Journal of Thermal Analysis and Calorimetry
https://doi.org/10.1007/s10973-023-12574-7

Preparation and characterization of surface-modified montmorillonite by cationic surfactants for adsorption purposes

Sara Arabmofrad[1] · Seid Mahdi Jafari[1] · Giuseppe Lazzara[2] · Aman Mohammad Ziaiifar[3] · Hoda Shahiri Tabarestani[1] · Ghasem Bahlakeh[3] · Giuseppe Cavallaro[2] · Martina Maria Calvino[2] · Mehdi Nasiri Sarvi[4]

Received: 30 March 2023 / Accepted: 18 September 2023

Abstract

In this study, surface modification of montmorillonite with three types of cationic surfactants was investigated by adding different levels of surfactants corresponding to the CEC (cation exchange capacity) of montmorillonite; the surfactants were tetradecyl trimethylammonium bromide, cetyl trimethylammonium bromide, and didodecyl dimethylammonium bromide. Moreover, montmorillonite and modified montmorillonites were characterized by X-ray diffraction, Fourier transforms infrared spectroscopy, thermal analysis, contact angle, and zeta potential. Their surface morphologies were also determined by using the field emission scanning electron microscopy. The basal spacing of montmorillonite increased after intercalation of cationic surfactants, while the maximum basal spacing was influenced by increasing the molar mass of the surfactant. Also, for the same surfactant, maximum basal spacing enhanced when the CEC increased from 1:0 to 2:0. The results of Fourier transforms infrared spectroscopy indicated that intercalation of surfactants between montmorillonite layers leads to changes in functional groups of modified montmorillonite. To summarize, we successfully modified montmorillonite, making it a potential nanoadsorbent that could be used for the adsorption of valuable compounds such as phenolic compounds from wastewaters and byproducts of food industries.

Keywords Clay · Montmorillonite · Modification · Surfactants · Characterization · Morphology

Introduction

Nowadays, there is a growing interest toward the investigation of clay-based hybrid materials as they are promising in a wide range of applications from catalysis [1], environmental [2, 3], and cultural heritage preservation [4, 5].

Montmorillonite (Mt) which is a 2:1-type layered clay mineral characterized by propensity features such as high cation exchange capacity, large specific surface area, low cost, high swelling, and a porous structure is a perspective material in a wide variety of fields [6–8]. Mt can be applied in cosmetic [6, 6], environmental [9], and food industries [10]. The structure of Mt consists of an octahedral sheet (SiO_4) with four oxygen atoms in corners sandwiched by two tetrahedral sheets of Al_2O_3 with six oxygen in the corners [11, 12]. Due to the isomorphous substitution (e.g., Al^{3+}/Si^{4+} and Mg^{2+} or Fe^{2+}/Al^{3+} substitutions in the tetrahedral and octahedral), Mt has negative charges that are balanced by interlayer cations, e.g., Na^+, K^+, Ca^{2+}, Mg^{2+} [6, 13]. The interlayer cations can be exchanged with organic cations [14, 15].

Modified Mt (m-Mt), an artificially synthesized engineering material, is produced from raw Mt by using hydrophobic materials, such as cationic surfactants to enhance the properties of Mt for using in contaminant adsorption [6, 7, 16, 17]. Furthermore, cationic surfactants change the hydrophilic surface of Mt to hydrophobic conditions and cause high dispersion of Mt by interlayer space expansions [18, 19]. Different cationic surfactants have been used to synthesize m-Mt. These include no alkyl chain [20], low alkyl chain [6], long alkyl chain [9, 21], and single, double

✉ Seid Mahdi Jafari
smjafari@gau.ac.ir

1 Faculty of Food Science and Technology, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran

2 Department of Physics and Chemistry, University of Palermo, Palermo, Italy

3 Department of Chemical Engineering, Golestan University, Aliabad Katoul, Iran

4 Department of Mining Engineering, Isfahan University of Technology, Isfahan, Iran