UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE EFFECT OF CARBON CONTENT (WT %) TO THE MECHANICAL AND THERMAL PROPERTIES OF RECYCLE GLASS CERAMIC

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Engineering Materials) (Hons.)

by

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BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

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Signature	:	………………………………………….
Author’s Name	:	MOHD IKHWAN BIN ISHAK
Date	:	23 June 2014

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Engineering Materials) (Hons.). The member of the supervisory is as follow:

………………………………

(Dr. Zaleha Bt Mustafa)

ABSTRAK

Kajian ini dijalankan untuk mengkaji kesan kandungan karbon terhadap sifat mekanikal dan haba gelas kaca silika. Dalam kajian ini, sifat fisikal, mekanikal dan haba dikaji pada kandungan karbon yang berbeza iaitu 85:0:15, 84:1:15, 80:5:15, 75:10:15 (kaca: karbon: tanah liat). Untuk mengkaji kesan tanah liat terhadap sifat spesimen, nisbah 99:1:0, 98:2:0 and 97:3:0 digunakan. Analisis kekerasan dan haba dijalankan menggunakan pelet silinder dan acuan persegi panjang berukuran 13 mm dan 7 cm x 2 cm x 3 cm dan disinter dalam pada 850°C. Peratusan keliangan, ketumpatan pukal, serapan air dan sifat kekerasan diukur menggunakan ASTM C-373. Pengaliran haba diukur menggunakan Penganalisis Sifat Haba KD2. Fasa dan analisis morfologi telah dijalankan dengan menggunakan X-Ray Diffractometer (XRD) dan Mikroskop Imbasan Elektron (SEM). Keputusan menunjukkan bahawa sifat kekerasan menurun manakala kekonduksian haba meningkat dengan peningkatan kandungan karbon. Peratus keliangan dan serapan air juga meningkat dengan peningkatan kandungan karbon sementara ketumpatan pukal menurun dengan peningkatan kandungan karbon. Analisa mikroskop imbasan elektron menunjukkan saiz keliangan bertambah dengan peningkatan kandungan karbon. Analisis fasa menunjukkan sampel menghasilkan struktur kristobalit dan silikon dioksida.

ABSTRACT

This investigation is carried out to study the effect of carbon content to the mechanical and thermal properties of recycled soda lime silicate glass. In this study, physical properties, mechanical and thermal properties were studied at different carbon content, which are 85:0:15, 84:1:15, 80:5:15, 75:10:15 (glass: carbon: ball clay). In order to study the effect of ball clay to the specimen properties, ratio of 99:1:0, 98:2:0 and 97:3:0 were used. The hardness and thermal analysis was carried out using cylindrical pellet and rectangular mould with dimension of 13 mm and 7 cm x 2 cm x3 cm respectively and sintered at 850°C. Apparent porosity,bulk density, water absorption and hardness properties were measured using ASTM C-373. Thermal conductivity was measured using KD2 Pro Thermal Properties Analyzer. Phase and morphology analysis was carried out using X-Ray Diffractometer (XRD) and the Scanning Electron Microscopy (SEM). Result showed that hardness property decreased while thermal conductivity increased with increased of carbon content. The porosity and water absorption also increased with the increasing carbon content while the bulk density decreased. The SEM analysis showed that the pores are increasing in size as carbon content is increasing. The phase analysis revealed that cristobalite and silicon dioxide crystalline phases are formed in the samples.

DEDICATION

To my father and mother for their love and support and my friend who have been very helpful to me all along.

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I would like to express my gratitude and thanks to those who have been very kind and helpful to me in conducting this research. First and for most, I would like to dedicate my millions of thanks to my supervisor, Dr Zaleha Bt Mustafa for her kindness, advices and guidance during completing my project whom have been providing most of the knowledge that I have never thought off before. I would like to express my gratitude also to all the others FKP lecturer and technicians who had provided technical help and assistance throughout the project. Lastly I would like express my gratitude with highly appreciation and dedication to my parents whom have been providing me a lot of love and continuous supports throughout my life. Not to mention, all my friends whom always beside me all along the years. Thanks.

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LIST OF ABBREVIATIONS

Al_2O_3	-	Aluminium oxide
ASTM	-	American Society of Testing Material
$BaCO_3$	-	Barium carbonate
BS	-	Bottom slag
C	-	Carbon
CaO	-	Calcium oxide
Cu	-	Copper
CO_2	-	Carbon dioxide
GPa	-	Giga Pascal
IBM	-	International Business Machine
LPS	-	Liquid phase sintering
MgO	-	Magnesium Oxide
MPa	-	Mega Pascal
MSW	-	Municipal Solid Waste
Na_2O	-	Sodium oxide
Rpm	-	Revolution per min
SEM	-	Scanning electron microscope
Si_2O	-	Silicon oxide
SLS	-	Soda lime silicate
SSS	-	Solid state sintering
XRD	-	X-ray diffractometer
XRF	-	X-ray fluorescent
ZnO	-	Zinc oxide

CHAPTER 1

INTRODUCTION

1.1 Background study

Glass can be defined as inorganic products of fusion that have been cooled to rigid conditions without crystallization (Smith and Hashemi, 2006). It has been used in great amount mainly in household appliances, structural application and electronic industries as well as in manufacturing industry. The amount of waste glass has been produced greatly per year due to increasing demand of glass products. The most commercialized used of glass is soda lime silicate (SLS) glass. The composition of SLS glass consists of 72.2 % of SiO_2, 12.3% of Na_2O, 8.9% of CaO, 5.5% of MgO and 1.1% of Al_2O_3 which is similar to typical commercial window glass (Taniguchi and Ito, 2003). In order to meet the demand of this SLS glass and to ensure the sustainability of the raw material, the glass needs to be recycled for future application.

The glass waste need to be recycled so that it can reduce the cost of new material and utilized as much as possible the abundant waste glass available. However it yet needs to be processed with excellent properties that any other commercially available SLS glass. This research involves the use of charcoal as the filler to the glass to explore the possible cooling properties of the material. Charcoal is organic material consisting of carbon which is good in conducting heat thus it exhibits good thermal conductivity properties. This project aimed to develop glass ceramic materials that made of recycle glass waste yet have the comparable properties with virgin raw material based product but cheaper and at the same time provide the environmental sustainability.

1.2 Problem statement

The handling and management of the domestic municipal solid waste in most developing countries are fairly limited (Aguilar-Virgen *et al*., 2010) The increasing in population contributed to the increasing production of waste daily. Thus, the need to utilize this waste is very important in order to meet the demand of source of material in the future. The failure to manage the domestic waste production brings a major impact towards the demanding of raw material and also to the financial of the citizen. In the states of the developing nations, the handling cost of the domestic waste involve almost half of the local government expenditures (Emmanuel *et al*., 2013). Glass is one of the major contributors to the domestic waste as it is the raw material for much of the consumer products such as beverages packaging, household equipments and also in structural application. According to Wollongong City Council, in 2008, the second largest consumption of residential waste was found to be glass accounting to 37.5% composition by weight percentage of the 240 L residential recycling bin. In Malaysia, most of the wastes are being thrown away in the disposal land and this practice is no longer promising as the land is limiting due to increasing population of the nation (Manaf *et al*., 2009). Thus, the need to bring awareness among people on recycling the waste materials are essential especially the glass.

Glass waste should be recycled in order to preserve the environment and at the same time providing opportunity of producing new material. West (2013) reported that every ton of glass that is recycled saves more than a ton of the raw materials are needed to create a new glass, including 1,300 pounds of sand, 410 pounds of soda ash and 380 pounds of limestone. The addition of filler towards the recycled glass can enhance the properties of the material in analytical manner. The characteristics of recycled glass produced with the addition of the carbon will be analyzed physically, mechanically and thermally.

1.3 Objectives

The objectives of this project are:

1. To study the effect of carbon content in hardness (HV) and thermal conductivity (k) of glass ceramic produced from recycled waste glass.
2. To identify the optimum loading composition in weight percentage (wt %) of the filler to the hardness and thermal conductivity properties of the glass ceramic made from recycled waste glass.
3. To study the effect of carbon loading to the physical properties of the glass ceramic produced from recycled waste glass.

1.4 Scope

The scope of this study is to utilize the abundant waste of SLS glass and convert it into useful glass ceramic products. The main raw material used in this project is soda lime silicate glass obtained from waste glass such as the bottles and the food containers. The filler used in this study is carbon from the charcoal. In addition, the ball clay was used as the binder for the green body of the ceramic. The benchmark sample composed of 85:00:15 wt% of SLS glass to the carbon and ball clay will be made. Two types of samples were made, with the presence and the absence of ball clay. For the sample produced with the ball clay, the amount was fixed to 15 of overall wt%. The batch formulation with the addition of carbon was varied with 1%, 5% and 10% of weight percentage of carbon and the remaining is SLS glass. For another type of sample, the batch formulation was varied with 1%, 2% and 3% of weight percentage of carbon and the remaining is SLS glass. The loading was made in weight percentage of the samples and weighted as 100 gm. The samples were analysed in term of its mechanical, physical and thermal properties of the products.

The samples were formed via uniaxial pressing and sintered to allow the densification of the green body of the ceramics. The sintering temperature was done at 850°C with heating rate of 2°C/min and 1 hour of soaking time.

The porosity, bulk density and rate of water absorption were analysed according to the American Society of Testing Material (ASTM) standards. The mechanical testing involved hardness testing to investigate the strength of the ceramic samples produced. KD2 Pro Thermal Analyser test was done to study the effect of carbon content to the thermal conductivity of the ceramic samples. Morphological study involved SEM and XRD to study the microstructure and crystalline phases present in the ceramic samples.

CHAPTER 2
LITERATURE REVIEW

2.1 Waste

Waste can be defined as any substances or products that no longer in use or needs by the consumers. It is normally disposed either by land disposal, incinerate them or being thrown away and each of the ways create other problems such as contamination of the soil, production of hazardous gases from the combustion of the wastes and create sight pollution. The increasing amount of waste brings awareness among people and lead to the waste management especially in developing countries. The difficulties in locating a suitable disposal land site made incinerations the major solution to the municipal solid waste (MSW) treatment. Since 1990, incinerators have been vastly built and planned in several urban areas in Taiwan (Cheng and Chen, 2004).

2.1.1 Household waste

One of the major contributors to the arising amount of waste is the household and it comes in variety of type of waste such as plastic, glass, papers and many more Aguilar-Virgen *et al.*, (2010) stated that that the composition of household waste generated are varied. The factors that contribute to the variety of waste produced are lifestyles, the growth of economy, the consumer trends, the people behavior, seasonal changes and geographical factor of the residential areas. Thus, it can be said that different standard of livings, cultures, geographical site of the people settlement resulted in variety of waste generated by the population. Figure 2.1 summaries the composition of municipal solid waste generated by the population.

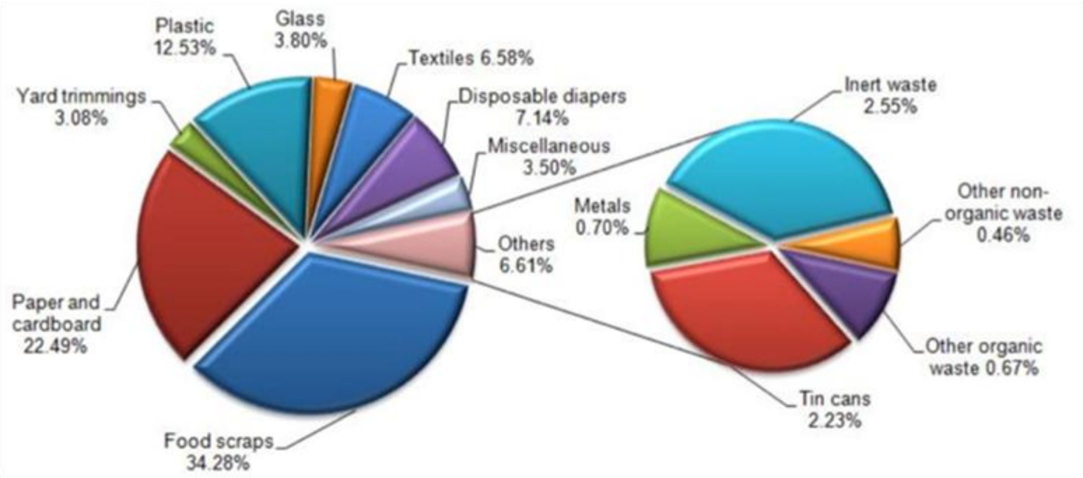

Figure 2.1: The composition of municipal solid waste generated in Ensenada (Aguilar-Virgen *et al.*, 2010)

2.1.2 Industrial waste

Over the century, vast changes in the global economy contribute to rapid development of industrial operations. Industrial waste can be defined as the waste of any operation or processed that have been greatly produced by the industrial and manufacturing world (Abduli, 1996). Manufacturing process starts as low as from the extraction of the virgin raw materials until the testing of final products. During this processes, a lot of waste may be produced such as the ashes develop during extracting an ore to the rejected parts or products that do not meet specifications. For example Grodzin´ska-Jurczak (2001) reported that for the last 30 years Poland has seen a steady developing amount of waste generated per years as shown in Figure 2.2. 145 million tons of wastes were generated per years and more than 90% of the amount was industrial waste and the rest are municipal solid waste.

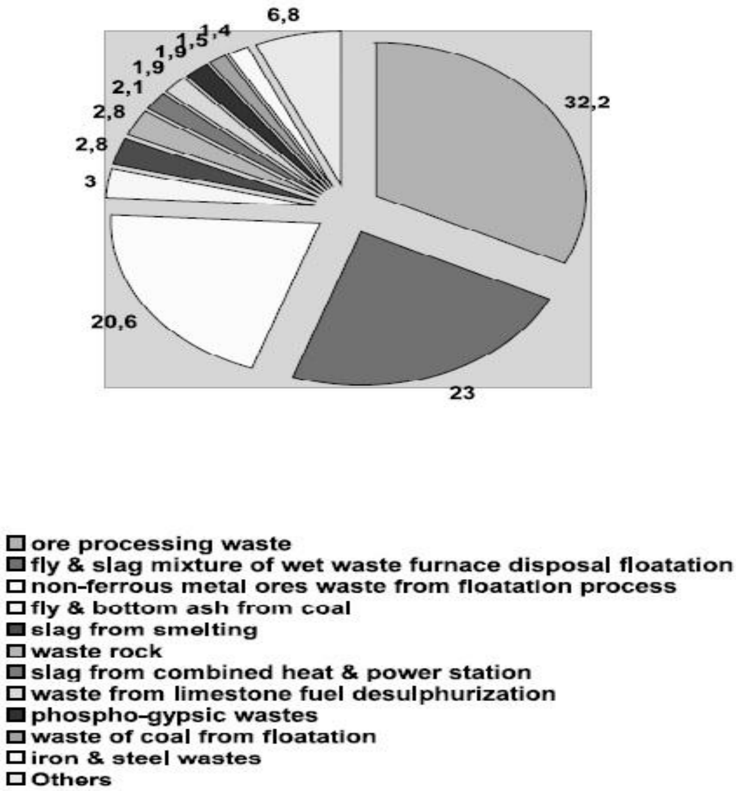

Figure 2.2:Percentage of Poland`s industrial waste composition in 1998 (Grodzińska-Jurczak, 2001)

Similarly to other waste resources, industrial waste contributed to a lot of waste-related environmental problems (Mbuligwe and Kaseva, 2006). Rapid development in industrial areas, contributes variety type of industrial waste such as ashes, coal, slag, non ferrous metal wastes and others.

2.1.3 Impacts towards society

The mismanagement of waste brings several impacts towards society. The land use for the disposal of waste becomes larger and thus may create a situation where there will not much space to sustain this waste. According to a report produced by Clean Up Australia Ltd (2009) almost half of the nation total rubbish was being recycled and each of the item recycled will cause one less item to be disposed in the land. In order to decompose biologically, glass needs a very longer period of time, sometimes extending to one million years. During the bodies breaking down, some of the pieces may still contained in the soil, taking up the valuable land. The disposal of waste