ASSESSMENT OF ALUMINA AND MUSCOVITE AS FILLERS FOR EPOXY SUBSTRATE MATERIAL

by

ERFAN SURYANI BINTI ABDUL RASHID

Thesis submitted in fulfillment of the requirements for the degree of Master of Science

June 2009

ACKNOWLEDGEMENT

I would like to express the gratitude and utmost appreciation for the guidance, inspiration, suggestion, criticism and support that Assoc. Prof. Dr. Hazizan Bin Md. Akil has given throughout this project. I also grateful to my co-supervisor Dr. Kamarshah Bin Ariffin and Dr. Chee Choong Kooi from Intel Technology Sdn. Bhd. for their suggestions and time during this project were done.

A special thanks is given to Dr. Jannick Duchet from Institute National Applied Science Lyon for her invaluable suggestion and advice particularly in ion exchange treatment. Sincere appreciation is given to Lindau Chemical and Bidor Mineral Sdn Bhd for providing epoxy resin and mica samples. Gratitude is also expressed to all the technicians in Materials, Mineral Resources and Polymers Divisions for their technical assistance and their kindness and support. Appreciation is expressed to my fellow collogue for their friendship, support and willing assistance at all times when needed.

I also would like to express my sincere appreciation to my parents, Abdul Rashid Bin Salleh and Zainab Binti Lebai Ismail, my brothers and my sisters for their years of patience, affection, understanding, endless support and encouragement.

Thank you very much.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURE

LIST OF PROCEEDING AND PUBLICATION

1. Abdul Rashid E.S., Ariffin K., Chee C.K., Akil H.M., (2006) Flexural and morphological properties of alumina filled epoxy composites, Malaysian Polymer Journal, Vol 1 (1), p. 25-38

2. Abdul Rashid E.S., Ariffin K., Chee C.K., Akil H.M., (2006) Thermal Properties of Mica Filled Epoxy Composites, In : National Symposium on Polymeric Materials 2006 (NSPM 2006), 19 – 20 December.

3. Abdul Rashid E.S., Ariffin K., Chee C.K., Akil H.M., (2006) Mechanical and Thermal Properties of Alumina Filled Epoxy Composites, In : 31st International Conference on Electronics Manufacturing and Technology (IEMT 2006), 9-10 November.

4. Abdul Rashid E.S., Ariffin K., Chee C.K., Akil H.M. (2007) Study on Flexural and Thermal Properties of Mica Filled Epoxy Composites, In : National Postgraduate Research on Material, Minerals and Polymers 2007 (MAMIP 2007), 9-10 April.

5. Abdul Rashid E.S., Ariffin K., Chee C.K., Akil H.M. (2007) Preparation and Thermal Properties of POSS filled epoxy composites, In : 3rd Thermal Analysis Conference 2007, 23-24 October.

6. Abdul Rashid E.S., Ariffin K., Chee C.K., Akil H.M. (2007) Properties of Polymer Composites for Electronic Packaging Application, 3rd place for Best Poster in International Conference Structure Advanced Materials (ICSAM 2007), Greece

7. Abdul Rashid E.S., Ariffin K., Chee C.K., Akil H.M. (2008) Mechanical and Thermal Properties of Polymer Composites for Electronic Packaging Application, **Journal of Reinforced Plastic and Composites**, In Press, Corrected Proof (First online: March 2008)

8. Abdul Rashid E.S., Ariffin K., Chee C.K., Akil H.M. (2008) Preparation and Properties of POSS/Epoxy Composites For Electronic Packaging Application, **Materials and Design**, Vol. 30 (1), January 2009, p. 1-8

9. Abdul Rashid E.S., Ariffin K., Chee C.K., Akil H.M. (2008) Effect of ion exchange treatment on thermal properties in muscovite filled epoxy composites, International Conference and Exhibition on Composites Materials and Nanostructure 2008 (IC2MS 08), 5-7 August

PENILAIAN ALUMINA DAN MUSKOVIT SEBAGAI PENGISI UNTUK BAHAN SUBSTRAT EPOKSI

ABSTRAK

Kajian melaporkan tentang penyediaan dan sifat-sifat komposit epoksi yang terisi pelbagai komposisi pengisi menggunakan kaedah pengacuanan. Dua jenis pengisi digunakan iaitu muskovit dan alumina. Rawatan pada permukaan pengisi-pengisi dilakukan untuk meningkatkan daya kelekatan permukaannya dan penyerakannya di dalam matrik epoksi. Pengisi-pengisi berjaya dirawat berdasarkan pencirian Perubahan Gelombang Infra Merah (FTIR). Kesan rawatan dan komposisi pengisi telah dikaji melalui sifat mekanikal komposit. Didapati kekuatan dan modulus regangan meningkat pada semua komposisi kedua-dua jenis pengisi. Modulus regangan meningkat daripada 3GPa (epoksi kosong) kepada 7GPa (40wt% pengisi) bagi komposit muskovit dengan modulus regangan yang diperlukan ialah 15GPa. Komposit muskovit dengan rawatan penukaran ion memberikan sifat-sifat terma yang lebih baik berbanding dengan komposit muskovit tanpa rawatan. Angkali haba pengembangan (CTE) telah berjaya diturunkan dari 69.4 ppm/°C (epoksi kosong) kepada 32 ppm/°C (40wt% pengisi) dengan nilai CTE yang dikehendaki ialah 16-20ppm/°C. Komposit epoksi terisi alumina dirawat menunjukkan nilai modulus regangan yang lebih tinggi iaitu 9GPa (50wt% pengisi) dan nilai CTE lebih rendah 22 ppm/°C berbanding epoksi kosong. Nilai CTE yang rendah diperlukan untuk mengurangkan tekanan dalaman dan rekahan pada substrat.

ASSESSMENT OF ALUMINA AND MUSCOVITE AS FILLERS FOR EPOXY SUBSTRATE MATERIAL

ABSTRACT

The research reports the preparation and performance of particulate filled epoxy composites at various filler loading using casting method. Two types of fillers were used in this study; muscovite and alumina. Surface treatments were carried out to muscovite and alumina particles in order to improve the interfacial adhesion and dispersion in epoxy matrix. The treatments were characterized using Fourier Transmission Infra Red (FTIR), which indicate both particles have successfully treated. Mechanical properties were investigated in order to evaluate the effect of treatments and filler loading on the composites. It was found that the flexural strength and the flexural modulus increase over the range of filler loading investigated for both composites. In terms of flexural modulus, treated muscovite composite increase from 3GPa (neat epoxy) to 7.5GPa (40wt% treated muscovite) with targeted flexural modulus 15GPa. It was observed that muscovite composites with ion exchange treatment give better performance in terms of thermal properties as compared with untreated muscovite composites. In addition, the coefficient of thermal expansion (CTE) has successfully reduced from 69.4 ppm/°C (neat epoxy) to 32 ppm/°C (40wt% treated muscovite) with targetted CTE value of around 16-20ppm/°C. Apparently, the treated alumina exhibit high flexural modulus; 9GPa (50wt% treated alumina) and low CTE at as low as 22 ppm/°C compared with neat epoxy. The closer the CTE value of the substrate to the chips is preferable in order to minimize the internal stress and fatigue cracking.

CHAPTER 1

1.1 INTRODUCTION

The electronic industry is one of the fastest growing industries in the world today. As this market continues to grow, the demand for packaging processes in electronic packaging also increases. The packaging however requires a minimal cost and maximum efficiency. For many years, the ceramic substrate materials were used due to the low difference on coefficient of thermal expansion (CTE) between the silicon die (2-3 ppm/°C) and the substrate (15 – 18 ppm/°C). However, ceramic substrate materials are expensive and thus are undesirable in electronic application. In 1997, Intel proved that the same connection density and superior dielectric properties could be achieved by sequential build-up (SBU) laminate organic substrate (Veldevit, 2008). Therefore, organic substrates are preferable as reported by previous works (Veldevit, 2008, Petefish et al., 1998). In addition, the polymer composites are typically favored for their cost-effectiveness and design flexibility, while they can meet the processing and reliability requirement (Fan et al., 2004).

Many of the most critical reliability attributes are related to silicon die size and packages construction. The CTE mismatch between the silicon die and the board induces plastic strain in the solder joint during operation resulting in lower fatigue life and eventually cause solder joint failure (Bank et al., 2005, Tummala et al., 2004). The factors that influenced the performance of the substrate materials properties such as layer count, substrate thickness and even the metallization pattern on individual layers, also affect the stress condition and therefore reliability. Stress condition also causes package warpage or nonflatness of the substrate material. Usually warpage and delamination are the main problems due to the continuous thermal cycle exposure (He et al. 2000). Therefore, the substrate material has to possess high thermal reliability during service. The warpage and the delamination problems are partly associated with the coefficient thermal expansion (CTE) mismatch as mentioned before between the solder and the substrate coupled with low flexural rigidity of substrate (Wakharhar et al., 2005 , Sun et al., 2005), Figure 1.1.

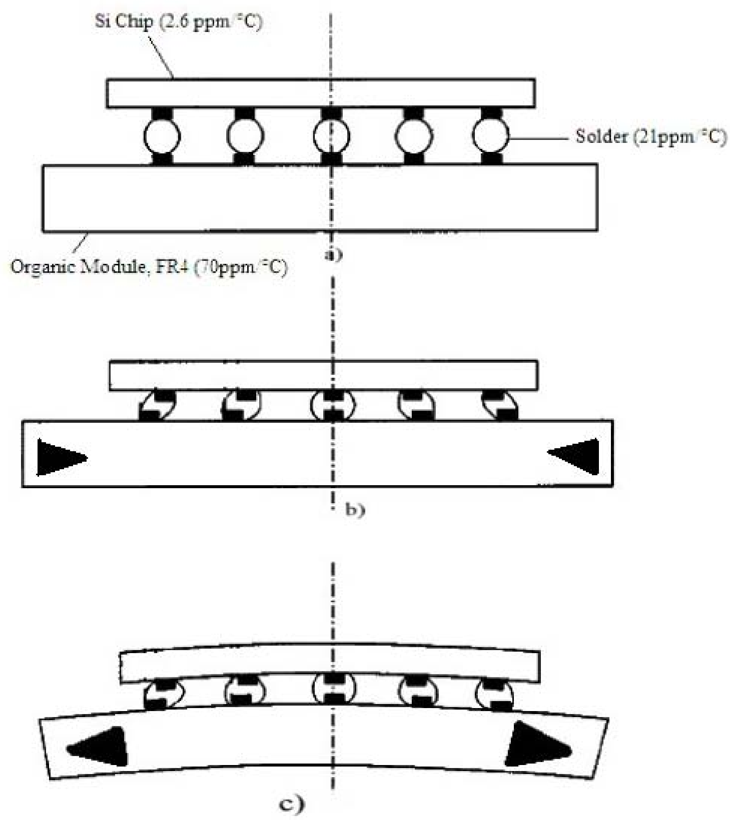

Figure 1.1: Schematic of package in reliability stress illustrating CTE mismatch a) Illustration of flip chip packaging b) cooling by relative humidity c) heating by temperature will cause warpage and thermo mechanical stresses in package.

1.2 Problem statement

As mentioned before, the major problem in electronic packaging is the CTE mismatch between the silicon die and organic substrate in zeroth level package. The mismatch usually resulted in warpage and delamination of the organic substrate during thermal cycle. In addition, after the thermal cycle, the substrate will not be flat enough due to the rigidity of the substrate. To solve these problems, the CTE must be reduced and at the same time improved the rigidity of the substrate in order to avoid the failure in the package. Hence, low CTE fillers and high rigidity were chosen. With those requirements as stated above, in this study was decided to choose alumina and muscovite as fillers. Alumina is rigid particles with modulus >350GPa and good in thermal properties. While muscovite has platelet shape and expected will given better performance in mechanical properties. In addition, both fillers have low CTE (<6ppm/°C).

1.3 Objective of the study

There are a few objectives in this research:

1. To investigate the various fillers like alumina and muscovite filled epoxy composites in terms of mechanical and thermal properties.
2. To study the effect of silane coupling agent on the properties of alumina filled epoxy composite.
3. To study the effect of ion exchange treatment in muscovite filled epoxy composite.
4. To improve the rigidity of alumina and muscovite filled epoxy composites and to reduce the CTE mismatch.

1.4 Scope of research

To solve the warpage and CTE mismatch, underfills are applied in packaging industry to improve the reliability. However, they tremendously increase the assembly costs and assembly complexity in processing [Veldevit, 2008, Tummala et al., 2004]. In order to attain the required reliability without underfill, the CTE of the substrate material has to match exactly with the silicon die and high modulus. The substrate of most rigid boards is made from FR-4 epoxy resin impregnated fiberglass cloth with 20GPa in modulus with CTE value between 16-20 ppm/°C [Blackwell, 2000]. However, FR-4 have the limitation which is it will not be flat enough to meet the requirements during thermal cycle. Therefore, particulate fillers in epoxy resin are applied in order to obtain the required properties and hence improved the warp and reliability of the package.

In this research, particulate fillers such as alumina and muscovite with layered silicates structure was selected in order to study the performance of the particulate in thermal and mechanicals properties. Beside that, surface treatment was done using silane coupling agent on the alumina surface. The effect of the surface treatment will be investigate. Meanwhile, for muscovite filler, ion exchange treatment was carried out. There have been several works on ion exchange treatment for montmorillonite (MMT) and a few studied was reported for muscovite [Agag et al., 2007]. In this study , muscovite are selected to done ion exchange treatment and the properties will be investigate.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of electronic packaging

In electronic packaging, the effectiveness of electrical function such as the reliability and cost of the system, not only depends on the electrical design but also by the packaging materials. According to Pecht et al., (1999) electronic packaging refers to the packaging of integrated circuit (IC) chips (die), their interconnections for signal and power transmission and heat dissipation.

In package materials, there are designed to enable the electrical and thermal performance requirement such as provide thermal paths and as electrical conductor or insulator. In addition, the package materials must provide high-reliability performance in order to keep pace with silicon and package technology advances and to protect circuit from environmental factors such as moisture, hostile chemicals etc (Wakharhar et al., 2005).

In order to classify materials in the electronic packaging, these packaging materials are separated in four levels of packaging such as chip, components, printed wired board and assembly level packaging that are referred as the zeroth, first, second and third level packaging as shown in Figure 2.1. The details about these levels are summarized as below:

a) Zeroth level packaging

This level focuses on semiconductor die materials, die attach materials and substrates.

b) First level packaging

Also known as, component level packaging is designed to enable interconnection between the devices and packages while providing the protection for the device against mechanical stress and chemical attack.

c) Second level packaging

Another name for this is Printed Wired Board (PWB). A typical PWB provides good in mechanical, thermal and electrical properties in an electronic system. In terms of mechanical, it is provide support for the component and a thermal conduction path for the heat dissipated by components. While electrical provides an insulator for the conductors.

d) Third level packaging

This level includes the interconnections and hardware required to realize an electronic system after the PWB have been assembled. Required electrical interconnections are primarily achieved using backpanels, connectors and cable.

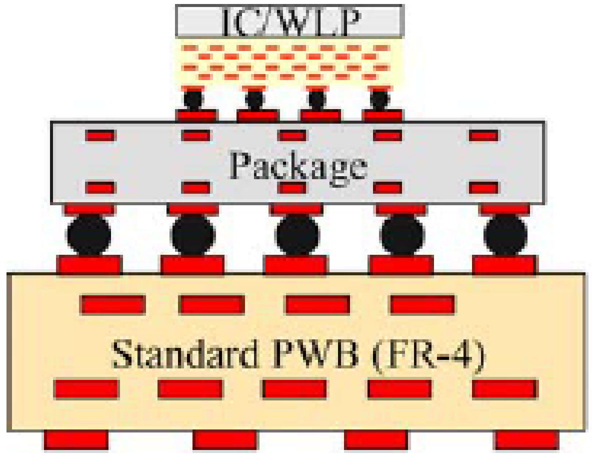

Figure 2.1: A diagram of packaging materials with consist zeroth, first and second levels packaging (Tummala et al., 2004)

2.1.1 Flip chip technology

In the traditional IC packaging, the silicon chip is wire-bonded to a leadframe and sealed by a ceramic substrate or plastic shell (He et al., 2000). Following Luo (2000), IC devices have moved to higher level and higher input/output (I/O) counts pushing the limit of the peripheral array of distributing the leads of an IC. Flip chip technology uses an area array of solder balls to provide a much longer I/O count over a given area of the IC. Figure 2.2 is an illustration of the flip chip package.

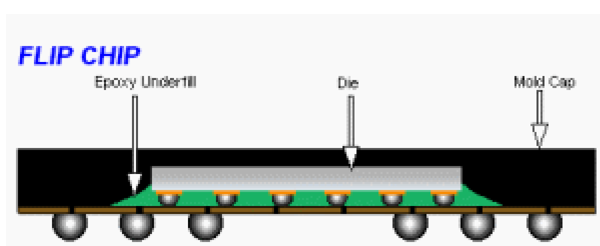

Figure 2.2: A schematic of flip chip packaging