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Controllable synthesis of three kinds of zinc borates and flame retardant properties in polyurethane foam

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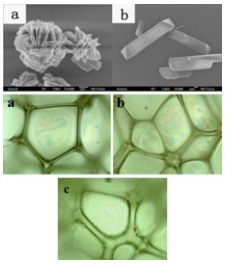
HIGHLIGHTS

- A new method for preparing $2ZnO{\cdot}3B_2O_3{\cdot}3.5H_2O$ has been proposed.
- The morphologies of three types of zinc borates are peculiar.
- Zinc borates transform with each other by appropriately controlled.
- Polyurethane/zinc borate materials have excellent retardant properties.

GRAPHICAL ABSTRACT



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ABSTRACT

Depending on the molar ratios of $ZnO{:}B_2O_3{:}H_2O$, zinc borates can be classified into many kinds of categories. In this paper, we successfully synthesized three kinds of zinc borates ($2ZnO{\cdot}3B_2O_3{\cdot}7H_2O$, $2ZnO{\cdot}3B_2O_3{\cdot}3.5H_2O$ and $3ZnO{\cdot}3B_2O_3{\cdot}5H_2O$) by controlling the reaction conditions, using $Na_2B_4O_7{\cdot}10H_2O$, H_3BO_3 and $Zn(NO_3)_2{\cdot}6H_2O$ as the reactants. These three zinc borates transform with each other if the reaction conditions were appropriately controlled. The morphologies of three products are peculiar. The synthesized $2ZnO{\cdot}3B_2O_3{\cdot}3.5H_2O$ is anomalous spheric-like or flaky, $3ZnO{\cdot}3B_2O_3{\cdot}5H_2O$ is flower-like, and $2ZnO{\cdot}3B_2O_3{\cdot}7H_2O$ is club-shaped. According to the thermodynamic performance of three kinds of zinc borates, we selected $2ZnO{\cdot}3B_2O_3{\cdot}3.5H_2O$ which had the best flame retardant properties, then doped it into the polyurethane to synthesize polyurethane/zinc borate materials. The maximum decomposition temperature of the polyurethane foam doped with zinc borate was increased by 54 °C before 300 °C. Furthermore, the maximum decomposition temperature was increased by 104 °C after 400 °C.

1. Introduction

Zinc borates are usually used as flame retardant, afterglow suppressant, smoke suppressant, and antitracking agent in both halogen-containing and halogen-free polymers [1–6]. Depending on the reaction conditions, a host of zinc borates with different molar ratios of $ZnO{:}B_2O_3{:}H_2O$ can be produced [7–15]. The most widely used zinc borates have the molecular formula as follows: $2ZnO{\cdot}3B_2O_3{\cdot}7H_2O$, $2ZnO{\cdot}3B_2O_3{\cdot}3.5H_2O$, $4ZnO{\cdot}B_2O_3{\cdot}H_2O$ [16,17], $2ZnO{\cdot}3B_2O_3{\cdot}3H_2O$ [7,18]. The dehydration temperatures of $4ZnO{\cdot}B_2O_3{\cdot}H_2O$ and $2ZnO{\cdot}3B_2O_3{\cdot}3.5H_2O$ are 410 °C and 290 °C, respectively, which enable them to prefer in the polymers that require high processing temperature [19]. Compared with $2ZnO{\cdot}3B_2O_3{\cdot}3.5H_2O$, $2ZnO{\cdot}3B_2O_3{\cdot}7H_2O$ is not stable in higher temperature, but it is economical while the processing conditions allow. Zinc borate ($2ZnO{\cdot}3B_2O_3{\cdot}3.5H_2O$) in general is produced with the reaction between zinc oxide and boric acid, with high reaction temperature and high reaction concentration.

In our study, we got $2ZnO{\cdot}3B_2O_3{\cdot}3.5H_2O$ by reacting between $Na_2B_4O_7{\cdot}10H_2O$, H_3BO_3 and $Zn(NO_3)_2{\cdot}6H_2O$ for the first time. We also synthesized the other two zinc borates, that is, $2ZnO{\cdot}3B_2O_3{\cdot}7H_2O$ and $3ZnO{\cdot}3B_2O_3{\cdot}5H_2O$ through the fine tuning of the reaction conditions. According to the knowledge we have learned, the reports of the composition preparation of

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