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Research Article

Effect of Solid Loading on Fabrication of Porous Cordierite

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ABSTRACT

The cordierite powder was synthesized through glass melting method using silica, magnesia and alumina as raw materials. The cordierite powder was used to fabricate porous cordierite. The porous cordierite was fabricated through gel casting method. The cordierite powder, polyethyenimine and distilled water was mixed together for 2 hours. The solid loading of cordierite slurry were varied to get the best properties of porous cordierite (62 - 72 wt.% solid loading). The foaming agent was added to be the cordierite foam, the green body was sintered at 1350 °C. The porosity of porous cordierite show when solid loading increase, the porosity decrease. The compressive strength also increase when solid loading increase.

Keywords: Porous ceramic; Solid loading; Cordierite

1. Introduction

Cordierite ($Mg_2Al_4Si_5O_{18}$) is a magnesium-aluminium-silicate mineral. There are great deal of intension since it has a lot of excellent properties of cordierite ceramics such as low thermal expansion coefficient, excellent thermal shock resistance, low dielectric constant, high resistivity, high chemical durability, high refractoriness and high mechanical strength[1]. These excellent properties contribute to wide application such as electrical porcelains, catalytic converter substrates for exhaust gas control in automobiles, heat exchanger for gas turbine engines, industrial furnaces, packing materials in electronic packing, refractory coating on metals and integrated circuit substrates[2].

Porous cordierite is one of the great interest in porous ceramics due to its demand for wide application such as filters, membranes, catalytic substrates, thermal insulation, gas burner media, and as refractory material[3]. Porous cordierite has become the new development of cordierite materials[4]. In porous ceramics, the pore structure influenced the mechanical properties of porous ceramic[5] while the solid lading will influence the pore structure of porous ceramic. The aim of this study is to investigate the effect of solid loading on fabrication of porous cordierite.

2. Materials and Methods

2.1 Synthesis of ordierite powder

A mixture of alumina (Al2O3), silica (SiO2) and magnesia (MgO) was dry mixed together for 6 hours using polyethylene bottle. The homogeneous mixture powder was put into alumina crucible and melted at 1550°C for 4 hours soaking timein Elevator Hearth, Lenton EHF 1700. Then, the melted powder was quenched in the water to get frit. The frit was dried for 24 hours at 80°C. The frit was crushed to the small size and milled for 5 hours (D50=7.39 μm) using Planatery Mill. After that, the milled powder was used for fabrication of porous cordierite using gelcasting method.

2.2 Fabrication of porous cordierite

The cordierite powder (62.0, 67.1, 72.0 wt.%), distilled water (28.8 wt.%) and polyethyeneimine (4.1 wt.%) as dispersant was mixed together for 2 hours at 600 rpm. After mixing, the sodium dodecyl sulfate(SDS) as foaming agent was added while the cordierite slurries were vigorously mixed at a rate of 1000 rpm to the mixture for expand the mixture 4 times from original volume. Then, 1.4 wt.%of gelation agent, Denacol-EX614B (Nagase Chemical Co. Ltd., Japan) was added to maintain the bubble

shapes of slurry. Immediately after the SDSas foaming process, the bubbled cordierite slurries wasmoulded. The moulded cordierite slurries was sealed for 1 hour at room temperature. The wet green bodies were demoulded and immediately moved to a drying oven at 80°C. After 24 hours drying using drying oven and sintering was performed using Lenton Furnace at 1350°C for 2 hours using heating rate 100°C/hour up to 600°C and the 200°C/hour up to 1350°C.The slower heating rate was used until 600°C due to decomposition of polymer in the green body.

2.3 Characterization

The purity of cordierite was characterized using X-ray diffraction analysis. The porosity of porous cordierite was measure using Archimedes Method, the morphology of porous cordierite was observed using Scanning Electron Microscope (SEM) and the compressive strength was measured using Instron Machine.

3. Results and Discussion

3.1 Glass produced after quenching

(**Figure 1**) shows the glass produced after melting. The glass was placed on white paper and the transparency was observed using the naked eye. Based on (**Figure 1**), all of the glasses produced are transparent. These glasses were produced after rapid cooling from molten state that is fast enough to avoid crystallisation. This result was in agreement with the previous study by Banjuraizah et al. (2011), which used the glass melting method to produce cordierite and they found that a transparent glass was in an amorphous phase. This is due to the molecules in the glass being stacked randomly. Random organisation of molecules in glass caused the formation of such gap and will be filled with air and as a scattering point for light penetration[6].

Figure 1: Glass produced after quenching.

3.2 X-ray diffraction of glass

XRD analysis was conducted to confirm that the glass produced after quenching. (**Figure 2**) shows the XRD pattern of the glass powder. A large amorphous hump and no crystalline peaks were detected in the diffraction pattern of the sample melted at 1550 °C.

The absence of peaks in the XRD pattern indicated that the compound was completely transformed into amorphous or glassy phase. Atoms in the glass were randomly moved during melting[7], producing an amorphous hump in the XRD pattern. The amorphous phase of the glass was proven by the transparent appearance shown in (**Figure 1**).

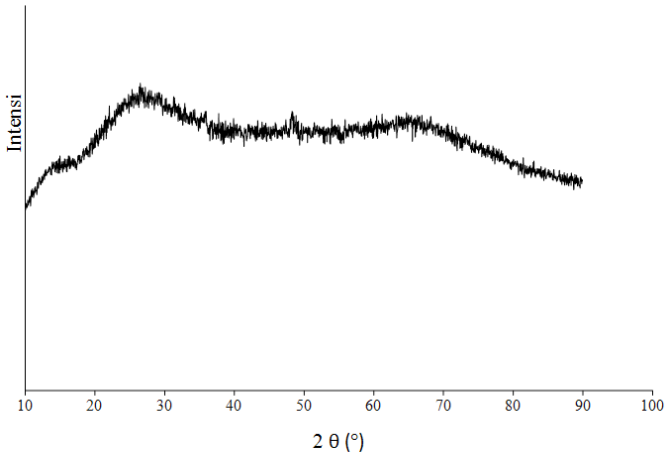

Figure 2: X-ray diffraction pattern of glass.

3.3 X-ray diffraction of porous cordierite

(**Figure 3**) shows the X-ray diffraction pattern of the sintered porous cordierite. The main component of the powder was 98.9% cordierite, plus small amount of cristabolite low, 1.1%. The high purity of cordierite powder was successful produced. The melting temperature, 1550°C will produced high purity of cordierite powder. The high purity of cordierite powder needed to ensure theproperties of porous cordierite maximized. The raw materials was melted in high temperature (above 1550°C).

The cristabolite lower, the so the high purity of cordierite will obtained[4]. Any molten substance will form a glass if it was cooled fast enough. Therefore, melting at a much lower temperature requires the molten glass to be cooled at a sufficiently high rate to avoid a significant degree of crystallization so that the 'disordered' atomic configuration of the liquid state is frozen in, thus avoiding the formation and growth of crystal[6].

The 62 and 67.1 wt.% solid loading samples was fabricated but 72 wt.% solid loading sample was fail to fabricate because the cordierite slurry too viscous. The bubble unable to form when foaming agent were added. (**Table 1**) shows the porosity of porous cordierite using 62 wt. % and 67.1 wt. % solid loading of cordierite powder.

According to the results, the porosity was decreased from 79.83% to 60.58% by increasing solid loading from 62 wt.% to 67.1 wt.%. Results obtained were in agreement with Le Huec et al. (1995) and Jamaludin et al. (2014). They stated that when the solid loading increases, the solid content in the slurry increases, which creates low porosity of porous ceramic[8,9].

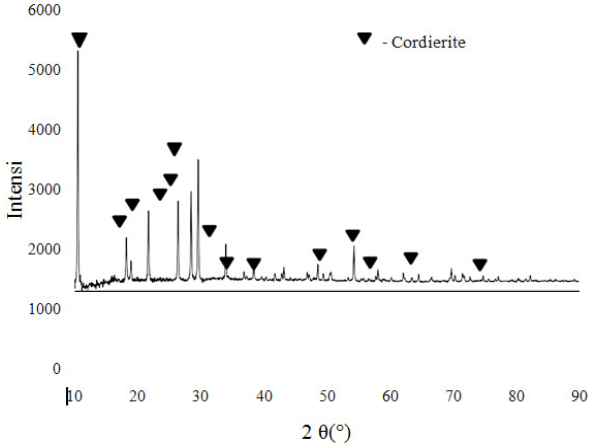

Figure 3: X-ray diffraction pattern of porous cordierite.

Table 1: Porosity of porous cordierite at different solid loading.

Solid loading (wt. %)	Porosity (%)
62.0	79.83
67.1	60.58

Pore size and pore distribution for porous cordierite produced using 62 wt.% and67.1 wt.% solid loading were observed through SEM and are presented in (**Figure 4**).

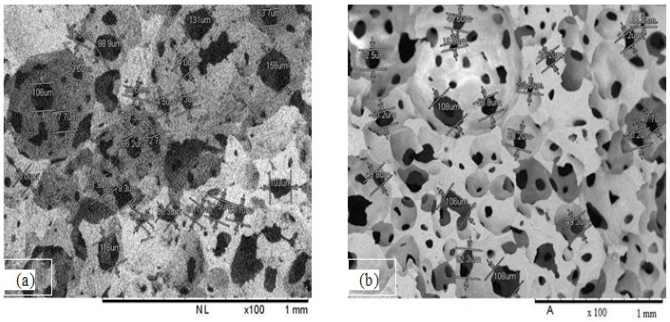

Figure 4: (a) 62 wt.% sample (b) 67.1 wt.% sample.

Both samples in (**Figure 4**) contained interconnected open pore structure with non-uniform distribution. However, a lot of broken struts were found on 62% solid loading sample (**Figure 4(a)**), which almost collapsed the structure. Meanwhile, no cracks were observed in the 67.1% solid loading sample (**Figure 4(b)**). It is strongly believed that the failure in the lower content of solid loading sample was due to insufficient solid content to strengthen the wall to prevent it from collapsing. The smoother surface structure were also observed in sample with higher solid loading (67.1 wt.%). Meanwhile, irregular shape and the present of cracks on the struts were observed in the 62% solid loading sample. In order to support the previous result, strength determination through compressive strength were completed on the sample produced using different amounts of solid loading. (**Table 2**) shows the strength of porous cordierite at different solid loading.

Table 2: Strength of porous cordierite at different of solid loading.

Solid loading (wt.%)	Compressive strength (MPa)
62.0	1.59
67.1	5.43

Result showed that compressive strength increased from 1.59 to 5.43 MPa by increasing solid loading from 62 to 67.1 wt.%. According to Macchetta et al.[10], the strength of porous ceramic strongly depended on the porosity, where the porosity decreased as the solid loading of the slurry decreased. The less solid proportion will cause low strength due to the fewer obstacles on external force[8].

4. Summary

The cordierite powder was successful synthesized through glass melting method. The porous cordierite were successful fabricated with different solid loading. The higher solid loading resulted lower porosity and high compressive strength. 67.1 wt.% sample show better structure compare to 62 wt.%.

5. References

1. Fuji Y, Shiroki RL, Menchavez H, et al. Fabrication of cordierite filter by in-situ solidification for high temperature dust collection. Powder Technol 2007;172(1):57-62.
2. Luyten J, Mullens S, Cooymans J, De Wilde AM, Thijs I. New processing techniques of ceramic foams. Adv Eng Mater 2003;5(10):715-718.
3. Benito X, Turrillas GJ, Cuello AH, De Aza S, De Aza AH, Rodríguez MA. Cordierite synthesis, a time- resolved neutron diffraction study. J Eur Ceram Soc 2011;32(2):371-379.
4. Bejjaoui R, Benhammou A, Nibou L, et al. Synthesis and characterization of cordierite ceramic from Moroccan stevensite and andalusite. Appl Clay Sci 2010;49(3):336-340.
5. Kim H, Lee S, Han Y, Park J. Control of pore size in ceramic foams: influence of surfactant concentration. Mater Chem Phys 2009;113(1):441-444.
6. Banjuraizah J, Mohamad H, Ahmad ZA. Effect of melting temperatures on the crystallization and densification of 2.8MgO·1.5Al2O3·5SiO2 glass-ceramic synthesized from mainly talc and kaolin. J Alloys Compd 2011;509(5):1874-1879.
7. Ngai T, Capaccioli S. The challenging problem of glass transition. J Am Ceram Soc 2008;91(3):709-714.
8. Le Huec JC, Schaeverbeke T, Clement D, Faber J, Le Rebeller A. Influence of porosity on the mechanical resistance of hydroxyapatite ceramics under compressive stress. Biomaterials 1995;16(2):113-118.
9. Jamaludin AR, Kasim SR, Abdullah MZ, Ahmad ZA. Sago starch as binder and pore-forming agent for the fabrication of porcelain foam. Ceram Int 2014;40(3):4777-4784.
10. Macchetta A, Turner IG, Bowen CR. Fabrication of HA/TCP scaffolds with a graded and porous structure using a camphene-based freeze-casting method. ActaBiomater 2009;5(4):1319-1327.