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The Effects of B_2O_3 Addition on the Properties of Anorthite Prepared from Algerian Kaolin

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The aim of the present work is to explore the utilization of Algerian kaolin (DD2) and calcium carbonate ($CaCO_3$) to synthesis of anorthite. Also, the effect of B_2O_3 addition on the properties of prepared anorthite was investigated. Compacted samples were sintered at temperatures between 1100 and 1300 °C for 2 h. All samples were characterized by X-ray diffraction, differential thermal analysis/thermogravimetric analysis, apparent density and open porosity measurements. The experimental results show the formation of anorthite in all samples. The increase in B_2O_3 ratio promoted the formation and the densification of anorthite at lower temperature.

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1. Introduction

Anorthite ($CaAl_2Si_2O_8$) is one of the mainly important members of the plagioclase feldspar [1]. It is very interesting from a technological point of view, because is characterized by good resistance to thermal stress, low dielectric constant, and low thermal expansion coefficient [2, 3]. This is what qualifies for use in wall tiles and porcelain, in the field of electronics industry and biomedical materials [4–7]. In general, fabrication of anorthite was widely studied by using different methods such as sintering of kaolin and calcite mixtures, mechanochemical treatments and sol–gel process [8, 9].

Different additives in solid state sintering process such as B_2O3, TiO_2 and CaF_2 were used for promote the densification of anorthite [3, 9].

In this study, we synthesized anorthite from local raw Algerian kaolin (DD2) and calcite. Finally, the effect of boron additions on sintering of anorthite was investigated.

2. Materials and equipments

The raw materials used in this study were: kaolin (DD2) from Djebel Dbag in Guelma (Algeria), calcium carbonate $CaCO_3$ and boron additives (B_2O_3). The chemical compositions of kaolin are given in previous work [10]. Four compositions were prepared, while changing the ratio of B_2O_3 by 0, 1, 3, and 5 wt%. These are named KC00, KC01, KC03 and KC05, respectively. The ball-milling experiments were performed through planetary ball mill (Pulverisette 6) for 10 h. The mixtures powders were sintered under normal conditions during 2 h at temperatures between 1100 and 1300 °C. The heating rate was kept constant and equal to 10 °C/min. X-ray diffraction (XRD) analyses were carried out using a Bruker D8 diffractometer. The XRD tests conditions were Ni-filtered Cu K_α X-ray radiation (40 kV–30 mA) with a scanning speed of 37° (2θ) per minute and at an increment of 0.02°. Differential thermal analysis (DTA) was conducted in the temperature range of 25–1400 °C under static air. A mass of 20 mg of powders mixture was heated at rate of 10 °C/min by Setaram LABevo TG-DSC 1600 °C equipment. The bulk density and open porosity of fired samples were determined by the Archimedes method.

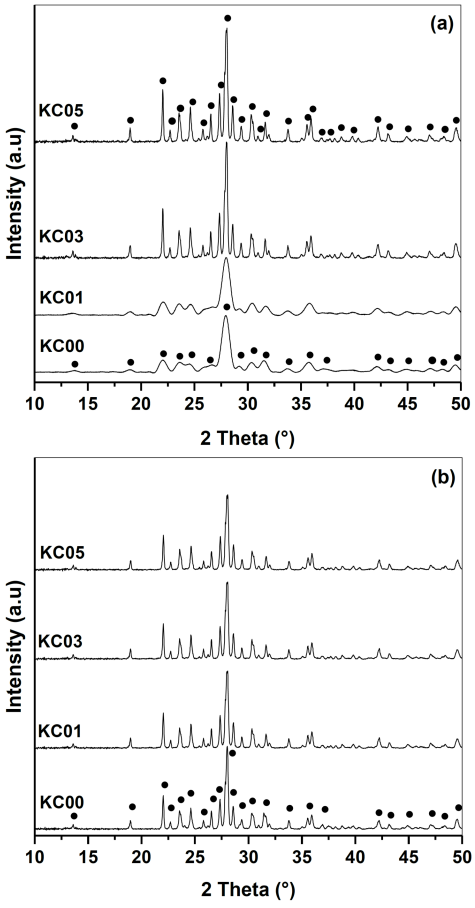

Fig. 1. XRD patterns of kaolin/$CaCO_3$ mixtures with different B_2O_3 addition and heated at different temperature (a) 1100 °C and (b) 1300 °C.

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3. Results and discussion

XRD patterns obtained from the samples with different B_2O_3 addition are shown in Fig. 1. The XRD spectra show the presence of only phase of anorthite in all samples. The samples heated at 1100 °C (Fig. 1a) present a poorly crystallized anorthite in the case of the samples containing 0 and 1 wt% of B_2O_3. On the other hand, the improvement of the crystallization of anorthite increases with the increase of B_2O_3 addition. In the case of the compacts heated at 1300 °C (Fig. 1b), we note the presence of uniform crystallized anorthite in all samples. This confirms the complete reaction between kaolin and calcite.

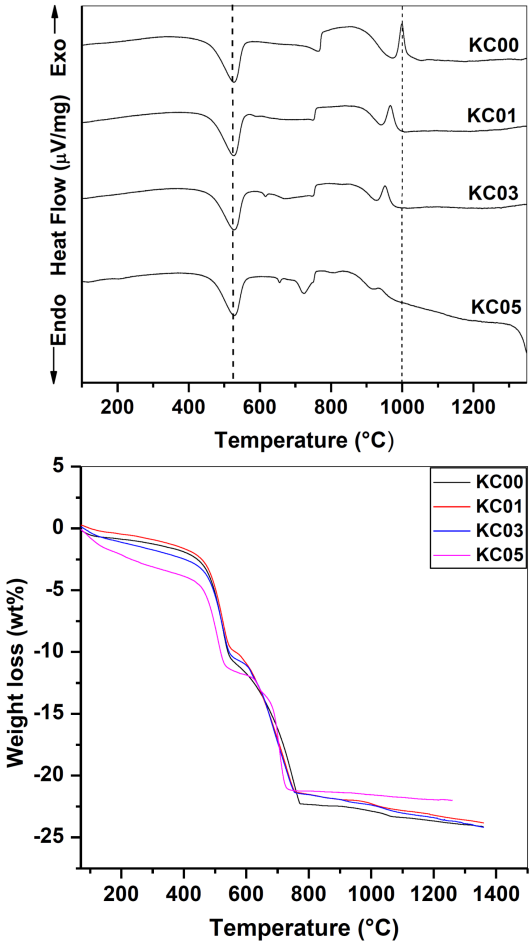

Fig. 2. DTA and TG curves for kaolin/$CaCO_3$ mixtures during heating.

Figure 2 shows DTA and thermogravimetric analysis (TGA) curves recorded during heating from 25 to 1400 °C. Two clear endothermic peaks and one exothermic peak are observed in DTA curves at about 520, 750, and 1000 °C, respectively. The first one peak is due to the dehydroxylation of kaolinite and the formation of metakaolinite [8]. The second one related to the thermal decomposition of $CaCO_3$ in CaO and CO_2 [11, 12].

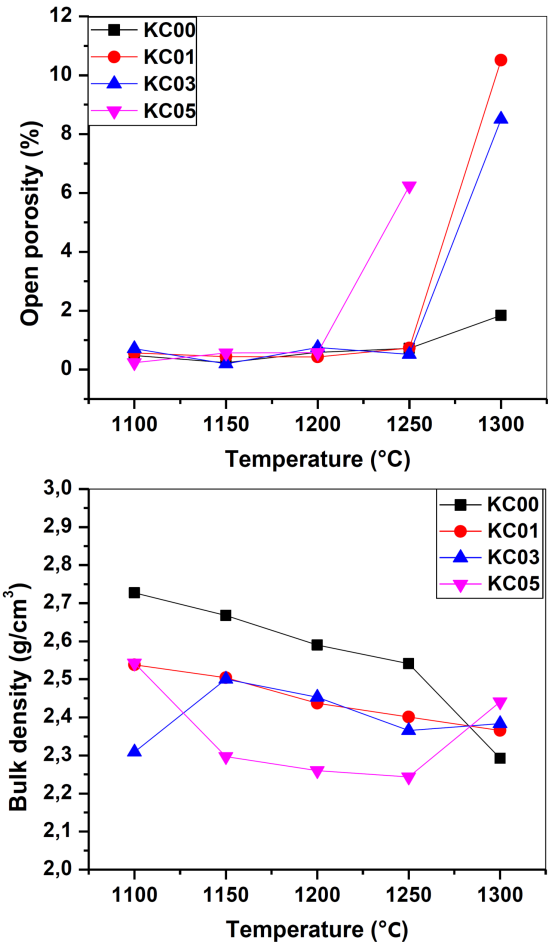

Fig. 3. Open porosity (a) and apparent density (b) as a function of sintering temperature.

The last one due to the spinal formation (disappears with B_2O_3 addition). Endothermic peak at about 1380 °C was observed in the sample containing 5 wt% of B_2O_3 related to the beginning of melting. A two-step mass loss is observed on the TGA curves (Fig. 2b). The mass loss in the first step observed at 500 °C corresponds to the dehydroxylation of kaolinite and the formation of metakaolinite. The second loss of mass observed between 600 and 750 °C is correlated to the decomposition of $CaCO_3$.

Figure 3 shows the variation of open porosity and bulk density as a function of the sintering temperature. The results indicate that the samples KC00, KC01, KC03, and KC05 have very small open porosity between 1100 and 1250 °C (Fig. 3a). A gradual increase in the open porosity was observed for after 1250 °C, which is due to release of CO_2 outside the samples facilitated by the appearance of the vitreous phase. The bulk density of all samples showed the same variation (decrease in bulk density with increase of temperature (Fig. 3b). The addition of B_2O_3 leads to a lower bulk density, because the presence of the boron facilitates the appearance of the liquid phase.

4. Conclusion

In this study, the effects of B_2O_3 addition on the properties of anorthite prepared from Algerian kaolin (DD2) and calcite ($CaCO_3$) were investigated. The addition of boron to kaolin/calcite leads to:

— Facilitating the disintegration of metakaolinite which leads to the appearance of spinal.

— Facilitating the formation of anorthite, because the boron promotes the formation of liquid phases.

— Finally, it has also been found that B_2O_3 additions help to appear a liquid phase.

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