Journal of Science and Technology, Vol. 8 No. 1 (2016) p. 9-12

Influence of Phlogopite on the Physico-Mechanical Properties of a Porcelain

N. A. A. Kutty, *M. Z. Noh

Material Physics Laboratory, Science Department, Faculty of Science, Technology and Human Development, Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor

Abstract: This research was conducted in order to obtain the optimum composition of phlogopite and sintering temperature of phlogopite in order to get the robust structure of porcelain. Clay, feldspar, quartz, and phlogopite were first sieved, mixed and compacted. Then, the samples were sintered at 1000°C to 1300°C. It is observed that the properties of the porcelain are highly depend on the composition of phlogopite and the sintering temperature of porcelain. Results showed that 10 wt% of phlogopite was the optimum composition and 1200°C was the optimum sintering temperature. The microstructure of the samples were analyzed by using two microscopes and it was evidenced that the pore in the samples were smaller and the structure are denser thus lead to a dense porcelain structure and improves the physical and mechanical properties of the porcelain.

Keywords: phlogopite, porcelain, mica, physical, mechanical.

1. Introduction

Ceramic industry is a multibillion dollar industry. White ceramics or known as porcelain is one of the most useful ceramic materials been applied in household, electrical insulators, laboratory equipment and biomedical applications. This is due to the excellent properties of porcelain which are low porosity, high density, low permeability and elasticity, high resistance to chemical attack and thermal shock, translucence and high hardness rating [1]. In porcelain industry, it is very common to add other materials in order to enhance the performance tailored to many applications. Mica is known as one of the potential material to be used in ceramics production [2].

In the last decades, porcelain has been commercialized as a houseware such as tiles in the bathroom, sinks, washers and dryers. However, the drawbacks of porcelain are its difficulty in handling, easy to break thus lead to significant losses. The other limitation is the reaction with chlorinated water or strong acids that lead to eroding and tend to be brittle [3]. Production of porcelain with the addition of phlogopite is one of the alternative in order to get a stronger structure of porcelain in which phlogopite is one of the mica content and have good properties which are high dielectric strength, low expansion coefficients, cold and heat resistance, and high tensile strength making this mineral an excellent raw material for electrical insulators, reinforcing material in high-temperature applications [2]. Airi *et al.* who studied on the addition of phlogopite on a clay body, found that the optimum sintering temperature is between 1050°C to 1100°C. Phlogopite also lowers the sintering temperature from 1200°C to 1100°C [4]. It is expected that the addition of phlogopite will improve the porcelain's strength. The objectives of this study are to determine the optimum composition of phlogopite and the optimum sintering temperature which shows the best physical and mechanical properties of porcelain. Six different compositions of phlogopite were added into the porcelain and the effect on the physical and mechanical properties were analysed.

2. Materials and Methods

Raw materials which are 50% of clay, 25% of quartz, 25% of feldspar and phlogopite were sieved separately in order to get the required particle size range which is less than 50 micron. Then, all materials were mixed together according to the composition of phlogopite which is from 0 wt% up to 50 wt% in order to get the homogeneous mixture. 1 wt% of PVA which acted as a binder were added into the mixture and then it was pressed into pellets with the diameter of 20 mm and the thickness is 4 mm at a pressure of 2 ton per minute for each pellets. All the pellets underwent the cold Isostatic pressing process with the pressure of 40 MPa and then sintered according to sintering temperature from

**Corresponding author: zaky@uthm.edu.my*

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1000°C up to 1300°C at 2 hour soaking time. Bulk density of the pellets was determined based on the Archimedes' principle under the standard of ASTM C373. The compressive strength was determined using the universal testing machine (Testometric) that have maximum load of 100 kN under the standard of ASTM C773-88. The microstructure of the best sample in physical and mechanical properties were observed by using two microscopes which are optical microscope (Olympus DSX100) with 1.6× enlargement scale and metallurgical microscope (Meiji-MT8530) with 20× enlargement scale.

3. Results and Discussions

Figure 1 shows a non-consistent increment in the percentage of shrinkage at different sintering temperature. The lowest percentage of shrinkage is at 1000°C while at 1300°C, the percentage of shrinkage dropped dramatically when added with the phlogopite. This is due to the property of phlogopite that cannot sustain at high temperature. The highest percentage of shrinkage is at 10 wt% of phlogopite at a sintering temperature of 1200°C in which the value of the shrinkage is 26.36%. At 1200°C, phlogopite displayed increase in stability [4]. During the sintering process, the bonding of powder particles was formed and combined to each other which then reduced the pore and size of the sample [5].

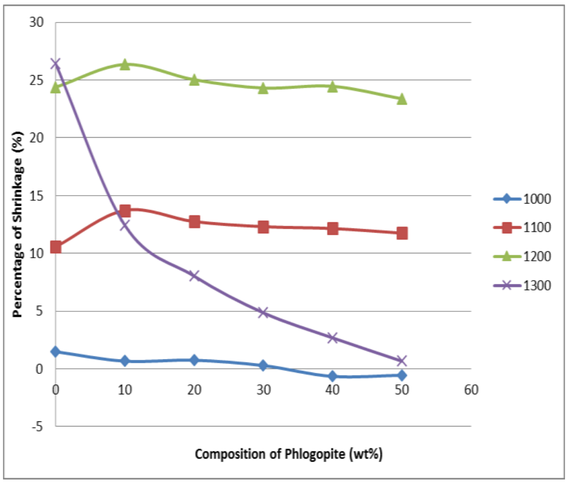


Figure 1 Graph of the percentage of porcelain shrinkage against composition of phlogopite at different sintering temperatures

Figure 2 shows the bulk density of the porcelain that increased irregularly according to the compositions of phlogopite at different sintering temperatures except for 1300°C. The highest bulk density was at 1200°C in which it starts to increase at 10 wt% of phlogopite up to 50 wt% where the value of the bulk density is 2.4378 g/cm^3. From the graph, the increase in bulk density of porcelain is proportional to the composition of phlogopite. This is because of the phlogopite that act as a filler and melt during sintering process. Due to its small grain size, it will fill the pores between the particles which lead to a dense porcelain structure [6].

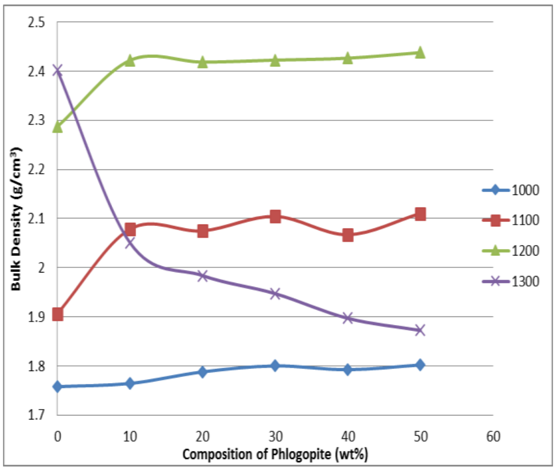


Figure 2 Graph of the bulk density of porcelain against composition of phlogopite at different sintering temperatures

Figure 3 shows that the highest compressive strength at 1200°C where the value of the compressive strength are 46.43 MPa at 10 wt% of phlogopite. The graph shows that at 10 wt% of phlogopite, the compressive strength was the highest and achieves the optimum compressive strength at 1200°C. The compressive strength decreased when the composition of the phlogopite was increased to more than 10 wt%. It is because of phlogopite contains a large amount of alkali metal ions, which lead to the decrease in mechanical properties [7].

Figure 4 shows the microstructure of the sample which has been observed by the metallurgical microscope at enlargement scale of 20× according to different sintering temperature. 10 wt% of phlogopite was found as the optimum composition while the optimum sintering temperature is at 1200°C. It was proved from the microstructure of the sample in Figure 4, in which the pore of sample that has been sintered at 1200°C was smaller compared to 1100°C and 1300°C. This is due to the phlogopite that has filled the pore between the particles in the structure of the porcelain which then lead to a dense structure and improved the physical and mechanical properties [4].

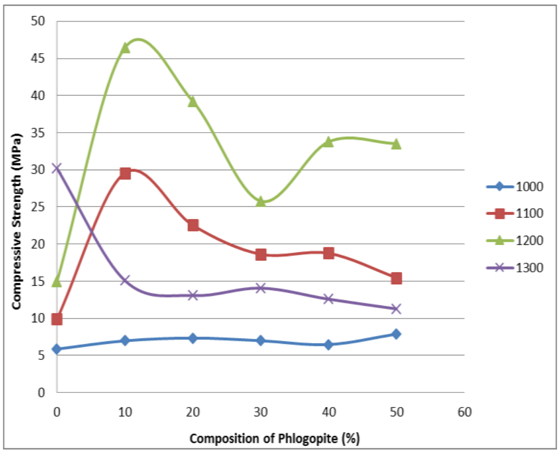
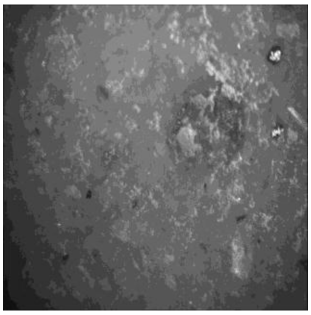
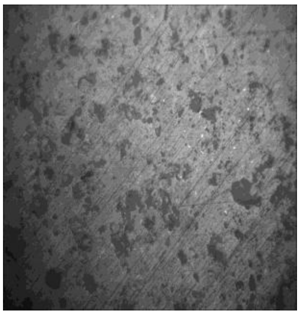


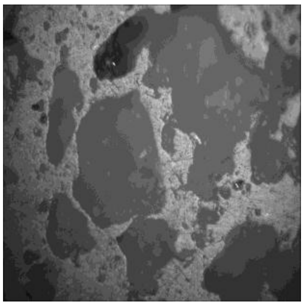
Figure 3 Graph of the compressive strength of porcelain against composition of phlogopite at different sintering temperatures.



10 wt% phlogopite at 1100°C



10 wt% phlogopite at 1200°C



10 wt% phlogopite at 1300°C

Figure 4 Micrograph of the samples of 10 wt% of phlogopite at different sintering temperature.

4. Conclusions

This study concludes that the optimum composition of phlogopite is 10 wt% and the optimum sintering temperature is 1200°C. At this composition and sintering temperature, the porcelain gives the highest value of compressive strength which is 46.43 MPa. 10 wt% of phlogopite was concluded as the stable composition in which the phlogopite has smaller grain size and exhibited stronger bonding between the particles, decreased the pore size thus lead to a denser porcelain structure. It also can be concluded that the best results of the percentage of shrinkage and value of the bulk density was obtained at 1200°C. The strength of the porcelain could be enhanced by the addition of phlogopite according to the optimum composition and sintering temperature in this study. To further this study, the microstructure of samples also can be analysed by using Scanning Electron Microscope (SEM).

Acknowledgement

The authors would like to thanks to lab assistants, Mr. Kamarul Affendi Bin Hamdan, Mr. Fazlannuddin Hanur bin Harith, Mr. Shahrul Mahadi bin Samsudin and Mr. Hasrul Bin Ismail for the technical supports.

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