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Effect Of Sintering Temperature On The Physical Properties Of Titania-Alumina-Silver Nitrate Foam

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Abstract. Nowadays, ceramic foam was widely used in bio-medical as well as engineering field such as thermal insulation and adsorption of environmental pollutants. Ceramic foam made of a porous structure that provides the physical and mechanical properties of both, low specific weight and high thermal fluidity. In this study, the selected starting ceramics powder are titanium dioxide (TiO_2), aluminum oxide (Al_2O_3) and Silver Nitrate ($AgNO_3$). In general, TiO_2 is very light weight compared to other substance. It is brightness and very high refractive index. On the other hand, Al_2O_3 is responsible for the resistance of metallic aluminum to weathering while $AgNO_3$ is plays important role as antiseptics. These unique properties of these ceramics has encouraged more study to be implemented on it. Preferred method for the ceramic foam fabrication is via slurry method. In which consists steps of mixing, dipping, pressing, drying and sintering. Three different temperatures of 1200°C, 1250°C and 1300°C, with compositions of 22.5wt% of TiO_2 + 7.5wt% Al_2O_3 + 1.25 wt% $AgNO_3$ with 2.5wt% of Carbolic methylcelulose (CMC) and 7.5wt% Polyethylene glycol (PEG) are apply in this study. Analysis of the phases, morphology, porosity, density and sringkage were carried out on all samples. From this study, foams of 47.8% to 62.6% porosity using TiO_2 + Al_2O_3 + $AgNO_3$ were successfully produced. The highest porosity value of 62.61% was fabricated at 1200°C and the highest density value of 2.06% at 1300°C. Thus, it is concluded that the optimal fabrication slurry method parameters of sintering temperature of 1300°C and the compositions of 22.5wt% of TiO_2 + 7.5wt% Al_2O_3 + 1.25wt% $AgNO_3$ with 2.5 wt% of CMC and 7.5wt% PEG has absorbability of heavy metal and bacteria in pre-treatment process can be develope.

Introduction

Water pollution affects drinking water, rivers, lakes and oceans all over the world. This consequently harms human health and the natural environment. The water pollution in Malaysia is originated from point sources and nonpoint sources. Point sources that have been identified include sewage treatment plants, manufacturing and agro-based industries and animal farms. Non-point sources are mainly diffused ones such as agricultural activities and surface runoffs. According to Malaysia Environment Quality Report 2006, the Department of Environment has recorded 9,060 @ 47.79% inclusive of 601 Network Pump Stations, 8,543 @ 45.07% for manufacturing industries, 869 @ 4.58% for animal farms and 484 @ 2.55% for agro-based industries [1]. Ceramic foam are functioning well extremely in the field of separation, waste treatment and pollution control because of their superior mechanical properties, chemical inertia, long working life and thermal stability. Ceramic foam is a porous materials with porosity ranging from 70% to 90% and volume density from 0.3 to 0.6 g/cm^3. It has three dimension frameworks structure, and inter-connected pores [2]. Due of its many advantages, such as low density, high porosity, large specific surface area, low heat transfer rate, high temperature resistance and corrosion resistance, the ceramic foam applied in a variety of industries such as filtration, heat insulation, sound insulation, catalysts, and extends to electron, optics and biochemistry over the past decade. Open-cell ceramic foam manufacturing techniques can be classified into three general categories such as sponge-replication, foaming agent addition and organic filling [3]. One technique that is interesting is the sponge-replication that was

first developed in the early 1960s. A natural sponge or polyurethane foam used as a form, that is infiltrated with ceramic slurry. The ceramic slurry is then fired to form ceramic foam. Based on gas bubbles in preceramic melts, gas evolving constituents are added to the melt. The generated bubbles formed the foam. Foaming uniformity and cell geometry can be adjusted by careful selection of surfactants and foaming agents [2].

Materials and Methods

Polyurethane foam is shaped into cubic form with dimension of 1.0 cm x 1.0 cm x 1.0 cm. Ceramic powder are scaled. TiO_2 powder is stirred for 2 minutes with gradual addition of distilled water. CMC and PEG were further added at a time. In the meantime Al_2O_3 and $AgNO_3$ are mixed together. After 3 minutes, the mixture of Al_2O_3 and $AgNO_3$ are poured in and were stirred together for 5 minutes forming slurry. Polyurethane foam is then dipped into the slurry, pressed for several times as to remove excess water.

After dipping and pressing, the foam cubes were dried at 100°C for 24 hours and further sintered for 28 hours. Three different sintering temperatures involves were 1200°C, 1250°C and 1300°C. Produced foam were analysed in terms of the physical properties, phase identification, morphology, porosity and density. Moreover, Thermogravitimetric Analysis (TGA) was performed for the purpose of sintering profile determination.

Results and Discussion

Porosity and Density result. Figure 1.1 shows porosity percentage variation temperature at 1200°C 62.61% of porosity is formed and decreased to 8.69% when temperature is increase to 1250°C. The porosity formed at 1250°C was 53.92%. Temperature of 1300°C, only performs to create 47.88% porosity marking significant difference of 14.73% from porosity formed at 1200°C and 1300°C. The size of the porosity grows as this occur in tandem with increasing temperature. Thus high temperature causes the gradual occurrence formation of the neck where the microstructure will be denser thus with decreasing porosity [4-5].

Figure 1.2 Bulk density formed at various sintering temperature at 1200°C, density of the sample is 1.52 g/cm^3 and increase to 1.69 g/cm^3 at temperature 1250°C. When the temperature increased to 1300°C, density of the sample is at the highest 2.0589 g/cm^3. The difference between two temperatures, 1200°C and 1300°C only took 0.17 g/cm^3 but it is quite large differences if compared to 1300°C. These make 0.5427 g/cm^3 difference compared to the density of a sample at 1200°C. Thus, it is clear that when the higher sintering temperature is set, higher densities to be achieved.

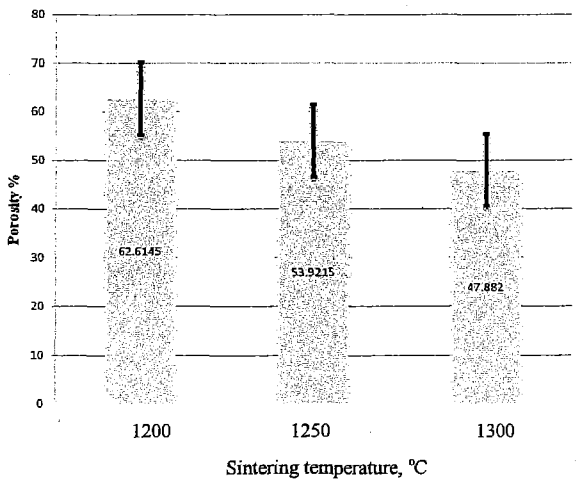

Figure 1.1: Porosity formation at different sintering temperature

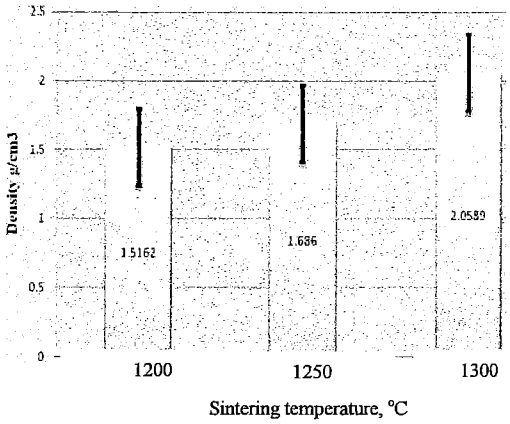

Figure 1.2: Density formed at different sintering temperature

Shrinkage result. Figure 1.3 shows shrinkage of samples at different temperature. Overall, shrinkage increases with increasing sintering temperature. At highest shringkage at the temperature of 1300°C, at 20 to 30 % is due the less composition of the filler material used in which, lower amount of porosity will be produced and porosity reduction will cause the sample's size to shrink [4,6]. Furthermore, it was found that shrinkage at 1300°C could be better because it didn't bring any changes to the shape after sintering process. Thus, the best sintering temperature is 1300°C since the shrinkage of samples yielded lower porosity with higher density.

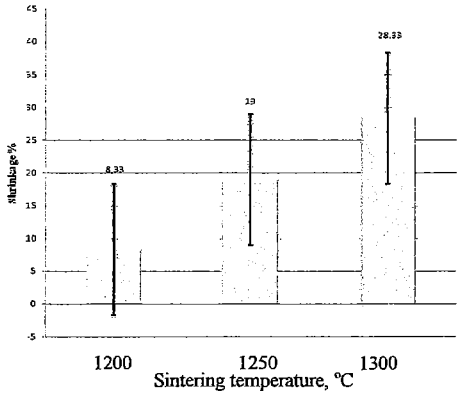

Figure 1.3: Shrinkage of samples at different sintering temperature.

SEM result. As seen from Figure 1.4 and Figure 1.5, macro and micro pores formations accurence are clear. The size of the porosity seems to grow as the "neck growth occur in tandem with increasing temperature. The high temperature causes the gradual formation of the neck has in which yielded dense and closed the microstructure with decreasing porosity. The same phenomenon was observed by others researcher [4,5 & 7].

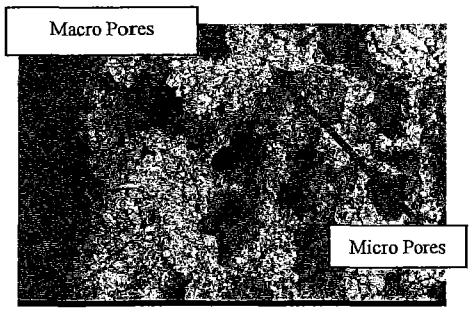

Figure 1.4: SEM image for porous ceramic foam with temperature of 1300°C with 30x magnification

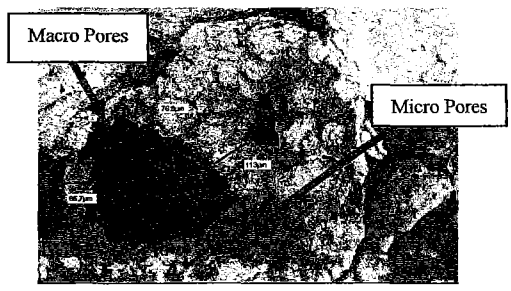

Figure 1.5: SEM image for porous ceramic foam with temperature of 1300°C with 120x magnification

Summary

It is clear that the preparation of TiO_2-Al_2O_3-$AgNO_3$ foam was successfully produced. A wide distribution of 47.8% to 62.6% porosity with low range of shrinkage (8.33%-28.33%) was obtained, thus indicating that the range of sintering temperature tested indeed affects the physical properties of the foams.

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