INDUSTRIAL CASE STUDY ON THE EFFECT OF PARTICLE SIZE ON WARPAGE OF ALUMINA SUBSTRATE

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

by

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TAJUK: **Industrial Case Study on the Effect of Particle Size on Warpage of Alumina Substrate**

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APPROVAL

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………………………………

(Principal Supervisor)

……………………………….

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ABSTRAK

Projek ini telah dijalankan di syarikat seramik yang menghasilkan alumina substrat untuk mencadangkan saiz zarah yang ideal dan konsisten saiz zarah yang memberikan peratusan peledingan terendah . Oleh itu, objektif projek ini adalah untuk menganalisis saiz zarah yang konsisten yang menghasilkan peledingan yang paling kecil dan untuk menilai hubungan di antara saiz zarah dan pengecutan dengan mikrostruktur dan ikatan dalam substrat alumina menggunakan Mikroskop Imbasan Elektron. Berdasarkan keputusan yang diperolehi, saiz zarah optimum sebanyak 2.0 mikron kepada 2.3 mikron dengan kadar pengecutan 1.1900-1.1910 memberikan peratusan warpage yang lebih rendah sebanyak 2.55%. Dengan saiz zarah ini, peratusan warpage dikurangkan daripada 3% kepada 2.55% selaras dengan objektif pertama. Pengumpulan zarah didedahkan oleh Scanning yang Electron Microscope pada sampel yang mempunyai peledingan. Ia juga mendedahkan keretakan pada segmen pengikat kerana tidak keseragaman pengecutan. Bagi analisis X-Ray pembelauan yang dilakukan, puncak untuk sampel yang mempunyai peledingan dengan sampel yang tidak mempunyai peledingan muncul di kedudukan yang sama dan fasa hadir untuk kedua-dua sampel adalah sama. Spektrum Raman mendedahkan bahawa puncak untuk kedua-dua sampel yang melending dan tiada pelendingan didapati di jalur yang sama. Tiada perluasan puncak atau kenaikan dalam keamatan dalam dua-dua sampel. Akhir sekali, analisis X-Ray pendarfluor mendedahkan bahawa peratusan alumina dalam sampel yang mempunyai pelendingan, 92% lebih rendah daripada peratusan alumina dalam sampel yang tiada pelendingan, 97%. Ini adalah disebabkan oleh ketidaksamarataan taburan saiz zarah yang mencegah ikatan seragam di antara zarah hadir.

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ABSTRACT

This project was conducted at a ceramic company producing alumina substrate to suggest an ideal and consistent range of particle size that gives the lowest warpage percentage ultimately leading to a lower yield lost percentage. Hence, the objectives of this project are to analyze a consistent range of particle size that yields the least warpage and to evaluate the relationship between particle size and shrinkage to the microstructure and bonding in alumina substrate using Scanning Electron Microscope for warp and unwarp samples. Based on the results obtained, the optimum particle size of 2.0 μm to 2.3 μm with a shrinkage rate of 1.1900 to 1.1910 gives a lower warpage percentage of 2.55%. With this range of particle size, warpage percentage is substantially reduced from 3% to 2.55% in line with the first objective. Grouping of particles or better addressed as agglomerates of particles was revealed by the Scanning Electron Microscope at the warp sample. It also revealed cracks at the binder segment due to non-uniformity in shrinkage. As for the X-Ray Diffraction analysis done, peaks for warp and unwarp sample appeared at the same position and phases present for both warp and unwarp are the same. Raman spectra revealed that peaks for both warp and unwarp samples are found at the same band. There is no broadening of peak or spike in the intensities of the warp sample compared to the unwarp and vice versa. Last but not least, X-Ray Fluorescence analysis revealed that the alumina percentage in warp sample, 92% is lower than the percentage of alumina in unwarp sample, 97%. This is due to the inhomegeneity of particle size distribution that deters uniform bonding among the particles present.

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DEDICATION

I dedicate this thesis

to my beloved grandmother, Mrs.Peruwathy, my mother, Mrs.Jaya Ranjinee,

my uncle, Mr.Kunasegaran and the rest of my family members.

I am slowly and slowly tramping my through towards achieving your dreams dismissing

the obstacles thrown at my path one by one.

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LIST OF ABBREVIATIONS, SYMBOLS AND SPECIALIZED NOMENCLATURES

Al_2O_3	-Aluminium Oxide
SiO_2	-Silicon Dioxide
MgO	-Magnesium Oxide
CaO	-Calcuim Oxide
SEM	-Scannin Electron Microscope
XRD	-X-Ray Diffraction
XRF	-X-Ray Fluorescence
R&D	-Research &Development
CRD	-Customer Requirement Date
IPA	-Isopropyl Alcohol
RIPA	-IPA+XYLENE
CIM	-Ceramic Injection Molding
γ	-gamma
θ	-theta
μ	-micron

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c	-corundum
cm	-centimeter
mPa/s	-metrePascal per second
°C	-degree Celcius

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CHAPTER 1

INTRODUCTION

1.0 Introduction

A case study had been carried out at a ceramic company producing alumina substrate for chip resistor used in mobile phones. The case study was done to investigate the effect of particle size on the warpage of alumina substrate since warpage is the highest percentage of defect found at the company.In order to diminish the warpage defect percentage, suitable range of particle size of raw material must be used to produce the substrate. This section will render the background of the study, problem statements, objectives and scope of this project.

1.1 Background

Alumina is widely being used in the electrical and electronic industries. For electronic application alumina substrate is highly used for its resistivity function on the order of 10^{12} ohm-cm whereby circuits are deposited. Other than its high resistivity, alumina also has excellent hardness and mechanical strength. It can also allow metallization by numerous techniques which requires chemical compatibility and good surface quality. Its coefficient of thermal expansion ranges from 4.3 to 7.4 ppm/°C (Pecht et al., 1998). Ceramic substrates are produced for use with high power, hybrid microelectronic circuits and power modules. These propelled ceramic items offer a wide scope of thermal, mechanical and physical properties and are a less-dangerous distinct option for other substrate materials utilized as a part of the

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past. These ceramic substrates are in a perfect world suited for use as stages for high power thickness electronic circuits or as single or different chip heat sinks whereby the heat form the circuit ought to be released efficiently to extend the lifetime of the product and boost the reliability of the system (Schwartz, 2006).

However, the major drawback at the ceramic company is warpage of ceramic substrate after the firing process. A condition which disables the acquirement of near-net shape forming that that eventually results in the failure of cost-effective manufacturing of complex-shaped ceramic products due to distortion from the dimensions as a result of either excessive shrinkage or very low shrinkage is termed as warpage (Tseng, 2000). Warpage is a shrinkage-related defect which should be discarded to attain near-net shape product. Asymmetrical residual stress is the main cause of warpage which resulted from non uniform thermal contraction during solidification. Thermal debinding also contributes to warpage particularly at a temperature range of binder loss rate (Tseng & Liu, 1998).

Hence, in this study, the effect of particle size on warpage will be seen here along with the suggestion of range of ideal particle size that yields the least warpage percentage. This is because, often times in ceramic processing problem comes from the packing density and pore size which can be altered if the particle size is changed (Chaiyabutr et al., 2009). A smaller particle size is desirable since it promotes sintering rate. As the sintering rate increases,porosity declines and and porosity declines, strength and toughness of the fired ceramic increases inhibiting the formation of crack or deflection (Kim et al., 1999).

With the already existing particle size range which is from 2.1μ to 2.4μ being used at the ceramic company, warpage percentage close to 4% still takes place. Thus, 10 green sheet samples were taken to discover the range of particle size that would yield the least percentage of warpage.

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1.2 Problem Statement

Monthly yield percentage at the ceramic company is affected by numerous defects at which warpage is the main contributor of yield lost. Warpage of ceramic substrate occurs after the firing process leaving dimensional distortion. Figure 1.1, Figure 1.2 and Figure 1.3 below show the trend of defects percentage for the past three months last year taken from the ceramic company.

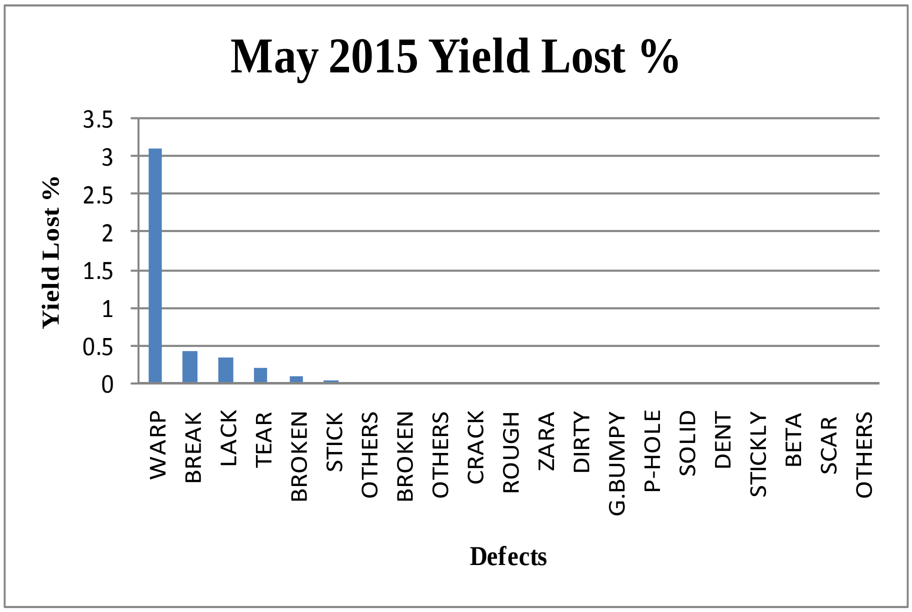

Figure 1.1: Yield Lost Graph for May 2015(Ceramic Company, 2015).

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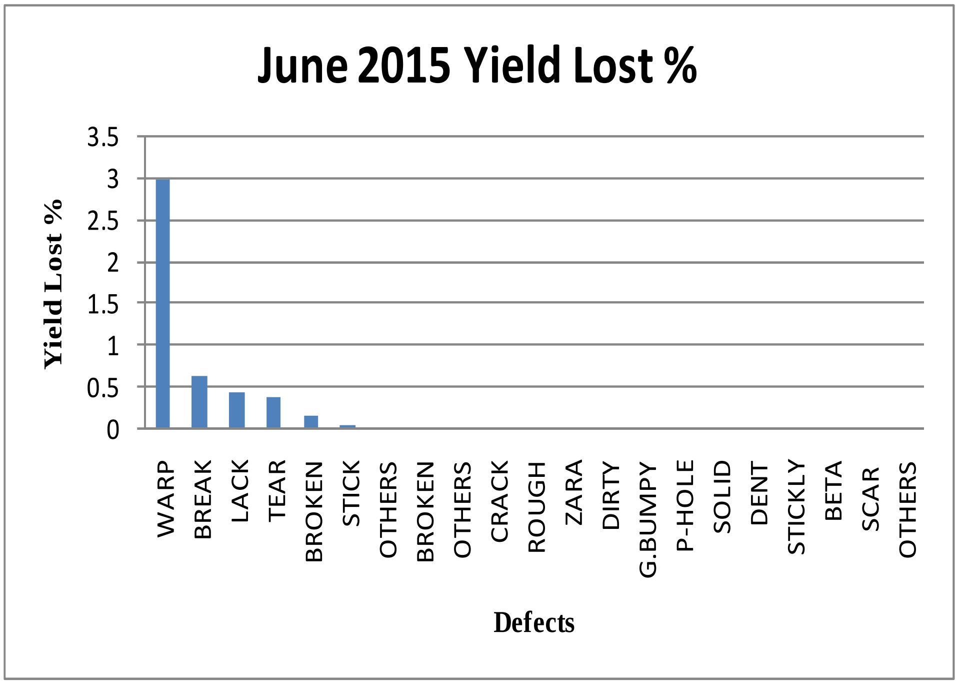

Figure 1.2: Yield Lost Graph for June 2015(Ceramic Company, 2015).

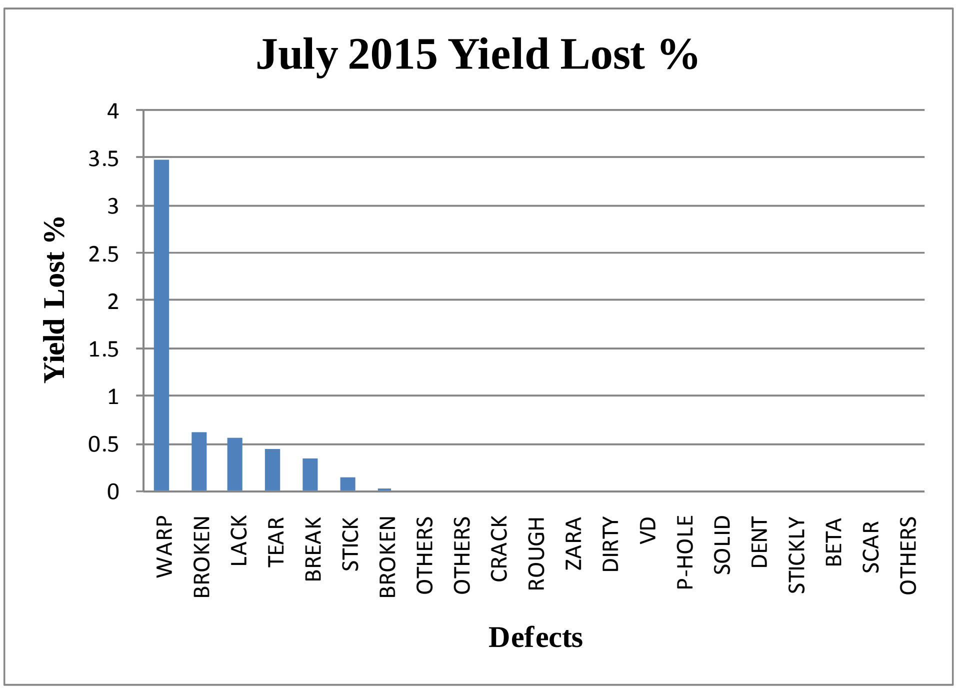

Figure 1.3: Yield lost graph for July 2015(Ceramic Company, 2015).

Based on the three graphs shown above, it can be clearly seen that warpage contributes the most to the percentage of yield lost for the three months consecutively ranging from May to July in year 2015 although there are still other

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defects leading to the yield lost. Thus to counter this ordeal, particle size measurement was done to determine the ideal particle size of the raw material that will be mixed to generate the slurry.

1.3 Objectives

The objectives of this project are:

1) To analyze a consistent range of particle size that yields the least warpage .

2) To evaluate the relationship between particle size and shrinkage to the microstructure and bonding in alumina substrate.

1.4 Scope Of Project

The scope of this project is study on the particle size which impacts the warpage percentage since warpage is the major contributor of yield lost% at the ceramic company. The aim of this study is to reduce the warpage percentage with the determination of the ideal range of particle size of raw material. Therefore, under a constant firing temperature of 1565°C at which the green sheets were taken for particle size analysis will be fired with a standardized thickness of product which is 0.56mm, ideal and consistent range of particle size of that gives the least warpage was determined. This study was confined to the product that has the highest demand at the ceramic company with 0.56mm thickness and fired at firing machine at a temperature of 1565 °C. Also the microstructure and surface morphology of fired product were studied under SEM (Scanning Electron Microscope) besides studying on the composition with XRD (X-ray Diffraction). Lastly, the percentage of the materials present in the product obtained through XRF (X-ray Fluorescence) and the bonding and polymorphism of the compounds studied using Raman spectra.

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CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This section provides explanation on the main material of the product which is alumina, and the processes involved to produce the ceramic substrate. Also, previous studies of particle size, shrinkage and warpage are discussed in this chapter along with one the former improvements done at the ceramic company to reduce warpage.

2.1 Alumina (Al_2O_3)

There are a lot of man-made ceramics raw materials present, for example, MgO, SiO_2. In any case, alumina is the most broadly utilized engineered raw material for ceramics due to their robust ionic holding. In spite of the fact that loss of quality at high temperature is unavoidable, horde of utilizations are being created for it due to its superb heat and corrosion resistance since of all accessible, Al_2O_3 has the most stable physical properties (Barsoum, 2002).Relying upon its crystalline structure, contamination particles, and the diameter of particles the nature Al_2O_3varies generally. There is a plenitude of crystalline structures subsequent to the required physical properties fluctuate as indicated by the proposed use. The most widely recognized type of crystalline aluminum oxide is known as corundum, which is the thermodynamically stable structure (Low, 2006). With aluminum particles filling 66% of the octahedral interstices, the oxygen ions almost frame a hexagonal close-stuffed structure, each Al^{3+} focus is octahedral. Corundum embraces a trigonal

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Bravais cross section with a space gathering of R-3c (number 167 in the International Tables) on the pretext of crystallography. The primeval cell consists two equation units of aluminum oxide. Aluminum oxide additionally exists in different stages, including the cubic γ and η stages, the monoclinic θ stage, the hexagonal χ stage, the orthorhombic κ stage and the δ stage that can be tetragonal or orthorhombic gave that each possesses an one of a kind distinctive crystal structure and properties (Riedel & Chen, 2011).

2.2 Alumina In Electronic Application

With all speculations that ceramics are by and large hard, wear-safe, frail, high refractory material, inclined to thermal stun, electrically and thermally insulative, nonmagnetic, chemically stable and oxidation-safe, there will be exemptions because a fair share of them are electrically and thermally very conductive, while others are superconducting. Many settle on them as the best materials for substrate in electronic bundles because of their insulative properties together with their low-loss elements and brilliant warm and natural soundness.

In contrary to metals at which just free electrons are in charge of conduction and in semiconductors, electrons and/or holes being the source of conduction, in ceramic, as a result of the vicinity of ions, the utilization of an electric field can actuate these ions to move. Substrate productions for chip resistors building are making full swing with alumina whereby chip resistors are utilized as a part of electronic application at which both the ionic and electronic commitments are exceptionally required for the general conductivity. It is crucial to introduce chip resistors in light of the fact that a known safe current inside electrical segments can be made and kept up.

The flow of electrical current will be opposed by these components which are used to protect, operate, or control circuits. Resistors may have resistance value variable or adjustable within a certain range or can have a fixed value of resistance. Chip

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