INCORPORATION OF SURFACE MOUNT TECHNOLOGY MANUFACTURING (CHIP MOUNTUNG) TO LED CHIP ON BOARD

By

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Chairman : Professor Ir. B.T Hang Tuah bin Baharudin, PhD
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Future manufacturing technology will drive global growth through innovation in production. Companies are riding on a scale economy to achieve lower costs and keep prices down; thus, keeping ahead of the competition is necessary to remain competitive. In LED Chip on Board (COB) industry, there has been a substantial increase in market demand in recent years, leading to a need for a more cost-effective manufacturing process. In Opto-Semiconductor, LED COB products are still produced using batch processing. When product development demand peaks, growth and production are frequently caught unprepared, leading to short-term business losses and long-term deterioration of consumer confidence waiting one year for product. Customers will then flock to the rivals for replacement goods, causing harm to the bottom line of the company. The ultimate objective of this research is to enhance the current LED COB manufacturing process by leveraging surface mount technology (SMT) at the front of the line, saving money, improving the process and improving overall product development cycle time. Based on the research carried out, positive results anticipated from the use of SMT with additional production output of six times more product performance compared to the current output of LED COB, with a capability of printing 960 glue dot in one print, able to maximize COB light-emitting surface (LES) size more than 50mm size and COB board with more panes. These options will help the designer of product development explore new LED COB in the future. This would ensure the competitiveness of production in the future. The Six Sigma method (Define, Measure, Analyze, Improve and Control-DMAIC) with the Design of Experiment (DOE) approach will be used.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Doktor Kejuruteraan

INCORPORATION OF SURFACE MOUNT TECHNOLOGY MANUFACTURING TO LED CHIP-ON-BOARD

Oleh

SAIFUL NIZAL BIN AMIRNUDIN

Ogos 2019

Pengerusi : Profesor Ir. B.T Hang Tuah bin Baharudin, PhD
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Pada masa hadapan, pertumbuhan global teknologi pembuatan adalah bergantung pada inovasi pengeluaran. Syarikat pastinya akan menggunakan skala kos ekonomi yang rendah bagi pengekalan harga yang rendah dan ini semua adalah sesuatu yang mustahak agar terus kekal berdaya saing. Di dalam dunia perniagaan, penggunaan LED Cip Komponen di permukaan PCB (COB) adalah meningkat saban tahun dan ini semestinya memerlukan proses pembuatan yang lebih menjimatkan. Produk Opto Semiconductor LED COB dihasilkan melalui pemposesan secara berkelompok. Apabila mendapat permintaan pembangunan produk baru secara mendadak maka pengeluaran produk serta pasukan produksi cenderung menjadi kucar kacir dan ini mengakibatkan kerugian jangka masa pendek dan panjang dan menyebabkan ketidakpuasan para pelanggan menunggu product selama setahun. Para pelanggan kemudiannya akan memilih pesaing untuk mendapatkan pengganti produk dan ini sesuatu yang merugikan syarikat. Matlamat penyelidikan ini adalah bagi meningkatkan proses pembuatan LED COB melalui kelebihan Teknologi Pemasangan Komponen Elektronik ke permukaan PCB (SMT) sebagai keutamaan proses bagi tujuan menjimatkan sumber bahan, memperbaiki proses, dan meningkatkan keseluruhan masa pembangunan produk. Berdasarkan kajian yang dilakukan, pandangan positif terhadap penggunaan SMT adalah dijangka dengan penambahan pengeluaran sebanyak enam kali lebih banyak berbanding pembuatan semasa LED COB, dengan kemampuan mencetak 960 titik gam dalam satu cetakan, begitu juga dapat memaksimumkan ukuran COB yang lebih besar ukuran pada permukaan pancaran cahaya (LES) dari 50mm dan dapat membersarkan lagi papan COB dengan lebih besar ukuran panel. Pilihan ini akan membantu pereka pembangunan produk baru untuk meneroka LED COB pada masa akan datang. Ini akan memastikan bidang pembuatan ini terus berdaya saing di masa hadapan. Pendekatan Enam Sigma (Tentukan, Ukuran, Analisis, Pembaikan,

and Kawalan - DMAIC) dengan Rekabentuk Eksperimen (DOE) akan digunapakai di dalam kajian ini.

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Saiful Nizal Bin Amirnudin

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Engineering. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

COB	Chip On Board
DA	Die Attach
JIT	Just In Time
PCB	Printed Circuit Board
PCBA	Printed Circuit Board Assembly
LED	Light Emitting Diode
UPH	Unit Per Hours
LES	Light Emitting Surface
InGan	Indium Gallium Nitride
YAG	Yttrium Aluminium Garnet
GL	General Lighting
CFL	Compact Fluorescent Lamp
EMS	Electronics Manufacture Service
CEM	Contract Electronic Manufacture
ODM	Original Design Manufacture
OEM	Original Equipment Manufacture
R&D	Research and Development
OPC	Operation Planning Capacity
OS	Opto-Semiconductor
SMT	Surface Manufacturing Technology
SMD	Surface Manufacturing Device
BOM	Bill of Material
NPI	New Product Introduction
PCF	Process control flow
DMAIC	Define, Measure, Analyze, Improve, Control

CHAPTER 1

INTRODUCTION

1.1 Overview

This chapter presents the current market performance of the Global Light Emitting Diode (LED) and, more precisely, the development of the product segment of the LED Chip on Board (COB). A summary of the related issues is discussed, along with the study's objectives and scope description.

1.2 The General LED Market

LED has become an integral part of our modern lifestyle because of the evolving technologies, some developed explicitly for lighting, while others borrowed from mature fields such as manufacturing. This uptrend, which is spurred by the competition between market leaders and new entrants to the industry to achieve economies of scale, is expected to continue well into the future general market.

The first high efficacy blue-green LED was developed by researchers from Nichia Chemical Industries Corporation Japan in the 1990s, led by Shuji Nakamura and Takashi Mukai. InGaN / GaN double-heterostructure LED produced high brightness light and was primed for commercial use. The white light is then produced using by using a chemical converter such as Cerium-doped Yttrium Aluminum Garnet (YAG: Ce), a yellow phosphor dispenses on the LED. (Schubert, et al., 2005)

Typically, an LED is around 75 percent more efficient than ordinary incandescent lighting (heated filament) and lasts 25 times longer. The high efficiency and high robustness nature of LEDs have made them suitable for industrial and domestic uses (U.S. Department of Energy, 2020). Not only that, but the eco-friendliness of LEDs has also been a subject of interest for researchers as a means of reducing the global carbon footprint—the 100 percent recyclability of LEDs, and the fact that it contains no hazardous chemicals. Unlike the more popular Compact Fluorescent Lamp (CFL) that contains a small trace of mercury, have made them a favorite replacement choice for governments and commercial entities alike that are now funding research (Whyte, 2017). With the recent development of progressive full and partial ban on incandescent lighting products across the world, the General Lighting LED market is set for a steep growth, as shown in Figure 1.1.

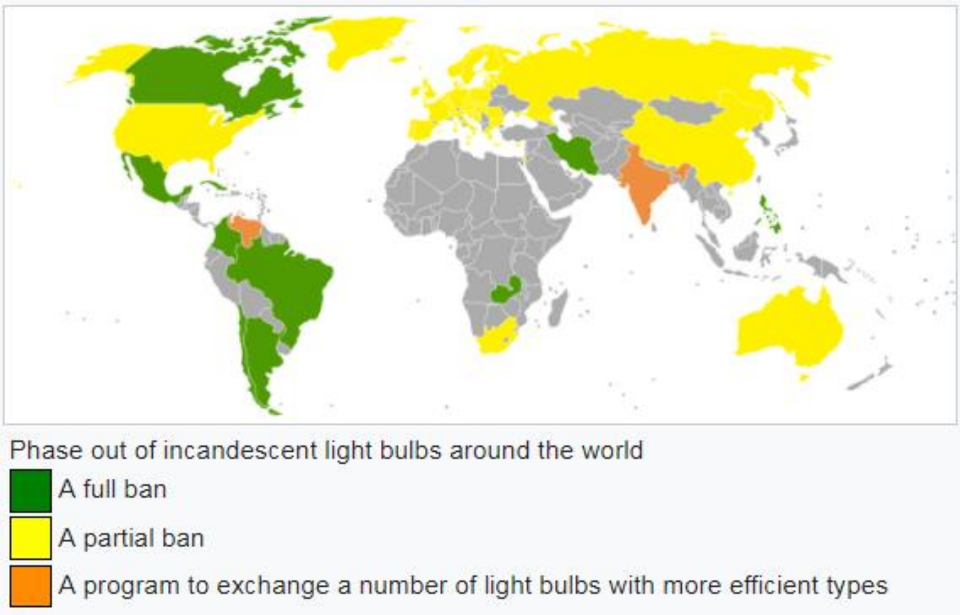


Figure 1.1 : Phase out the plan incandescent light bulbs around the world

Vohra et al., (2016) reporting from 2016 to 2020, it has estimated that the COB LED market in the Asia Pacific (APAC) region only, would grow at a compounded annual growth rate (CAGR) of around 34.79 percent. The market is slowly realizing the benefits of COB LED, as shown in Figure 1.2 compared to traditional LED packaging in SMD device, which could be briefly summarized:

i) COB consists of several LEDs, which are bundled in a single module. This is to ensure a greater lighting spread, a more significant viewing angle, decreased glare effects and increased color quality by offering high-intensity lighting.

ii) COB LED does not need a specified circuit. This offers ease of installation and configuration based on customer needs and requirements.

iii) COB LED is mounted on metal core boards (MCBs) or unique ceramics. This dramatically increases the heat conductivity, which results in a longer product lifetime. Apart from that, the fact that the mounting of chips decreases the amount of spot soldering and prevents the use of solder paste reduces the rate of failure and reduces the absorption of light.

It is also important to note that COB can be modules are easily integrated with Printed Circuit Boards (PCBs) that work as constant current or constant voltage drivers, as shown in Figure 1.3 (OSRAM Digital Lighting Systems, 2017). This reduces the efforts on the side of consumers and allows manufacturers to sell more value-added products (Miron, Rich, 2016).

Figure 1.2 : Chip on Board (COB) LED

Figure 1.3 : COB module integrated with PCB as a driver for the product

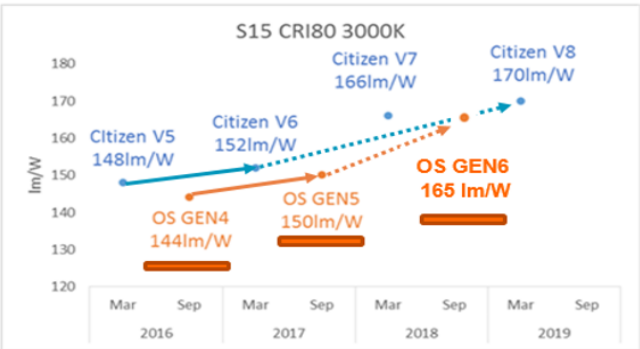
Companies with a strong foothold in the General Lighting segment are also well established as suppliers in the COB LED market. This market's competitive environment is expecting further intensify with an increase in product and service extensions and innovations in technology. According to the rank of COB market leaders, as follow shared by Technavio (2016), the top 10 company's rank is Citizen Electronics and followed by Cree, Nichia, Osram Semiconductor, Lumileds, Samsung Electronics, Seoul Semiconductor, Everlight Electronics, LG Innotek, and Lumens.

1.3 Problem Statement

To replace rivals in the top ranks of the COB LED market in the company, the incumbent must take advantage of the first-mover advantages of the new product release. This is only possible if it comes to the fact that the current manufacturing processes, especially in the case of chip mounting, are far from convincing. There are two fundamental problems that we see during the product production of Opto-Semiconductor.

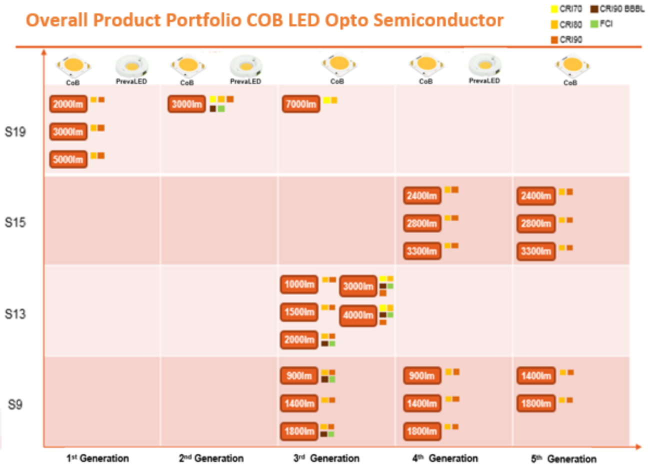
The first issue product roadmaps of market leaders indicate that a new product's complete portfolio is released yearly, en masse. As such, the most crucial factor in play is the lead-time, from R&D to mass production is required. Figure 1.4 shows one of the competitors versus Opto-Semiconductor roadmap and leading a technology development is a must be a product leader. This will be a weakness for Opto-Semiconductor and an opportunity to a competitor even though quality product COB is better to compare to others in the market.

The second issue is each time product launches a huge broader spectrum of product variants every year as shown in Figure 1.5, to match, if not exceed competitor's activities, and thus become the strategic substitute. Some of a complete COB LED portfolio of the COB Opto-Semiconductor product range is required to attract consumers, as competitor for Opto-Semiconductor is Citizen Electronics (2017), had release product full portfolio. This challenge will change the commercial release of the product and provide a market opportunity.



Remark:-
1) lm/w = Lumen per/watt (Product performance)
2) Citizen = Citizen company (Competitor in COB LED industries)
3) OS = Opto Semiconductor
4) V5,V6,V7,V8 = Citizen product revision / generation
5) Gen4, Gen5, Gen6 = Opto-Semiconductor product revision / generation

Figure 1.4 : Competitor (blue line) versus Opto-Semiconductor (orange line)



Remark:-
1) S9, S13, S15, S19 = Product size
2) 2000lm, 30000lm, 5000lm, = Product light output
3) 1st Gen, 2nd Gen, 3rd Gen, 4th Gen and 5th Gen = Generation of the product
4) COB and PraveLED = Product type to difference customer
5) Color code CRI70, CRI80, CRI90, FCI and CRI90 BBBL = Product Color

Figure 1.5 : Mass product release across the spectrum, over the years

On the other hand, as demand rises, the Operational Planner Capacity (OPC) gives tremendous strength to raise output capacity to keep up with the forecast increase,. Whereas planners and engineers will still fall back on the policy of buying new equipment, this adds significantly to the overhead expense of the plant (considering the procurement and potential servicing of new appliances). Fixed or variable cost (depending on the depreciation method used) which will ultimately affect the break-even value of revenue or marginal cost of output. With more machines coming in, existing production floors (space/area in production) will be quickly filled and congested. Increased manufacturing area comes with a high price tag considering the location of the factories; Figure 1.6 shows the general process flow when it comes to machine purchases. Furthermore, the exercise will only proceed to peak floor space, where the overall activity will become less economically efficient.

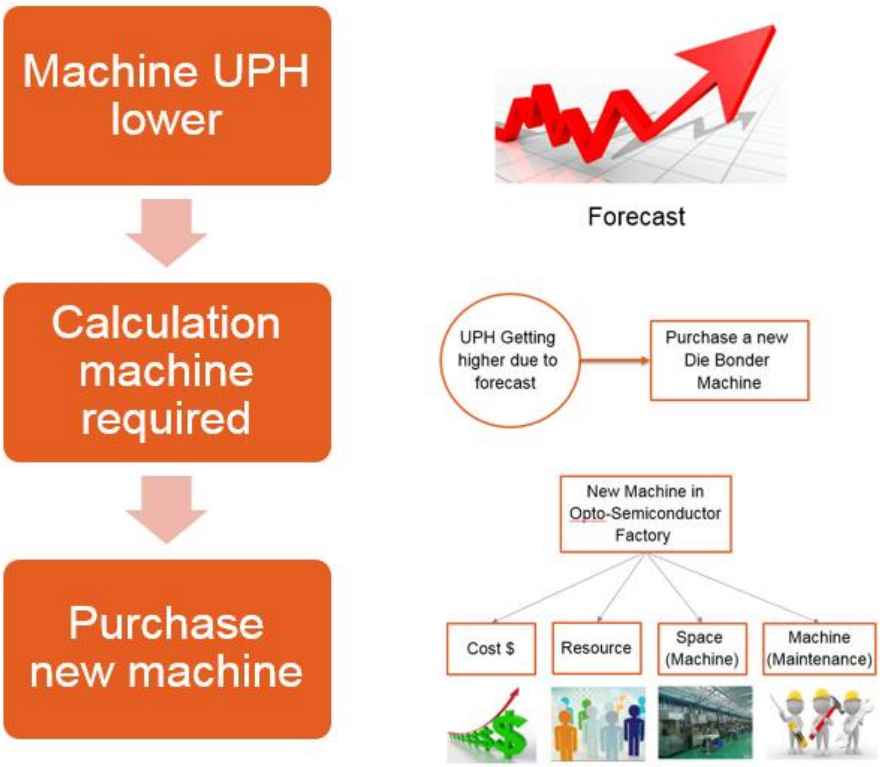


Figure 1.6 : Process flow increasing production capacity

To stay competitive on the market, Opto-Semiconductor is reviewing new production methods, in particular using the latest technologies or high-end current production processes with deference technology that can increase production performance over a short period. Opto-Semiconductor is, therefore, willing to implement every technology on the production floor to verify the prospect of rising its cycle time.

1.4 Objective

This thesis aims to improve the production of chip mounting cycle-time (UPH improvement) in terms of speed and flexibility by integrating Surface Mount Technology (SMT) machine technology to produce LED COB products. The comparison between both chip mounting technologies output (DA and SMT) will decide the manufacturing improvement, and the following four objectives will be explained in this study:

i. To develop phase mapping distinction between current process Chip on Board (COB) LED chip mounting versus surface mounting technology (SMT) manufacturing process.

ii. To develop new chip packaging and tooling to operate in Surface Mount Technology (SMT) printing, chip mounting and reflow curing machines.

iii. To create LED COB process product in the SMT manufacturing process without any changes to the process.

iv. To conduct a second assessment with the glue material instead of the solder paste.

1.5 Scope

Improvement of chip mounting manufacturing processes is chosen in the study; the difficulty in the overall measures would provide the most incredible opportunity to improve current COB manufacturing processes. However, in the actual analysis of the product Opto-Semiconductor, Die Attach (DA) and Surface Mount Technology (SMT) machines will be used to compare machine performance.

Project Scope item:

I. The chip on Board (COB) LES S19 package

II. S19 Substrate (Metal Core Board –MCB)

III. Glue (Die attach glue)

IV. Solder paste (Lead-free)

V. LED Chip (48 pcs Light Emitting Diode chip)

VI. Die Attach / Bonder Machine

VII. Oven curing (Glue curing)

VIII. Surface Mount Technology (SMT) Printing machine

IX. Surface Mount Technology (SMT) Chip Mounting

X. Surface Mount Technology (SMT) Reflow Oven

1.6 Outline

This thesis consists of five key chapters. Chapter 1 is an introductory section that contains priorities, scopes and issue statements. Chapter 2 explores the literature extensively on the previous studies of the subject business, current work details, as well as the theoretical context needed for comprehension. Chapter 3 details the methods of the project used in the evaluation/experiment. The findings obtained and the discussion is discussed in Chapter 4. Chapter 5 includes a review and conclusion of the evaluation/experiment and a set of guidelines to promote future studies.

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