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A study on preparation of cordierite gradient pores porous ceramics from rectorite

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ABSTRACT

Rectorite is a kind of new clay raw materials. To study properties of the gradient pores porous ceramics on the basis of rectorite clay raw materials is of great significance. Gradient pores porous ceramics having cordierite crystalline phases were made from rectorite, talc and α-alumina by adjusting grade of particle and pore-forming agents at 1200 °C for 1 h. The physical/chemical properties and microstructures of products were tested. The results show that the samples exhibit relatively high strength, low coefficient of thermal expansion and well-distributed gradient pores due to the excellent properties of rectorite clay material (i.e., good binder, great plasticity index, low drying and firing shrinkage, high refractoriness and good thermal shock resistance, combination and distribution).

1. Introduction

Porous ceramics have been extensively used in various areas including filters, catalyst supporters, electrodes, surgical implants, and etc [1–3]. Porous ceramics have been a research focus in recent years due to their good mechanical properties, chemical and abrasion resistance and thermal stability [4–6]. As an important and attractive branch of porous ceramics, gradient pores porous ceramics are especially fit to separate all kinds of particle of different size from fluid or gas, which is of high temperature and erosive, owing to their unique excellent properties such as lower filtration resistance, higher efficiency of separateness, poorer blockage, and better anti-wash [7]. The concept of gradient pores porous ceramics was firstly introduced by Chen Da Qian and Shen Jun Quan in 1991 [8].

Rectorite, coming from Zhongxiang, Hubei, central area of China, is a kind of layered silicate, with the structure and characteristic much like those of montmorillonite. It is a regularly interstratified clay mineral with alternate pairs of dioctahedral mica-like layers (nonexpansible) and dioctahedral montmorillonite-like layers (expansible) in a 1:1 ratio [9]. As a kind of new clay material, it has many excellent qualities, such as good binder, great plasticity index, low drying and firing shrinkage, high refractoriness and good thermal shock resistance. It is better than montmorillonite, kaolinite and illite as binder [10,11].

Cordierite ($2MgO \cdot 2Al_2O_3 \cdot 5SiO_2$) is one of the important phases of the $MgO \cdot SiO_2 \cdot Al_2O_3$ system due to many industrial applications. Cordierite is known to have a low coefficient of thermal expansion and low cost [12,13]. Cordierite ceramics have excellent thermal shock resistance due to their low thermal expansion coefficient ($\sim 1 \times 10^{-6}$/°C), low dielectric constant, high refractoriness and high mechanical strength. Therefore, cordierite based materials are extensively used in a broad range of applications, including filter, catalysts, microelectronic, integrated circuit boards, membranes and refractories [14]. Usually, cordierite ceramics is produced by calcination of a mixture of clays, talc and aluminium hydroxide, or by devitrification of cordierite glass with a suitable composition [15].

There are many papers in the literature about rectorite. Typical literature is characteristics of halloysite associated with rectorite from Hubei, China [16], characterization of CdS/rectorite nanocomposites and its photocatalytic activity [17], mechanism of tetracycline sorption on rectorite [18], rectorite as catalyst for wet air oxidation of phenol [19]. However studies on the use of rectorite into cordierite based porous ceramics are few.

The purpose of present work is to produce cordierite gradient pores porous ceramics using rectorite as a clay raw material, and to test their relevant properties, including primary crystalline phases, micrographs, porosities, bending strength, thermal expansion coefficient and refractoriness. The advantages of rectorite gradient pores ceramics are carefully investigated.

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Table 1
Chemical composition of raw materials (wt%).

Chemical Composition	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MgO	CaO	K_2O	Na_2O	I.L
Talc	60.64	0.45	0.10		31.10	1.67			7.44
Rectorite	44.20	34.08	1.17	2.22	0.30	4.12	0.89	1.29	10.45
α-alumina		98.60							

Table 2
Mixture of raw material (wt%) in the stoichiometry ratio close to the cordierite.

Raw material	wt%
Talc	38.38
Rectorite	47.71
α-alumina	13.92

Table 3
Weight percentage of raw material mixture and coal powder(wt%).

Number	Raw material mixture	Coal powder
1#	83.3	16.7
2#	76.9	23.1
3#	71.4	28.6
4#	66.7	33.3
5#	62.5	37.5

2. Experimental procedure

Rectorite, talc and α-alumina were used as raw materials whose chemical compositions are listed in Table 1. Talc ($3MgO\cdot4SiO_2\cdot H_2O$), coming from Guilin, Guangxi, China, is a kind of natural mineral. It could reduce sintering temperature, accelerating formation of mullite crystal. The α-alumina is a kind of calcination product of industrial alumina (Zhengzhou, Henan, China). The weight percentage of each raw material was calculated according to the chemical composition of cordierite, see Table 2. Then three kinds of raw materials were mixed. After being ball-milled for 12 h, the above raw material mixture was dried and passed through a 100, 200, 250 mesh sieve, respectively. Coal powders were used as pore-forming agents. After being ball-milled for 12 h, the coal powders were passed through a 100, 200, 250 mesh sieve, respectively too. Then the raw material mixture was further mixed enough with equal size of coal powers for further 30 min by using a blade-paddle mixer, respectively. Five kinds of content of pore-forming agents were designed in order to discuss the affection on the ceramics properties. The weigh percentage of the raw material mixtures and coal powder is listed in Table 3. The above three kinds of particle size mixture powders with identical weight percentage were put into a stainless

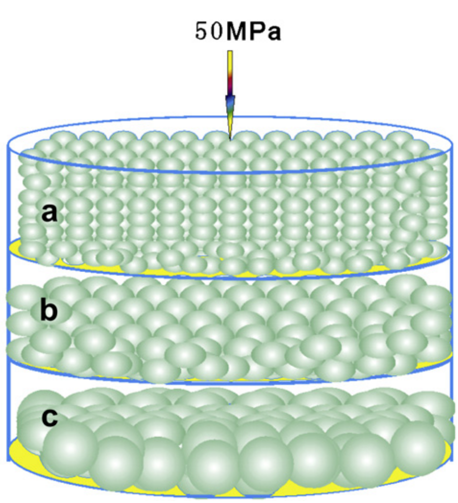

Fig. 1. Schematic illustration of the forming processes a. 250 mesh sieve b. 200 mesh sieve c. 100 mesh sieve.

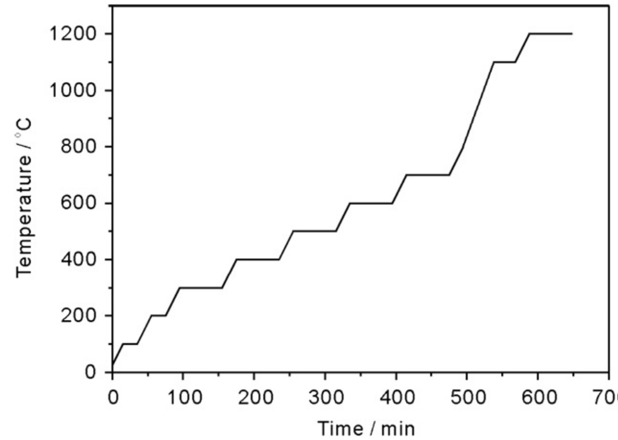

Fig. 2. The sintering schedule of samples.

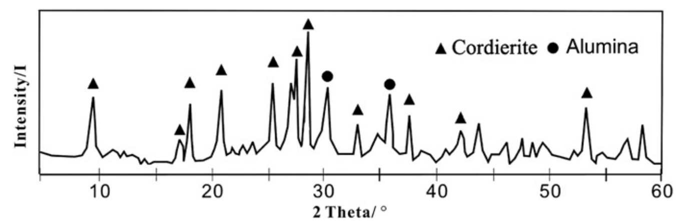

Fig. 3. XRD pattern of sample 3#.

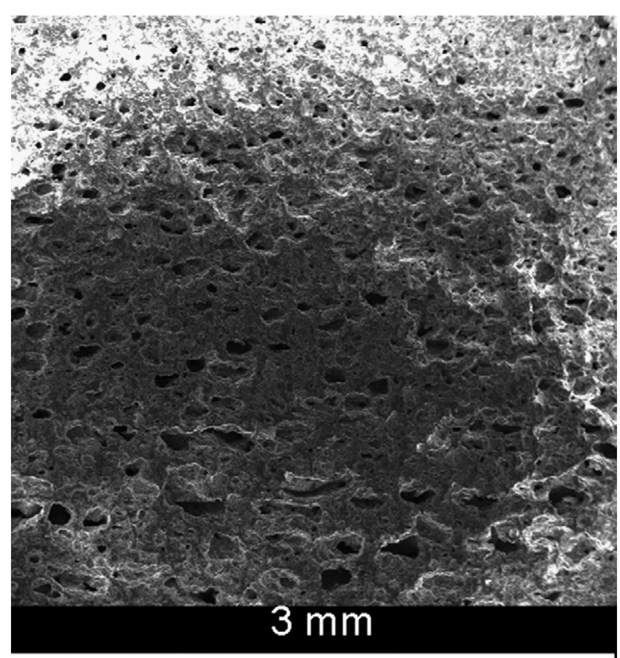

Fig. 4. The FESEM image of sample 3#.