ANALYSIS ABOUT THE EFFECT OF COMPOSITION OF GREEN BODIES ON MULLITE BONDED SILICON CARBIDE

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Analysis About the Effect of Composition of Green Bodies on Mullite Bonded Silicon Carbide

Thesis submitted in accordance with the partial requirements of the Universiti Teknikal Malaysia Melaka for the Degree of Bachelor of Engineering (Honours) Manufacturing (Material Engineering)

By

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APPROVAL

This thesis submitted to the senate of UTeM and has been accepted as partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process). The members of the supervisory committee are as follow:

…………………………………………

Main Supervisor

(Official Stamp and Date)

DECLARATION

I hereby, declared this thesis entitled "Analysis About the Effect of Composition of Green Bodies on Mullite Bonded Silicon Carbide." is the results of my own research except as cited in references

Signature : ……………………………………………

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Date : 5 May 2008

ABSTRACT

The main scope of this project is to study the effect on the properties of mullite bonded silicon carbide with a various green body’s composition. The composition use to produce the mullite bonded Silicon carbide is alumina and SiC. To produce the sample of porous SiC, there are certain procedure needs to be follow. The process sequences are as follow; set the composition, mix the composition, compact the mixture to green body, sinter the green body, and cut the sample to required dimension. The four different composition being use in this research are 1.5:1, 2.1:1, 3:1, and 4:1. The properties involve in this study are such as density, strength and elastic modulus of the SiC. Two type of test performed to the sample is the flexural strength test and density observation. In flexural strength, the selected method to do the test is three point bending test. Three point bending is the most suitable test for ceramic in order to determine the flexural strength. The value obtain from the flexural strength are as follow, 9.03 MPa (1.5:1, alumina 40wt%), 13.45 MPa (2.1:1, alumina 32.3 wt%), 15.75 MPa (3:1, alumina 25 wt%), and 20.06 MPa (4:1, alumina 20 wt%). The standard measurement of the sample is followed from the ASTM standard. For density observation, the density of every sample is compared to one another after all the samples had gone through sintering process. The values of the density are as follow 2472 kgm^{-3} (1.5:1), 2489 kgm^{-3} (2.1:1), 2536 kgm^{-3} (3:1) 2670 kgm^{-3} (4:1). Several analyses have also been done prior to this research. The types of analysis are SEM and XRD observation. The purpose of SEM observation is to recognize the microstructure of the samples with different composition while XRD analysis is to determine the phase composition of every sample. At the end of the research, the optimum composition to produce mullite bonded silicon carbide is selected.

ABSTRAK

Skop utama projek ini adalah untuk mengkaji kesan komposisi yang berlainan kepada sifat-sifat ikatan mulit silikon karbida.. Komposisi yang digunakan untuk menghasilkan ikatan mulit silikon karbida adalah alumina dan SiC. Untuk mengeluarkan sampel SiC yang poros, terdapat beberapa prosedur yang perlu dipatuhi. Urutan prosedur adalah seperti berikut, campurkan composisi bahan, padatkan campuran sehingga menjadi sampel berbentuk bulat, bakar sampel pada suhu yang ditetapkan, dan potong sampel mengikut urutan yang dikehendaki. Empat komposisi berlainan yang dikaji dalam penyelidikan ini adalahs eperti berikut 1.5:1, 2.1:1, 3:1, and 4:1. Sifat-sifat yang dikaji dalam projek ini ialah ketumpatan, kekuatan dan modulus kekenyalan SiC. Dua jenis ujian yang dijalankan ke atas sampel adalah ujian kekuatan pembengkokkan dan pemerhatiaan ke atas perubahan ketumpatan. Dalam ujian kekuatan bengkokkan, kaedah yang dipiilih untuk melakukan ujian tersebut adalah ujian bengkokkan tiga titik. Ujian ini adalah yang paling sesuai untuk sampel seramik bagi mendapatkan nilai kekuatan bengkokkan. Nilai yang telah diperolehi daripada ujian kekuatan bengkokkan adalah seperti berikut, 9.03 MPa (1.5:1, alumina 40wt%), 13.45 MPa (2.1:1, alumina 32.3 wt%), 15.75 MPa (3:1, alumina 25 wt%), and 20.06 MPa (4:1, alumina 20 wt%). Ukuran sampel diperolehi daripada piawaian ASTM. Bagi pemerhatian ketumpatan, nilai yang diperolehi dibandingkan di antara semua sampel. Beberapa analisis juga telah diadakan dalam penyelidikan ini. Nilai ketumpatan yang diperolehi adalah 2472 kgm^{-3} (1.5:1), 2489 kgm^{-3} (2.1:1), 2536 kgm^{-3} (3:1), 2670 kgm^{-3} (4:1).Analisa yang dilakukan adalah melalui pemerhatian SEM dan XRD. Tujuan utama pemerhatian SEM adalah untuk mengenalpasti struktur mikro sampel yang berlainan komposisi manakala analisis XRD adalah untuk mengenalpasti komposisi fasa bagi setiap sampel. Diakhir penyelidikan, komposisi yang paling optimum untuk menghasilkan ikatan mulit silikon karbida telah dipilih.

DEDICATION

"Thanks to my parents, my family, my friends and all persons that involve in this study for their support and guidance"

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

in	-	inches
kg	-	kilograms
m	-	Meter
Max	-	maximum
Min	-	minimum
s	-	Second
^0C	-	degrees Celsius
^0F	-	degrees Fahrenheit
K	-	Kelvin
%	-	Percent
+/-	-	plus or minus
SEM	-	Scanning Electron Microscope
SiC	-	Silicon Carbide
Al_2O_3	-	Alumina
Si	-	Silica
SiO_2	-	Cristobalite
$3Al_2O_3.2SiO_2$	-	Mullite
PMMA	-	Polymethyl Methacrylate
PVB	-	Polyvinylbutyral
H	-	Hydrogen
C	-	Carbon
O	-	Oxygen
XRD	-	X-ray Diffraction
CVD	-	Chemical Vapor Deposition
DPB	-	Double Positioning Boundary
LED	-	Light Emitting Diode
cc	-	cubic centimeter

μ	-	Micro
G	-	Giga
M	-	Mega
Pa	-	Pascal
ASTM	-	American Standard Testing Material
SI	-	Standard International
Wt%	-	Weight Percent

CHAPTER 1

INTRODUCTION

1.1 Introduction to Silicon Carbide

Silicon carbide is a type of ceramic composed of tetrahedral of carbon and silicon atoms with strong bonds in the crystal lattice. These particular bonds produce a very hard and strong material. Silicon Carbide is immune by any acids or alkalis or molten salts up to 800° C. When expose in air, SiC forms a protective silicon oxide coating at temperature of 1200° C and can withstand the heat for up until 1600° C. The high thermal conductivity joint together with low thermal expansion and high strength resulted for this material to have an excellent thermal shock resistant quality. The overall reaction of producing Silicon Carbide is $SiO_2 + 3C = SiC + 2CO$. There is a various type of how to produce SiC whereas it is divided into two type of growth. The two type of growth is bulk growth technique and epitaxial growth technique. SiC with only a few or no grain boundary impurities is capable maintaining their strength to a very high temperature which is approaching 1600° C without any strength loss. Silicon Carbide only go through decomposing when heated to about 2700° C. Silicon carbide was originally produced by a high temperature electro-chemical reaction of sand and carbon. Widely use as an abrasive, Silicon Carbide is marketed under such familiar trade names as Carborandum and Crystolon.

Very pure silicon carbide is white or colourless and crystals of it are used in semiconductors for high-temperature applications. Silicon carbide fibers, added as reinforcement to plastics or light metals, impart increased strength and stiffness.

Silicon carbide does not occur naturally on Earth so it cannot be mined like other minerals, hence the need for its synthesis in a high temperature furnace. The only occurrence of silicon carbide in nature is in meteorites, and it has been described by some researchers as a gift from the stars. Mineralogists call natural silicon carbide moissanite after the man who first identified it in a meteorite in 1905.

1.2 Problem Statement

The purpose of this project is to investigate the maximum capability of porous ceramic. Porous ceramic are hydrophilic and have the capability to transport a polar of substance like water through its capillary. This unique capability has become extremely important for porous ceramic to act as a filter to liquid substance. Although ceramic have very good mechanical properties such as high strength, high thermal conductivity, high hardness and high elastic modulus, but ceramic is a very brittle material. Porous ceramic tend to be even more brittle than solid ceramic. With that reason, this project has been conducted to study the mechanical properties of porous ceramic. There is actually a numerous type of porous ceramic available nowadays, but this project has focus on to study the hardest porous ceramic which is silicon carbide. There are several processes to produce the porous silicon carbide and this project is responsible to choose the best process to produce the product.

The main objective of this project is to study the effect of composition of green body on the properties of silicon carbide. Hence a certain composition is required in order to differentiate the mechanical properties of the porous silicon carbide. This project is also responsible to determine which composition is the most finest in order to produce the most notable porous silicon carbide. It is also important that the product from the best composition does not affect or weakened the other properties of porous silicon carbide.

1.3 Objectives

The objective of this study is:

i) To study the properties of Mullite-bonded Silicone Carbide with various green body's composition.
ii) To study the flexural strength of Mullite-bonded Silicone Carbide with various green body's composition.
iii) To analyze on the effect of composition to Mullite-bonded Silicon Carbide.
iv) To identify the optimum composition of the green body of prepared Mullite-bonded Silicone Carbide

1.4 Scope of the Study

In this project, the type of porous SiC being produce is Mullite-bonded Silicon Carbide. Mullite-bonded SiC require the mixture of silicon carbide and alumina. The processes of producing the sample are as follow; select composition, mix the composition, press the mixture and sinter the green body. The testing conducted for the study is flexural strength and flexural modulus test. Furthermore, the microstructure and phase composition of the Mullite-bonded Silicon Carbide is also studied.

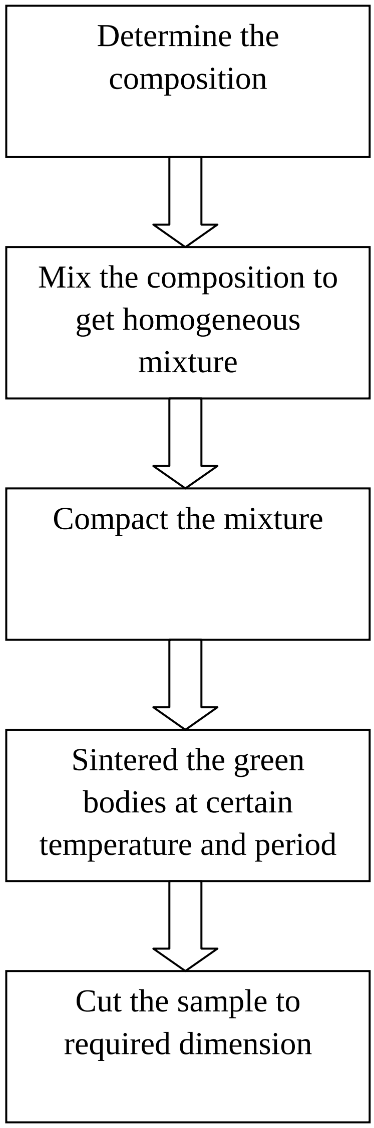

Figure 1.1: Flow chart of sample preparation

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of Silicon Carbide

Before the year of 1900, the existent of Silicon Carbide almost never been recognized and never attracted a fascination on man as in the case of diamond because of almost total absence of SiC crystals in nature. The natural SiC is first being found in a meteorite by Moissan in year 1905. For this reason mineralogists call natural SiC for moissanite. Because of the small abundance of diamond in nature, the existent of silicon carbide has provide mankind with a less expensive material that have almost the same strength as diamond. SiC in many ways is much better suited than diamond for electronic purposes. SiC was first observed in 1824 by Jöns Jacob Berzelius. In the early time, the properties of SiC were not totally understood up until the invention of the electric smelting furnace by E. H. & A. H. Cowles as shown on Figure 2.1. The interest on SiC become more progressive after its application to carbonaceous compound is discovered by Acheson. The main reason of Achesons invention was to produce a material substituting diamond and other abrasive materials for cutting and polishing purposes. The crystalline products Acheson found after the process were characterized by a great hardness, refractabiliy and infusibility. He called the product 'carborundum' and described it as silicide of carbon with the chemical formula SiC. The invention had a great impact and much material was produced using this process mainly for cutting and abrasive purposes. Shortly afterwards the electronic properties of SiC started to be investigated. The first Light Emitting Diode (LED) was made from SiC in 1907. In 1955, Lely presented a new concept of growing high quality crystals.

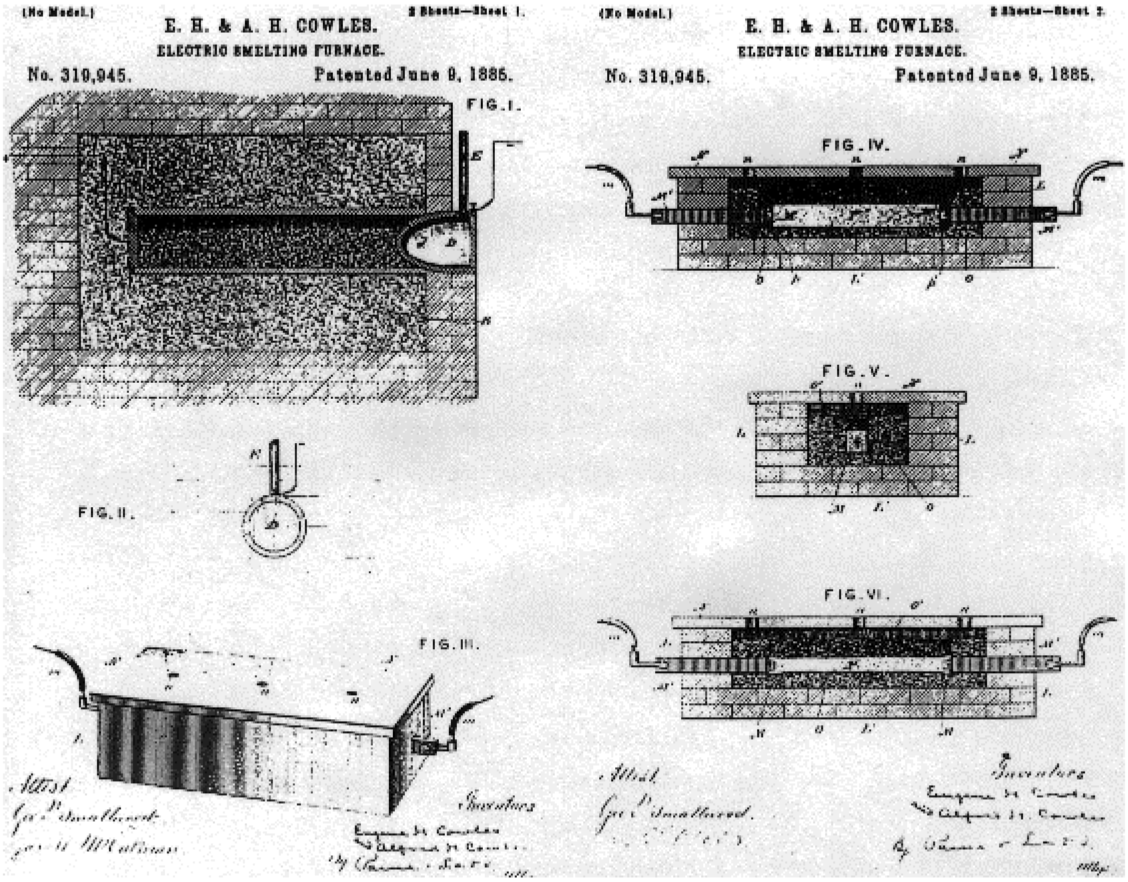

Figure 2.1: Drawing of the original electric smelting furnace. This type of furnace was later applied for the production of SiC by Acheson

The research in SiC became more intensified after this and the first SiC conference was held in Boston 1958. The success and rapid increase of the Si technology made, however, that the interest in SiC dropped. Research during this time (mid '60 to '70) was mainly carried out in the former Soviet Union. In the West, some research in SiC was still maintained in this time. In the year 1978 a discovery of comparable dimension and importance as the Acheson process was presented by Tairov and Tsvetkov. They discovered a way to produce substrates by a seeded sublimation growth. Due to this discovery the SiC technology gained new speed. The possibility to grow single crystal SiC on Si substrates which was invented by Matsunami in 1981 was an important milestone not so much technologically but more as a further 'temperature increase' in the SiC field. In 1987, Cree Research was