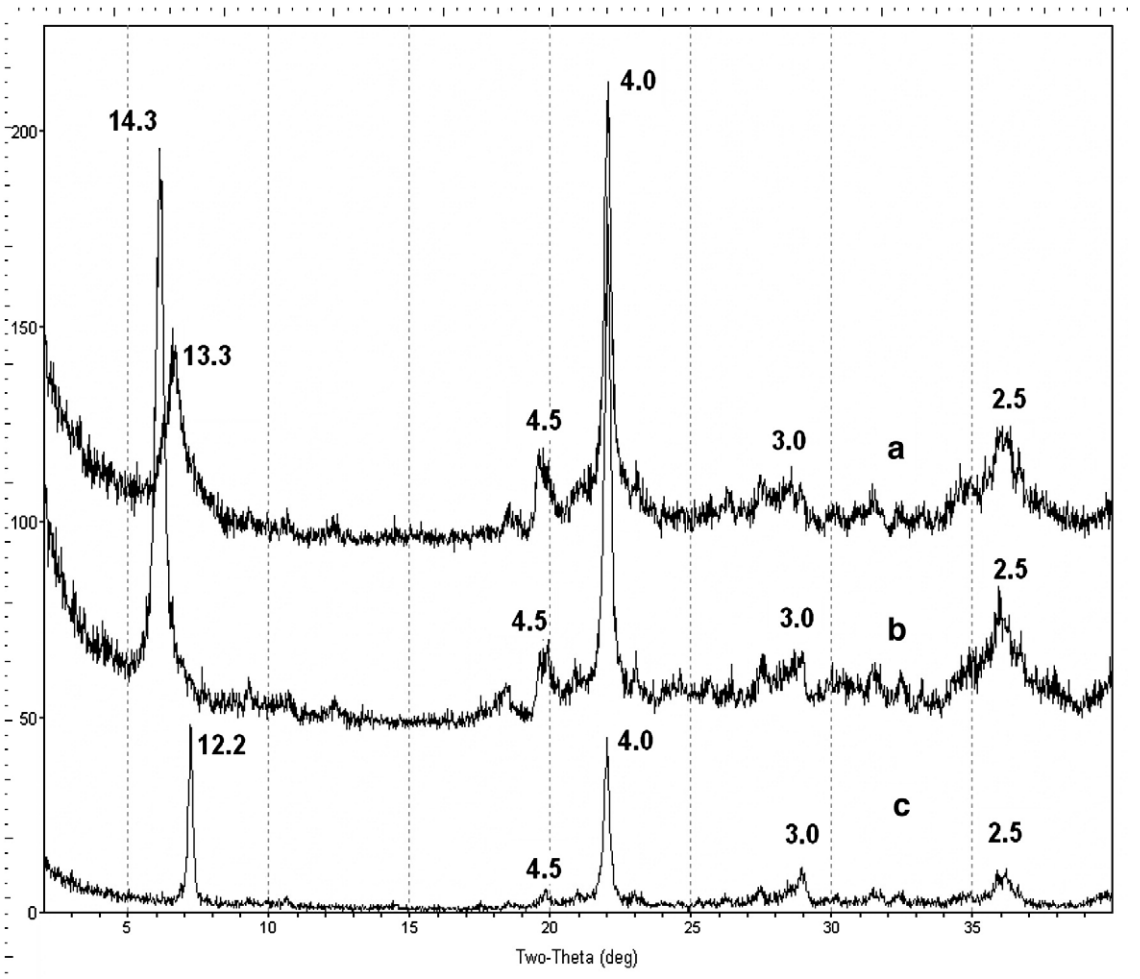

Fig. 1. Powder X-ray diffraction patterns of (a) cellulose nanocomposite (b) fructose nanocomposite and (c) Na mica.

2.1.2. Synthesis of nanocomposites

In a typical reaction 0.5656 mmol of organic was mixed with 0.7667 mmol of $Na_{0.125}$ mica and 2.23 mmol of deionized water. The whole reaction mixture was transferred to a teflon lined reaction vessel and heated at 120 °C for 24 h. The final products were washed with deionized water and alcohol several times to ensure the removal of excess organic molecules from the outside surfaces.

2.2. Characterization

Powder X-ray diffraction patterns were recorded on a Scintag diffractometer using CuKα radiation (λ=1.5418 Å). X-ray powder patterns were recorded at room temperature with a step size of 0.05° and data acquisition time of 2 s. FTIR spectra were was recorded on KBr pellets containing bionanocomposites using Nicolet 5DX spectrophotometer. TGA/DTA analyses were carried out using Perkin-Elmer TGA7 system on bionanocomposites samples in nitrogen atmosphere with a heating rate of 10 °C/min. UV spectra were recorded on well dispersed ethanol nanocomposite solution on a Varian Cary 100 UV–Vis spectrophotometer.

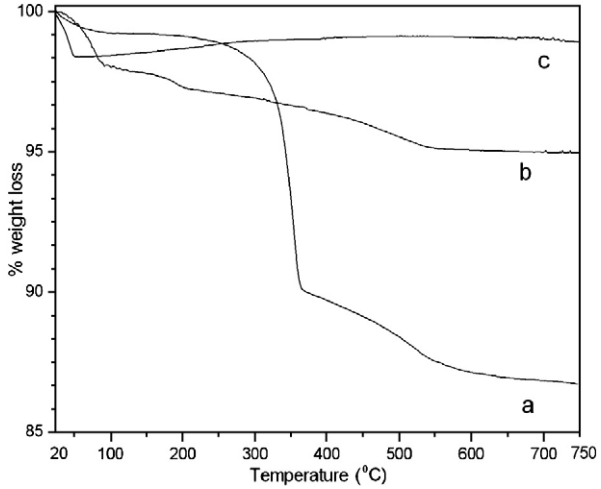

Fig. 2. TGA curves for (a) cellulose nanocomposite (b) fructose nanocomposite and (c) Na mica.

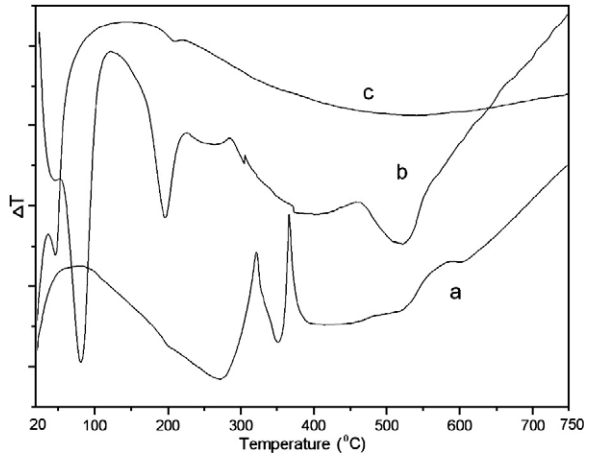

Fig. 3. DTA plots for (a) cellulose nanocomposite (b) fructose nanocomposite and (c) Na mica.