Journal of Hazardous Materials 357 (2018) 271–278

Contents lists available at ScienceDirect

Journal of Hazardous Materials

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

Smoke suppression properties of Si-Al mesoporous structure on medium density fiberboard

Biao-rong Zhuang, Yan-ping Zhan, Wei-yuan Huang, Hui-ling Ye, Yong-qun Xie*

College of Materials Engineering, Fujian Agriculture and Forestry University, Fuzhou, 350002, PR China

ARTICLE INFO

Keywords:
Smoke suppression
Absorption property
Carbon fixation
Char formation

ABSTRACT

In this article, smoke suppression of Si-Al mesoporous structure on medium density fiberboard (MDF) was investigated by cone calorimeter test (CCT), scanning electron microscopy (SEM), thermal gravimetric analysis (TGA), and fourier transform infrared spectrometry (FTIR). The CCT results show that the Si-Al mesoporous structure can effectively decrease heat release rate (HRR), total heat release (THR), smoke production rate (SPR), total smoke production (TSP), smoke rate (SR), CO and CO_2 concentration, etc. Particularly, the SR curves of MDF present that Si-Al mesoporous structure are considered to be a filter, which can net the solid particles and volatile flammable components in the smoke and fix onto wood fiber. Remarkably, the CO and CO_2 concentration curves of MDF indicate that the Si-Al mesoporous structure has an excellent adsorption property, which can rapidly absorb CO and CO_2 that generated in wood combustion process. On the other hand, the FTIR and TGA results reveal that the Si-Al mesoporous structure can significantly improve the structure of char residue.

1. Introduction

The direct reason that resulted the room fire disaster-the second disaster is that the smoke and toxic gas produced by the material for furniture manufacture and house decoration when burning [1,2]. It has been reported that more than 70% death is caused by inhaling the toxic smoke to induce asphyxia, in building fire disaster [3]. Medium density fiberboard(MDF) is an important part of packaging materials, indoor furniture materials and decorating materials. But the character of flammability for wood composite material makes them susceptible to fire and limits their application. Therefore, it was necessary and important to improve the flame retardancy of MDF [4].

To reduce the flammability of MDF, some researchers were able to do this using the new technology of making crack-free carbonized boards by carbonizing the MDF [5]. This treatment technique enables to forms a heat insulation layer on the surface of MDF, which can improve the flame retardancy of materials. Meanwhile, it has been reported that the addition of flame-retardant is beneficial to improve the flame retardant properties of MDF. Some research demonstrated that the phosphorus-nitrogen flame retardant could improve the flame retardancy of wood material. However, a lot of harmful smoke is produced in the process of pyrolysis for these flame retardants, the smoke does great harm to human health and pollutes the environment. There are some researchers experiments with guanylurea phosphate and boric acid to synthesized a fire retardant powder(FRW), and the results indicated that the FRW-treated wood materials had lower heat and smoke release than the unmodified samples [6]. Other researchers added the boron to urea formaldehyde binder(UF), and the result indicated that the flame retardant of materials has been enhanced [7]. However, in order to improve the flame retardancy, large amount of modified adhesive should be added, which usually produces more toxic gases, hence more damage. However, most of the studies were increasingly concerned about the flame retardancy and thermal stability of material, while few on smoke suppression.

In our previous study, the two components, modified liquid basically composed of silicate, aluminum salt and boride have been applied to the wood materials such as ultra-low density fiberboard (ULDF) and MDF by the sol-gel method, and both the modified wood materials showed excellent heat stability and flame retardancy [8,9]. Nevertheless, our previous research played more attention to the flame retardancy and mechanical property of wood materials and the smoke parameters of combustion process got less attention.

In this paper, the preparation of Si-Al mesoporous structure was synthesized from silicate and aluminum salt by hydrothermal synthesis under the hot-pressing technology of MDF according to synthesis mechanism of Si-Al mesoporous material ($T \geq 100$ °C, Pressure). The present study was designed to gain the smoke suppression properties of MDF modified by the Si-Al mesoporous structure. The modified MDF

* Corresponding author.
E-mail address: fjxieyq@hotmail.com (Y.-q. Xie).

https://doi.org/10.1016/j.jhazmat.2018.05.068
Received 14 January 2018; Received in revised form 29 May 2018; Accepted 30 May 2018
Available online 31 May 2018

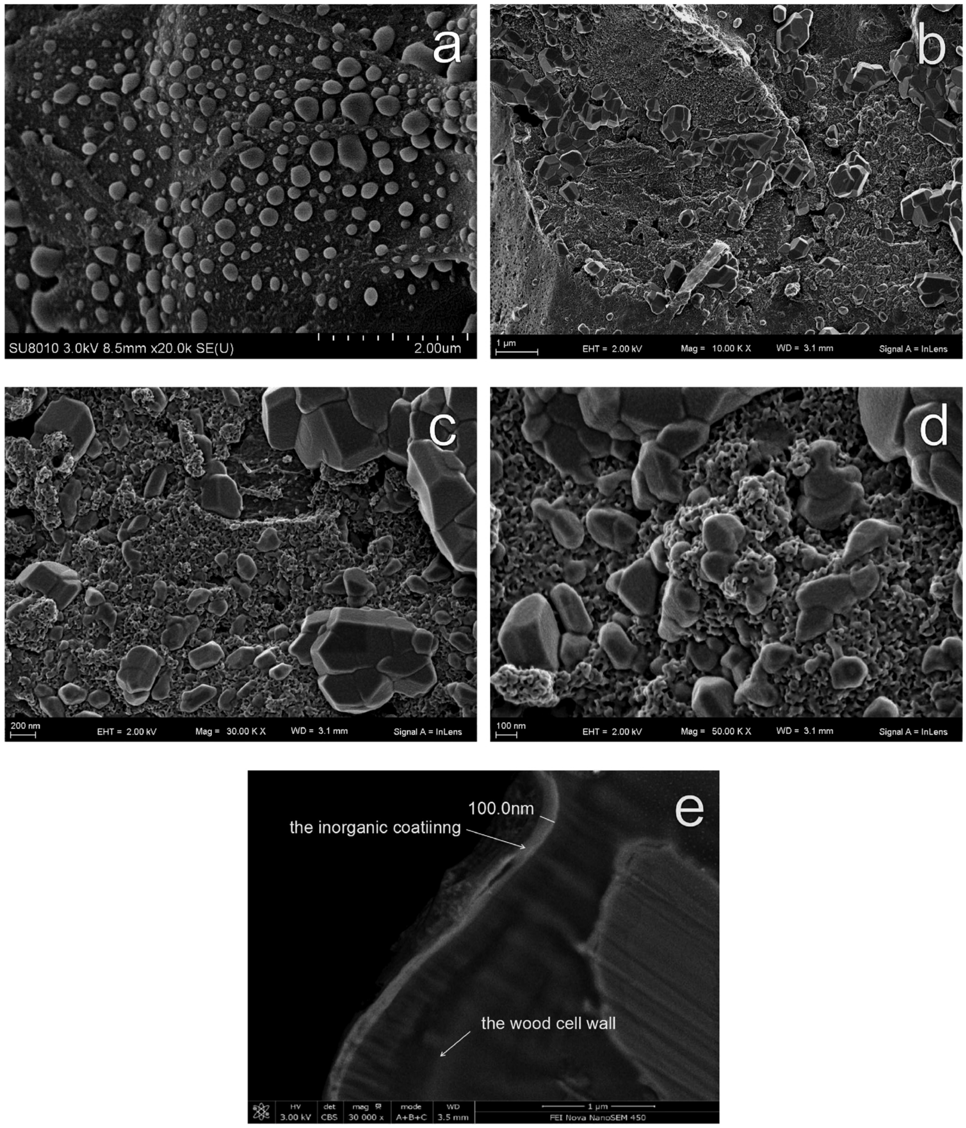

Fig. 1. SEM images of the fiber for MDF.

was characterized by scanning electron microscopy (SEM), cone calorimeter test (CCT), and thermal gravimetric analysis (TGA), respectively. In addition, in order to further explore the components of char, the residue chars of MDF samples left after cone calorimeter test was examined by fourier transform infrared spectra (FTIR) analysis.

2. Experimental section

2.1. Materials

Poplar wood fiber (*Populus ussuriensis Kom*) was produced by Furen wood industry Co., Ltd., Fujian, China. The melamine-urea-formaldehyde resin (MUF) was provided by Furen wood industry Co., Ltd., Fujian, China, which with the solid content of 52 percent.

The modifier is a two-component liquid. The component A is a mixture that consists of aluminum sulfate, phosphoric acid and boric acid (1:1:1 M ratio). Component B is composed of sodium silicate and borax (16:1 M ratio). In this study, component A and B were made into the aqueous solution of 10% and 38% concentrations, respectively. All the above-mentioned chemicals were procured from Fuchen chemical reagents Co., Ltd., Tianjin, China.

2.2. Sample preparation

2.2.1. Preparation of the modified fiber

The modified fibers were prepared by sol-gel method with help of concentration gradient using the two-component modifier. First, wood fiber was treated with component A solution, and then sprayed the wood fiber with the component B solution. After being sprayed, the wet fibers were dried oven until reaching 3–4 % moisture content. The ratio of component A to component B is 1.3: 1 (w/w) and the dosage of modifier is 5% (to oven dry wood fiber).

2.2.2. Preparation of MDF

The modified fiber was placed in a laboratory blender and then commercial liquid MUF resin was sprayed to the fibers, and the fibers were subsequently formed into a mat, using a 350 mm × 350 mm forming box. The fibers were pressed at 1.0 MPa for one minute under a cold press, and the mat was then fabricated into MDF using a conventional one-opening hot press (KS100H, Dongguan, Guangdong, China). The hot-pressing temperature, pressure, and time was 175 ℃, 2.1 MPa, and 5 min, respectively. Additionally, the MDF without addition of modifier was included in this study as a control group. The average thickness of the MDF is 9 mm, the density was 0.76 g/cm^3.