Effect of sintering temperature on mechanical properties and crystallography of sintered green glass ceramic composite (GCC)

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ABSTRACT – The influence of sintering temperature on properties of green glass ceramic composite (GCC) on various filler loadings was investigated. The GCC prepared for mechanical testing were square shape with dimension of 18 × 18 × 4 mm at 0, 5 and, 10 wt.% of filler loading and sintered at 750, 800, 850 and, 900 °C for 2°C /min with holding time at 1 hour. The GCC was analysed in terms of mechanical properties and crystallography analysis. The highest hardness contributed by sample A3 which is 886.02 HV. These results indicated the higher the sintering temperature, the hardness is improved. The XRD analysis confirmed the present intensity of wollastonite and cristabollite peaks increased almost linearly with sintering temperature. The findings concluded that the suitable sintering temperature can be controlled for alternative materials for structural applications.

1. INTRODUCTION

The interest in soda lime silica glass (SLSG) waste is because of its composition and the large volume which is produced in Malaysia. Among the conventional glasses, SLSG is known as the most common commercial glass product that contributes up to 90 - 95% of the glass produced around the world. These types of glasses are commonly used because SLSG have a virtuous glass forming nature compared to others several conventional glass system. Spent bleaching earth is one of the palm oil solid wastes that can be utilized to produce recycle product. SBE is commonly disposed in landfill without any pretreatment and usually contains 20-40 wt% of oil. Eggshell which contains about 94 wt% calcium carbonate (CaCO3) in its composition is not being considered a hazardous waste, its inappropriately landfill disposal can result in considerable environmental liabilities due to the large amount of eggs produced. This element of $CaCO_3$ through process calcination to transform to CaO which is very important for structural applications since it attributed the improvement in strength in structure and thermal stability.

Waste glass is solid disposal that has been recycled as renewable resources into useful products by adding with others waste materials such as spent bleach earth and eggshell. The method recycling waste from glass via conventional sintering process. However, the process is long and requires high temperature which incur high cost. Long process are not suitable for natural wastes as it is influenced by exposure to high temperature which can contribute to high porosity. High strength of glass composite can be obtained if the glass composite with combination of filler from waste materials are well densified via a direct sintering controlled. For this problematic material, this study represents an important contribution to developing new waste management option. This study reports on the effect of sintering temperature of green glass ceramic composite by analyzing the mechanical properties by Vickers Micro-hardness and crystallography analysis via X-ray Diffraction (XRD) analysis.

2. METHODOLOGY

Recycled SLSG was collected from household waste were crushed by using disk crusher (Model Retsch) machine. The SLSG powder was then milled using planetary ball milling. Eggshells waste were cleaned and crushed by using planetary ball mill. Vibratory sieve shaker is used to sieve the powder to get an average particle size of < 45µm. SBE supplied was unprocessed, and the sonication process was used to extract oil. Then the eggshells is divided for calcined process to eliminate carbon dioxide from carbon carbonate compound. Temperature involve is at 1000 °C with 2 °C /min heating rate and 1 hour holding time. The powder was compacted using a uniaxial die pressing machine at 3.2 gram for square mould at 2.5 tonnes. Tables 1 shows the composition of sintered green glass ceramic composite. The green bodies were sintered using a laboratory electric furnace Carbolite (1300 model) at 750, 800, 850 and 900°C at a constant heating rate of 2°C/min for 1 hour. Cooling rate for 750°C (6.25 hours), 800°C (7.07 hours), 850°C (7.08 hours) and 900°C (7.5 hours). Mechanical analysis which involved Vickers Micro-hardness were conducted according to ASTM C1327. The square samples were manually polished to get mirror surface and was performed using diamond indenter with load applied of 1 kg to indent the samples for 15 seconds. The XRD was performed by using X-ray Diffraction (Model PANalytical, X'Pert PRO) to determine the crystallographic structure of materials. The detector was scanned over the scan range of 2θ from 10° to 90°.

Table 1 Composition of sintered green glass ceramic composite

Sample	SLSG (wt.%)	SBE (wt.%)	ES (wt.%)
A1	55	45	0
A2	50	45	5
A3	45	45	10

3. RESULTS AND DISCUSSION

3.1 Micro-Hardness of Sintered Green Glass Ceramic

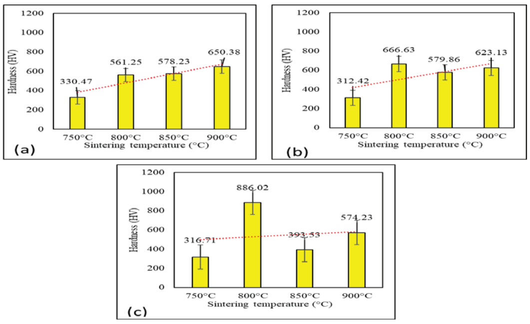

Figure 1 Hardness of sintered green glass ceramic for different sintering temperature on various filler loading (a) 0 wt.%, (b) 5 wt.% and, (c) 10 wt.%

Figures 1 shows Vickers micro-hardness at different sintering temperatures on various eggshells loadings as filler. As shown in the figures, as the sintering temperature increased, micro-hardness was increased. As shown in Figure 1, hardness of the samples parallel with sintering temperature. The highest hardness was contributed at 886.02 HV by sample labelled as A3 at 800°C. Meanwhile at 5 wt.% of filler, the lowest hardness is at 750°C which is 312.42 HV. At high sintering temperature, as the filler loading increases, smaller pores were created. This is due to smaller size gas bubbles were produced during sintering and left behind as pores during cooling. As the smaller pores were formed, bigger area of denser surface was created and thus increased the hardness value [1].

3.2 Crystallography of Sintered Green Glass Ceramic

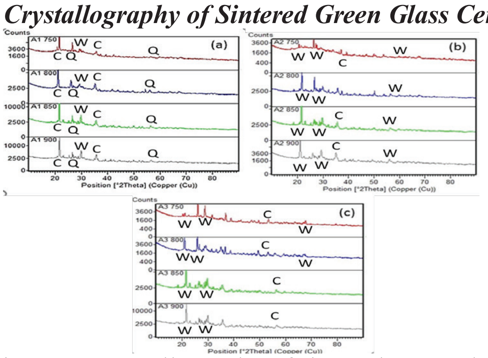

Figure 2: Crsytallography of sintered green glass ceramic for different sintering temperature on various filler loading (a) 0 wt.%, (b) 5 wt.% and, (c) 10 wt.%

Figure 2 shows that the height and intensity of wollastonite and cristabollite peaks, and also the quantity of that phase significantly increased with increasing sintering temperature. The most common phase are cristobolite, wallastonite and quartz. At low sintering temperature, 750° (0 wt.%) the major phase was dominated by cristobolite with dominant peak 21.80° with 100% intensity. At high sintering temperature, 900° (10 wt.%) the major phase was dominated by wollastonite with dominant peak 26.19° with 100% intensity. The formation of wallastonite was due to the content of CaO in the composition of both recycled glass and SBE [2]. With the presence of high sintering temperature, a small amount of cristobollite converted to wollastonite upon firing at high temperatures of 900°C. This result indicated that SLSG plays an important role as a backbone in the structure of ceramic with the modification of the increased glassy phase content on waste glass addition [3]. The changes in sintering temperature slightly increased the crystalline peaks.

4. CONCLUSIONS

The influence of sintering temperature on properties of GCC on various filler loadings was investigated. The sintering temperature is important for mechanical properties and crystallography of GCC. From this study, indicated the higher the sintering temperature, the hardness is improved. The XRD analysis confirmed the present intensity of wollastonite and cristabollite peaks increased almost linearly with sintering temperature. The findings concluded that the suitable sintering temperature can be controlled for alternative materials for structural applications. These findings encourage further investigation in different weight percentage of filler loading and also its microscopy.

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