ENCAPSULATION OF MULTIPLE CHIPS LED MODULE USING COMPUTATIONAL FLUID DYNAMIC

MUHAMMAD FAUZAN BIN IBRAHIM

SCHOOL OF AEROSPACE ENGINEERING
UNIVERSITI SAINS MALAYSIA
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ENDORSEMENT

I, Muhammad Fauzan bin Ibrahim hereby declare that all corrections and comments made by the supervisor and examiner have been taken consideration and rectified accordingly.

Fauzan

(Signature of Student)

Date: 9 July 2021

Hafifi

(Signature of Supervisor)

Name: Dr. Mohammad Hafifi Hafiz Ishaik
Date: 9 July 2021

(Signature of Examiner)

Name: Dr. Chang Wei Shyang
Date: 9 July 2021

DECLARATION

This thesis is the result of my own investigation, except where otherwise statedand has not previously been accepted in substance for any degree and is not beingconcurrently submitted in candidature for any other degree.

Fauzan

(Signature of Student)

Date: 9 July 2021

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ABSTRAK

Permintaan untuk diod pemancar cahaya (LED) telah meningkat dengan ketara kerana kelebihannya berbanding lampu pendarfluor dan pijar. Lampu LED mempunyai penggunaan kuasa rendah, jangka hayat yang panjang, serta teknologi yang lebih mesra alam. Selain itu, ianya jauh lebih cekap, mengubah sebahagian besar tenaga menjadi cahaya dan dengan itu mengeluarkan lebih sedikit haba. Bahan polimer yang bertindak sebagai bahan bukan konduktif memenuhi ruang antara lensa dan cip LED. Enkapsulasi digunakan untuk melindungi perangkat dari kesan mekanikal yang dapat melemahkan sambungan. Tujuan penyelidikan ini adalah untuk melakukan simulasi dinamik cecair komputasi proses pengisian bahan polimer. Menurut model reologi, kelikatan mempunyai pengaruh pada aplikasi dispensi ini. Oleh itu, kesan tiga bahan enkapsulan dengan kelikatan yang berbeza telah dikaji. Bentuk dan pergerakan bahan enkapsulasi diramalkan menggunakan pemodelan “Volume of Fluid” (VOF) yang terdapat dalam ANSYS FLUENT. Hasil simulasi akan dibandingkan dengan kajian sebelumnya mengenai enkapsulasi LED. Keputusan berangka menunjukkan isipadu pengisian cenderung berlebihan apabila kelikatannya meningkat. Selain itu, bahan kelikatan tinggi mempunyai kandungan kekosongan yang lebih tinggi daripada bahan kelikatan rendah. Selain itu, ia memerlukan masa pengisian yang lebih lama untuk menampung bahan kelikatan tinggi yang digunakan dalam proses enkapsulasi. Hasil simulasi akan dibandingkan dengan kajian sebelumnya mengenai enkapsulasi LED. Akibatnya, isipadu pengisian cenderung berlebihan apabila kelikatannya meningkat. Selain itu, bahan kelikatan tinggi mempunyai kandungan kekosongan yang lebih tinggi daripada bahan kelikatan rendah. Selain itu, ia memerlukan masa pengisian yang lebih lama untuk menampung bahan kelikatan tinggi yang digunakan dalam proses enkapsulasi. Hasil simulasi akan dibandingkan dengan kajian sebelumnya mengenai enkapsulasi.

ABSTRACT

The demand for light emitting diodes (LED) has risen significantly due to their advantages over fluorescent and incandescent light bulbs. LED lighting has low-power consumption, long-life, and ecologically friendly technology. Additionally, they are significantly more efficient, converting most energy to light and thus emitting less heat. A polymeric material that acts as a nonconductive material fills the space between the lens and the LED chip. Encapsulation is used to protect the device from mechanical forces that could weaken the connection. This research aimed to conduct a computational fluid dynamics simulation of the filling process for polymeric materials. According to rheology models, the viscosity affects this dispensing application. Hence, the effect of three different encapsulant materials with varying viscosities was investigated. The shape and motion of the encapsulant materials are predicted using ANSYS FLUENT's volume of fluid (VOF) multiphase modeling. The simulation result will be compared to previous research on LED encapsulation. As a result, the filling volume tends to overfill as the viscosity increases. Additionally, high viscosity materials have a higher void content than low viscosity materials. Additionally, it requires a longer filling time to accommodate the high viscosity material used in the encapsulation process.

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LIST OF SYMBOLS

SYMBOL	DESCRIPTION	UNITS
P	Pressure	Pa
t	Time	s
ρ	Density	Kg/m^3
v	Velocity	m/s
Tb	Temperature constant	K
N	Power law	-
ui	Velocity of the flow	m/s
$\dot{\gamma}$	Shear rate	s^{-1}
η	Viscosity	Pa.s
k	Thermal conductivity	W/mk
g	Specific gravity	-
x,y,z	Cartesian coordinates	mm

LIST OF ABBREVIATIONS

2D	2-dimensional
CAE	Computer-Aided Engineering
CFD	Computatonal fluid dynamic
CTE	Coefficient of Thermal Expansion
DGEBA	Bisphenol A digycidyl ether
FDM	Finite Difference Method
FEM	Finite Element Method
FVM	Finite volume method
GIT	Grid Independence Test
GNF	Generalise Newtonian Fluid
IC	Integrated Circuit
LED	Light Emitting Diode
UDF	User Define Function
USM	Universiti Sains Malaysia
UV	Ultra Violet
VOF	Volume of fluid

CHAPTER 1

INTRODUCTION

1.1 Background Study

Demand for light emitting diodes (LED) has increased dramatically due to their advantages over fluorescent and incandescent light bulbs. LED lighting is a low-power, long-life, and green technology. Additionally, they are significantly more efficient, converting most energy to light and emitting the most minor heat (Jade Bridges, 2015). However, the gap between the lens cover and the LED chip is typically filled with a polymer such as epoxy or a transparent, non-conductive silicone enclosure. Encapsulation protects the device from mechanical forces that could cause the connection between the chip and the substrate to deteriorate. The purpose of this research is to conduct a computational fluid dynamics simulation of the LED encapsulation mechanism. Thus, in this project, we will be working with the LED and examining its output after being encapsulated in three different encapsulating materials with varying viscosities. In addition, ANSYS FLUENT polymer filling process management software evaluations of previous LED encapsulation research must be conducted to provide us with a more appropriate approach and recommendation for the problem at hand.

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1.2 Problem Statement

If there are air bubbles adjacent to components, wiring, or tracks, corona can build up inside these voids and eventually destroy the components or wiring. Additionally, voids serve as a point of weakness for thermal and physical shock, resulting in resin cracking in service. As a result, numerous studies on LED packaging materials have been conducted to improve their performance, such as Ronzhang (2012), which focusing on the variation of waffle size and the effect of the trench patterns to limit the spreading of the encapsulant. This enables the geometry control of encapsulation to reduced the void content. However, only a few study implemented CFD applications to incorporate their research and one of them is Hanif (2014), but the scope of research mainly focuses on a variety of velocity injection and injection pressure during encapsulation. Hence, in this paper, an investigation on how viscosity behaviours affect dispensing applications will be conducted. Hence, the effect of different encapsulant materials with varying viscosities toward the filling distribution, void content, and filing time must be investigated as there are very few studies of LED encapsulation using CFD simulation. The use of ANSYS FLUENT software to manage the polymer filling process and compared with previous research on the LED encapsulation process to provides us with a better solution and suggestion for the problem at hand.

1.3 Objective

1. To study the effect of three different encapsulant materials with different viscosity toward the LED

2. To study the best material to achieve the lowest void content

3. To study the parameter that influences the failure during dispensing

1.4 Scope of research

The simulation of fluid flow in this research work is focused on generalized Newtonian fluid (GNF) by incorporating a cross viscosity model of the LED encapsulation process. Additionally, this research focuses on encapsulant materials with various viscosities ranging from 1 to 16 Pa.s. The density and surface tension of the materials is constant at 980 kg/m^3 and 0.023 N/m. The injection moulding experiment data obtained by previous researchers is used and compared with the simulation result to validate the CFD software's ability to solve the polymer flow behavior of the encapsulation process. The effect and filling time is also investigated in the conventional encapsulation technique. The volume of fluid (VOF) technique is used to determine the material's flow front position.

1.5 Thesis Outline

The thesis paper has been categorized into several chapters for a better understanding of this study. Hence, this paper contains five chapters.

Chapter 1: This chapter briefly explains the fundamental essence of the research and offers an outline of this study's contents. This chapter discusses the project's philosophical framework, including scientific challenges, hypotheses, and basic research structure.

Chapter 2: This chapter establishes a well-documented argument for analyzing research topics and formulating a research methodology. This chapter sets out the theoretical context for the thesis and outlines the topic, the primary research problem, the question(s), and the design elements.

Chapter 3: This chapter contains the method of study of the dissertation. The CFD software implementation is discussed in detail, including the setup required to simulate the LED encapsulation in ANSYS and the material used in the simulation.

Chapter 4: This chapter summarizes the data obtained, interprets the data, and reports the findings. The comparison of experimental results and Simulated results are presented in this chapter. In addition, the effect viscosity toward filling time, void content, and flow distribution is also discussed in this chapter.

Chapter 5: This chapter presents a concise overview of the context for the analysis Conclusions and suggestions for future works are included in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

As is well known, LEDs have been used in a variety of electronic devices for many years. Recent advancements in this field have resulted in various applications in industries, including lighting, signage, and domestic appliances. The light-emitting diode (LED) market has risen dramatically in recent years due to its advantages over fluorescent and incandescent light bulbs. LED lighting is a low-power, long-life, and environmentally friendly technology**.** They are also considerably more efficient, converting most of the energy into light and minimizing the heat emitted (Jade Bridges, 2015).

The necessity for LED packaging types should be designed according to the requirements of each distinct type of LED (Bowman, 2002). For example, as common packaging materials, silicone and phosphor are sensitive to high temperatures. The functionality will be failed easily and then cause the failure of the whole LED under high temperature (Nie et al., 2014). As a result, an appropriate packaging solution with good thermal diffusivity, good light efficiency, and less footprint will prevent the device from any environmental variables that could cause it to malfunction or shorten its life. (Ye Xie et al., 2013)

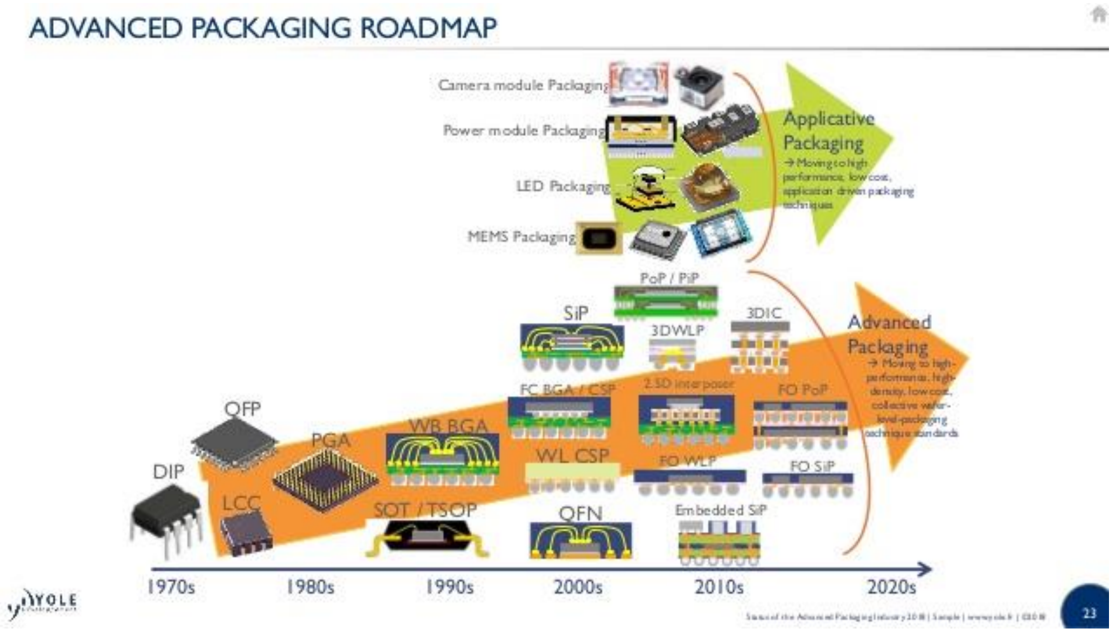

Figure 2.1 Evolution of packaging technology by years

On the other hand, the fluorescent light bulb needs a starter to operate, and the starter consumes a significant amount of energy (nearly 100 kilowatts) during the start-up phase. If the fluorescent light is turned on and off constantly, it will lose much energy and has a short life. Figure 2.1 illustrates the technical milestones in the context of low-power to high-brightness LED systems.

The LED chip is mounted to a reflecting cup and sealed in a transparent epoxy resin in the majority of the designs using a basic LED technology. LEDs usually have better shock and vibration resistance than typical incandescent bulbs and may be cycled on or off without substantial damage. Transparent epoxy resins are frequently used in LED manufacturing technology to increase their visibility. LEDs are intended for use at 25 C ambient temperature and up to 100 000 hours operating time (Kersjes, 2014). LED chips are capable of producing extremely high temperatures, resulting in thermal shock and reduced brightness. Therefore, epoxy resins must be capable of withstanding elevated temperatures in normal usage.

Additionally, when soldering the chips to the circuit board, epoxy resins' high glass transition temperature is required. Additionally, the materials chosen for outdoor applications should be resistant to UV light and should prevent sunlight from penetrating. The material also acts as a shield that preventing the chips from coming into contact with humidity or oxygen.

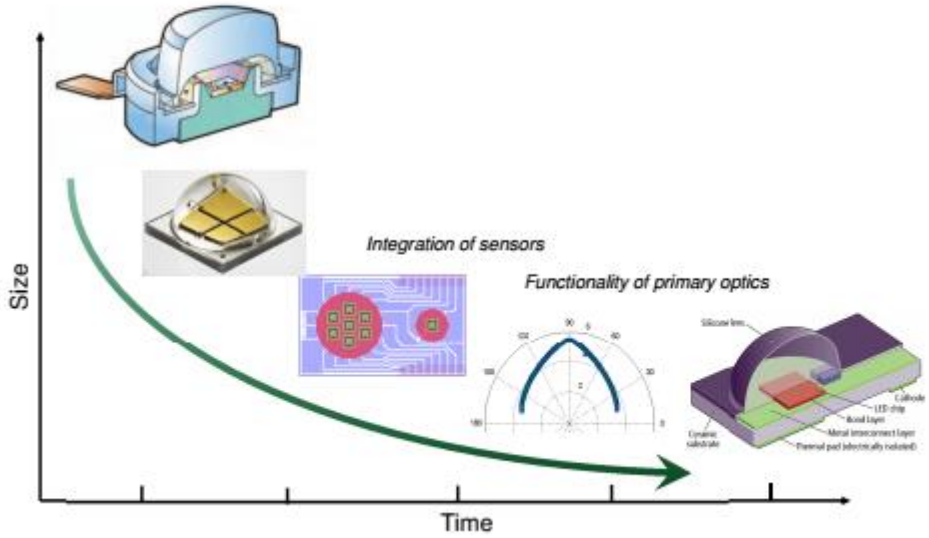

Figure 2.2 Trend of LED encapsulation

The process of encapsulation typically prefers a high-curing rate and a low-viscosity formula. An epoxy resin made from a hardener/curing agent with a low molecular weight is typically used. Bisphenol A diglycidyl ether (DGEBA) is the epoxy resin most widely used. It can be used as oligomers with various molecular weights. For encapsulation applications, a low molecular resin weight with a low viscosity is more suitable. A unique feature of bisphenol Epoxy resin is that as the number of repeat groups in the epoxy backbone increases, the number of hydroxyl groups also increases while maintaining the functionality of two epoxy groups (J. A. Brydson, 1989). Certain hydroxyl functions of the liquid epoxy resin are crucial to its performance. The hydroxyl groups' concentrations affect reactivity, viscosity, pigment wetting, dispersion of the filler, and thixotropy. Cycloaliphatic epoxies, particularly (3–4-epoxycyclohexane) methyl 3–4-epoxycyclohexyl-carboxylate (ECC) cured with an acid anhydride, perform exceptionally well in LED encapsulation (Wen et al., 2017)

General lighting applications are divided into indoor lighting, light-emitting diode (LED) lighting bulbs, desk lighting, and surface lighting (Chang et al., 2012). LED chips packages need to have critical handling due to their sensitivity to their operational and surrounding, which can affect their functionality. AIn addition, asthe packages are small As a result, silicone is difficult to deal with and requires precision, accuracy, and consistency in manufacturing.

2.2 Encapsulation Process

Understanding all processing parameters' interaction is necessary if silicone filling behavior in the LED chip package is predicted correctly during the distribution process. It is known as a process of encapsulation. In the final stages of LED manufacturing, the bare LED chips are packaged with epoxy or silicone. The silicone physically protects chips and is also used to focus on the right of the chips. Many researchers have made much effort to model the LED chip encapsulation process and determine its factors.

A general encapsulation process with thermoset material such as epoxy encapsulant is injected over the wafer from a nozzle and cured with UV light, as shown in Figure 2.3. This process can be easily automated, thereby increasing production capacity and reducing LED packaging manufacturing costs. However, various design and processing issues need to be examined to improve this newly developed encapsulation process (Z. Chen et al., 2011). These include the encapsulant volume, the groove geometry, and a few epoxy dispensing and curing parameters (Zhang & Lee, 2007). The goal is ultimately to help fill the LED chips and produce better quality components with high value.

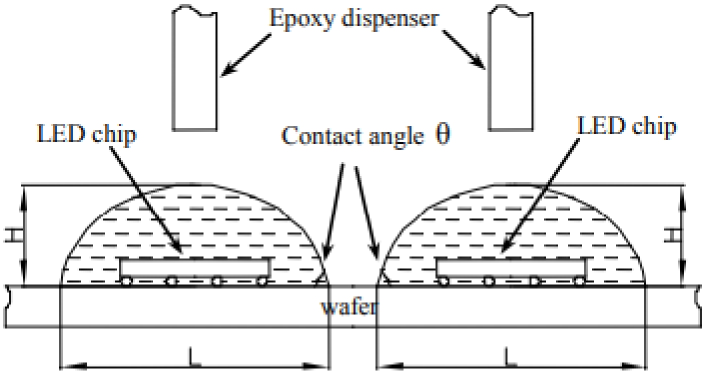

Figure 2.3 Schematic drawing of the encapsulation process (Zhang & Lee, 2007)

There is another method that can be used for silicone encapsulation. According to Chien et al. (2013), the design study for producing a moldless lens-type LED packaging technology was dispensed to encapsulate the LED chip and produce the dome-type lens as shown in Figure 2.4 by using liquid silicon with high viscosity and thixotropy indices.

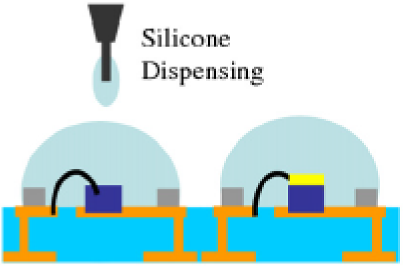

Figure 2.4 Silicone dispensing to achieve the dome-type package (Chien et al., 2013)

Transfer molding is used as one of the semiconductor encapsulation techniques (Alam et al., 2018). Kulkarni et al. (2019) pointed out that transmission molding is the most commonly used microsystem encapsulation technology. Transfer molding is a process where silicone-based thermosetting plastic is placed in a heated chamber. The material is transferred to LED chips packages during delivery from the nozzle by applying force, as shown in Figure 2.5.

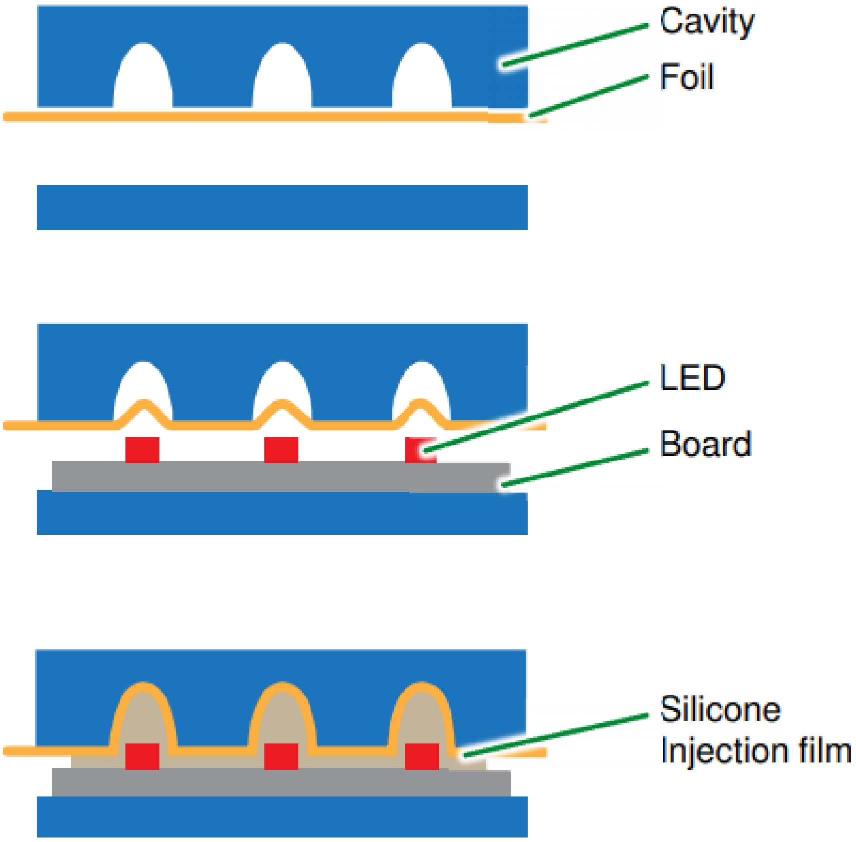

Figure 2.5 The illustrated transfer molding in the encapsulation process (Hanif, 2014)

Kulkarni et al. (2019) also have reported a study on the LED packaging technology for the moldless lens used to restrict silicone dispensing. The silicone dome-type lens can be formed at any substratum location with the structure. The luminosity of the LED package is therefore improved. In order to minimize void formation, a few speed parameters, nozzle position, injection pressure, and various silicone envelopes are significant in the processing parameter for a good flow pattern. The effects of piston velocity, silicone characteristics, and injection pressure were investigated.

This type of dome-type lens could be formed without being injected into the closed mould on any substrate. The silicone is also used for protecting the gold wire and chip interconnection as the encapsulating material. The shape of the silicone lens type dome is thus determined by the surface tension properties in the sidewall and silicone surface and the gravity of the silicone. This study simplifies the technological process for obtaining dome-type lenses while reducing production costs and times

2.3 Rheology model

Model rheology is used to describe polymer fluid flow typical of Newtonian and non-Newtonian fluids. Polymeric material flow behaviour is an essential aspect of the analysis of the LED encapsulation phase. To solve the complex flow problems, an appropriate approach is established.

Newtonian fluids exhibit the simplest fluid behaviour, with the viscosity proportional to the product of shear stress and the shear rate at constant pressure and temperature. As the shear rate increases and influences the shear stress, hence the Newtonian fluid flow immediately. The shear stress plot compared to the shear rate for the Newtonian fluid indicates a straight line passing through the origin. The pitches of the lines indicate the fluid's viscosity or dynamics (Franco & Partal, 2010), as shown in Figure 2.6.