CHAPTER 2

LITERATURE REVIEW

The following chapter will discuss furthermore about yield discrepancy and its fundamental elements which are collected through literature surveys done. It includes information about semiconductor, productivity, Kaizen concepts and relevant data to be added to further enhance the understanding and knowledge about this study.

2.1 Productivity

According to Sumanth (1990), productivity is concerned with the efficient utilization of resources (inputs) in producing goods and services (outputs). Similarly, capital productivity and material productivity are examples of partial productivity. There are three basic type of productivity. First, partial productivity is the ratio of output to one class of input. For example is labor productivity (the ratio of output to labor input) is a partial productivity measure. Second, total-factor productivity is the ratio of net output to the sum of associated labor and capital (factor) inputs. “Net Output” is the total output minus intermediate goods and services purchased. The denominator of this ratio is made up of only the labor and capital inputs factor. Third, total productivity is the ratio of output to the sum of all inputs factor. Thus, a total productivity measure reflects the joint impact of all the inputs in producing the output [3].

2.2 Semiconductor Overview

The term "semiconductor" refers to a material that has electrical conductivity greater than an "insulator but less than a "conductor". The term is, however, more commonly used to refer to an IC (Integrated Circuit) of various functions, manufactured by arranging resistive material onto a semiconductor substrate.

The black package of a semiconductor contains an IC chip, a piece of silicon on which transistors and diodes embedded by microfabrication processes are interconnected to function as an electronic circuit [4].

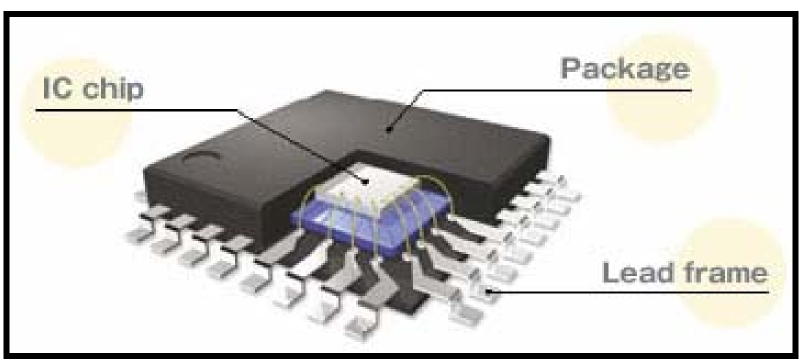

Figure 2.1: Cut-section of semiconductor Integrated Circuit Package

(**Source**: http://www2.renesas.com/fab/en/index.html)

2.3 Semiconductor Assembly Process Flow

The semiconductor industry has some of the most demanding applications in motion control. A combination of extreme accuracy and precision combined with high throughput makes for exciting technology. Semiconductor processing can be divided into two parts - "front-end" and "back-end".

Front-end refers to the fabrication from a blank wafer to a completed wafer (i.e. the microchips are created but they are still on the wafer). **Back-end** refers to dicing the wafer into individual chips and all the processes thereafter; such as test, assembly and packaging [5].

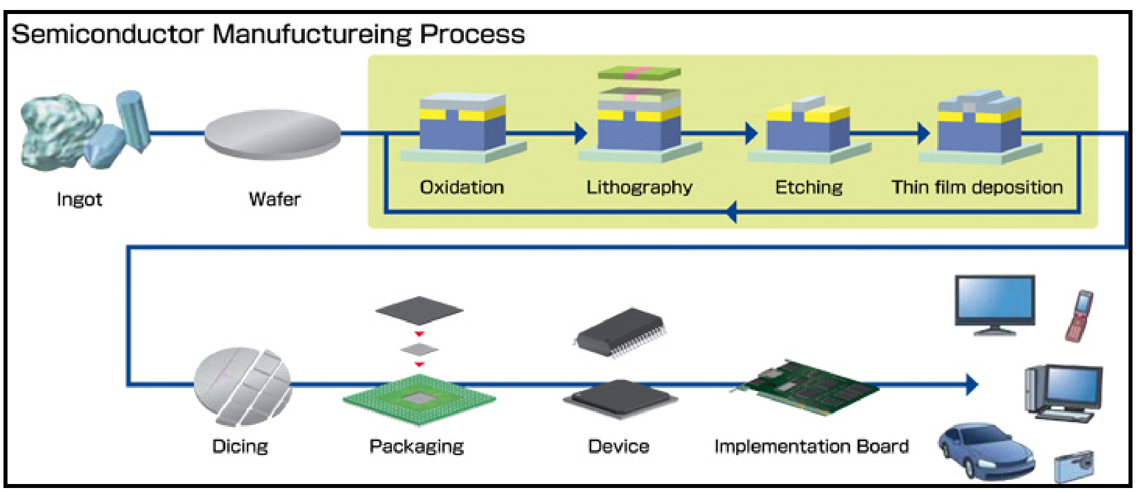

Figure 2.2: Semiconductor Manufacturing Process

(Source: http://www.hitachi-hitec.com/global/hightec-guide/semiconductor/page01.html)

2.3.1 Front-End Process

The front-end process creates circuits on silicon wafers while in the post-process the silicon wafers with circuits etched are cut into chips and packaged. The chips are then mounted on circuit boards together with other electronic parts and incorporated into various electronics products.

The front-end process includes lithography, dry etching, and other processes that are indispensable to achieve very small semiconductor sizes. The post-process, meanwhile, is responsible for chip packaging and other assembling processes. Its purpose is to protect bare chips from the external environment such as impacts, moisture, and dust. In addition, it also involves processing associated with electrical properties. For example, external signals are imported to facilitate a mounting of chips on the circuit boards of final electronics products. For thermogenetic semiconductor devices such as central processing units (CPUs) and microprocessor units (MPUs) for computers, a process for facilitating heat radiation is also implemented.

In comparison with facilities for the front-end process, manufacturing equipment used in the post-process are traditionally required to be accurate, speedy, and economic. Accuracy and speed mean that they must produce semiconductors with assured quality in a short period of time and at a high yield. Being economic refers, for example, to durability and maintenance-free features. Nowadays, semiconductor manufacturers are investing aggressively in die bonders and other systems for the post-process, something they were formerly hesitant to do. The die bonding and surface mounting technologies are now being revalued as key technologies for deriving extra value from semiconductors [6].

2.3.2 Back-End Process

The starting point for semiconductors is the wafer, which contains a (very large) number of devices, separated by small gaps, and electrically isolated from each other as part of the processing. Starting with a blank wafer of extremely pure silicon, building up layers by deposition techniques, etching patterns, and implanting dopants into the silicon structure using high energy particles, the semiconductor ‘fab’ ships a wafer which is partially probe-tested, but needs terminations in order to communicate with the outside world.

The ‘back end’ process consists of sawing the wafer into individual dice (the terms ‘chip’ and ‘die’ are equivalent), mounting the die on a lead-frame or other mount using conductive adhesive, and finally making fine wire connections to the top surface – this ‘wire bonding’ process uses gold and aluminium wires typically 25-33 μm in diameter. Because wires and semiconductor are relatively fragile and easy to contaminate, the die will then be protected in some way [7].

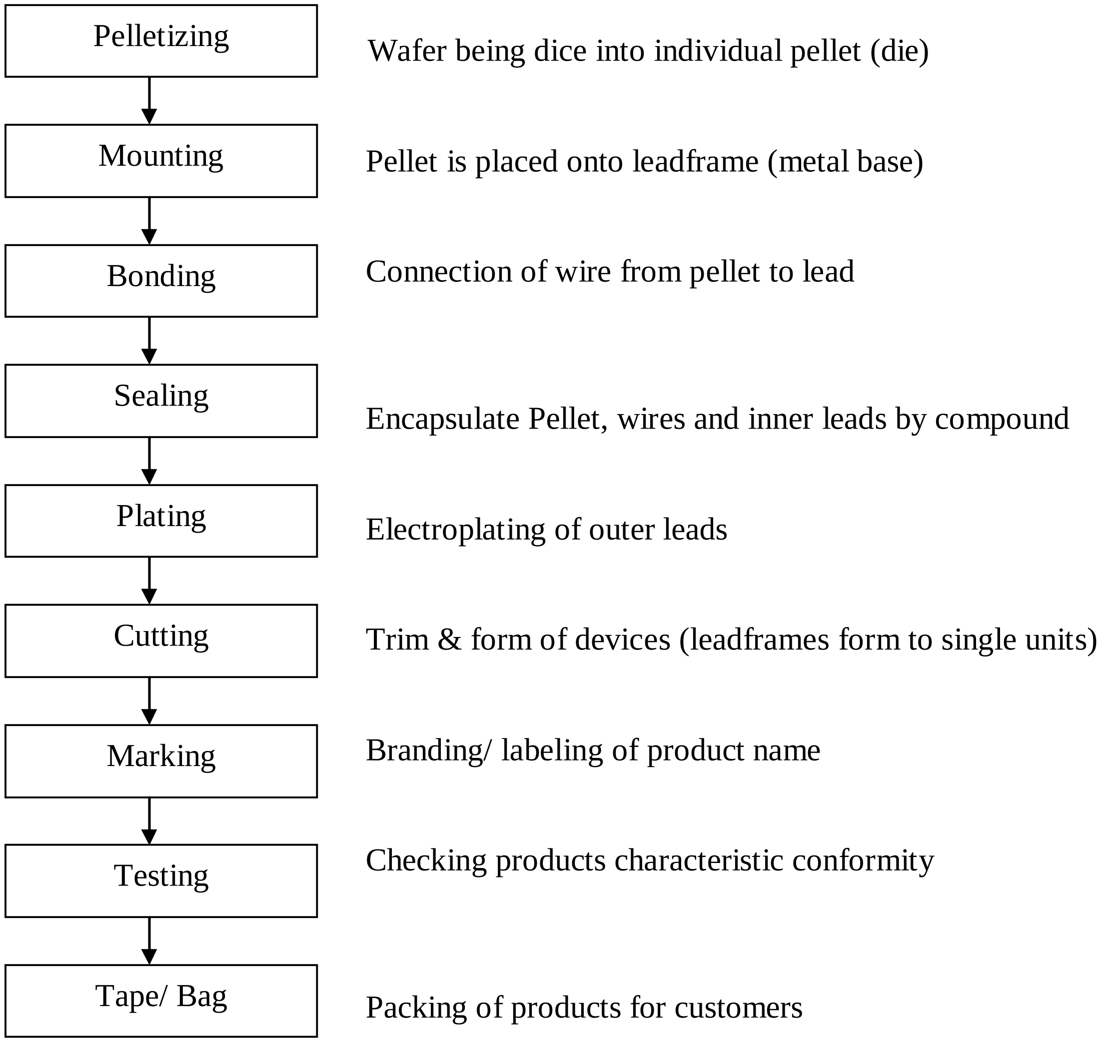

Figure 2.3: Semiconductor Manufacturing Process

2.3.2.1 Pelletizing

TAPING

Process where wafer mount onto adhesive sheet

↓

DICING

The dicing machine will cut the wafer into smaller individual pellets.

↓

DRYING

The wafer is spin at a high speed to dry the wafer with the supply of the nitrogen gas (to speed up drying process)

↓

PMM (Pellet Marking Machine)

To mark a black dot on Not Good (NG) pellets surface so that they will not be picked up during mounting process.

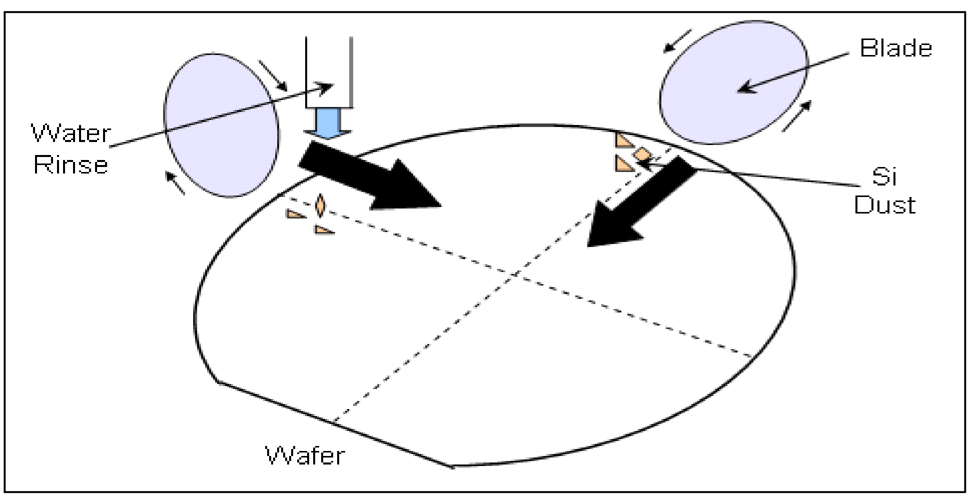

Figure 2.4: Image of Dicing Process

2.3.2.2 Mounting

The mounting tools consist of two parts, which are the collector and a push-up pin. When pick up, the push up pin will move up until it touches the tape; mean while, the collector will move downward to touch the pellet. The push up pin later will push up the pellet as to reduce the tape stickiness [8].

Basically, mounting is the process that involves picking up the pellets that has been cut and put onto the lead frame individually. During the mounting process, the wafer is place in a set up position, and a recognition unit (camera) will plays its role as to identify the good pellets and not good pellets. The purposes of mounting process are:

i) To fix the chip on the lead frame in order for easy handling bonding process
ii) Make electrical conductivity between chip and island
iii) Radiate heat from chip
iv) Reduce thermal stress between chip, lead frame and mold resin

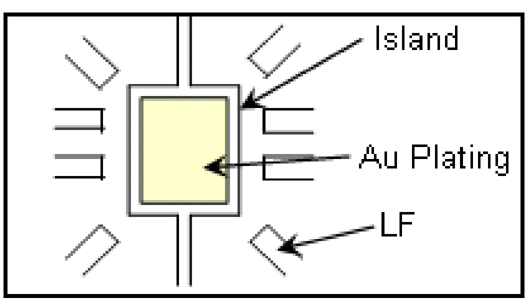

Figure 2.5: Pre-Plated Chip on Leadframe Island Area

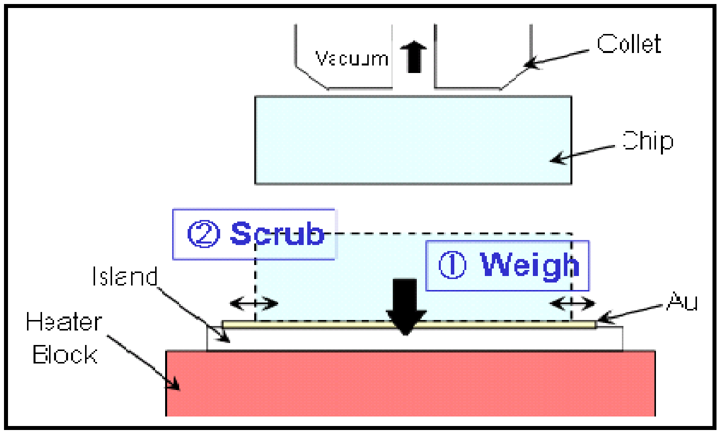

Figure 2.6: Mounting Mechanism for Au-Si Eutectic Mounting

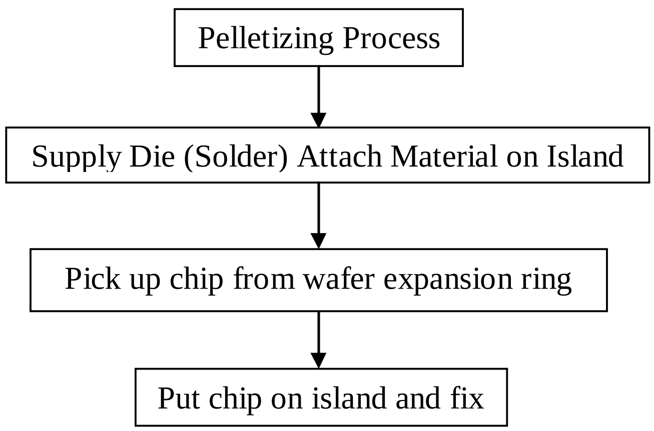

Figure 2.7: Process Flow of Mounting Process

2.3.2.3 Bonding

Bonding process is a process where the pellet is connected to the lead frame with gold or aluminium wire where the current will be contacted from the chip through the gold wire to the inner lead frame [8]. There is few bonding method that can be used, such as:

i) Nail Head Thermal Compression Bonding (NTC) - Au wire

ii) Ultra Sonic Bonding (USB) - Al wire

iii) Ultra Sonic nail head Thermal Compression Bonding UNTC - Au wire

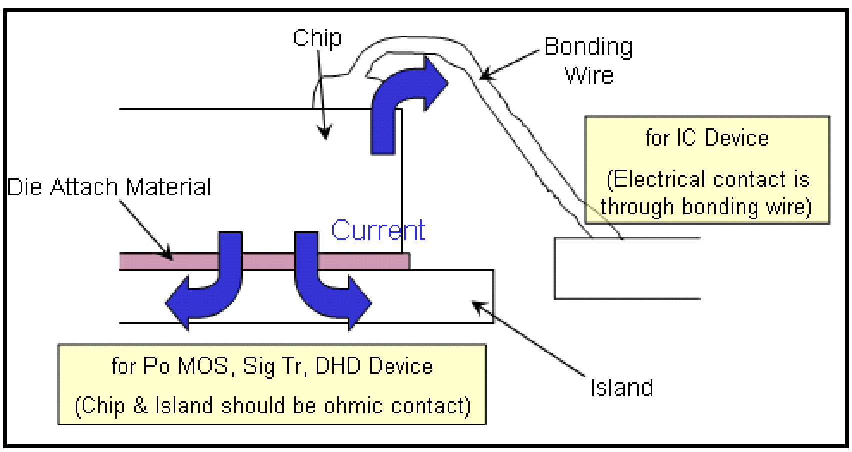

Figure 2.8: Bonding Mechanism for IC Chips

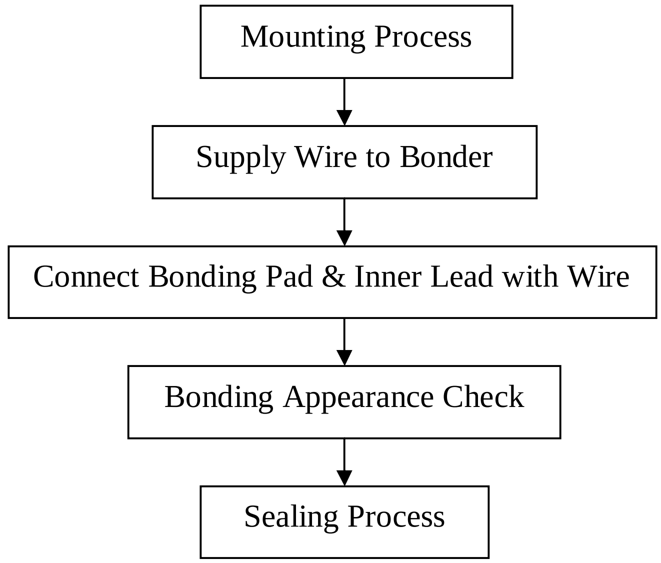

Figure 2.9: Process Flow of Mounting Process

2.3.2.4 Sealing

In sealing process, the resin is preheated up to a specified temperature to soften the resin. After that, the lead frame is placed on the loading frame and later the loading frame will be placed into the mold where is between the upper and lower cavity. The lower cavity later will move upward and press against the upper cavity. The softened resin later will be put into the top chute in the upper cavity where it is melted. Softened resin will later be injected into the cavities by a plunger. The resin later will cool down and the process is completed [8]. The purposes of sealing process are:

i) Electric Isolation (electric contact from only lead)

ii) Release heat from chip

iii) Protect chip from outer physical stress

iv) Easy handling of product

v) Protect chip from light & α- Ray (for memory products)

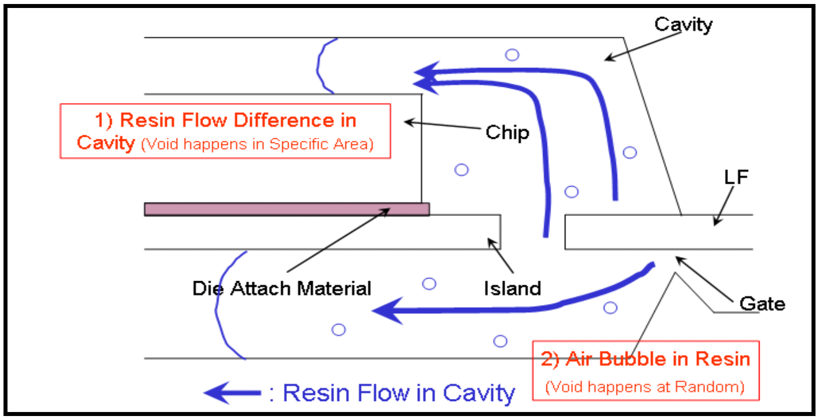

Figure 2.10: Mechanism Operation of Sealing Process

2.3.2.5 Cutting

Basically cutting involves three stages where remove excess resin, tie bar and lead frame .In most products, cutting tools are the upper and lower dies with sharp edges. In order to achieve a good cutting edge and not to damage the product, it is necessary to control the alignment between the upper and lower die.

After that, the leg of the product will be bent into a dimensions either based on the international standard specifications or a special specification set by customer [8].

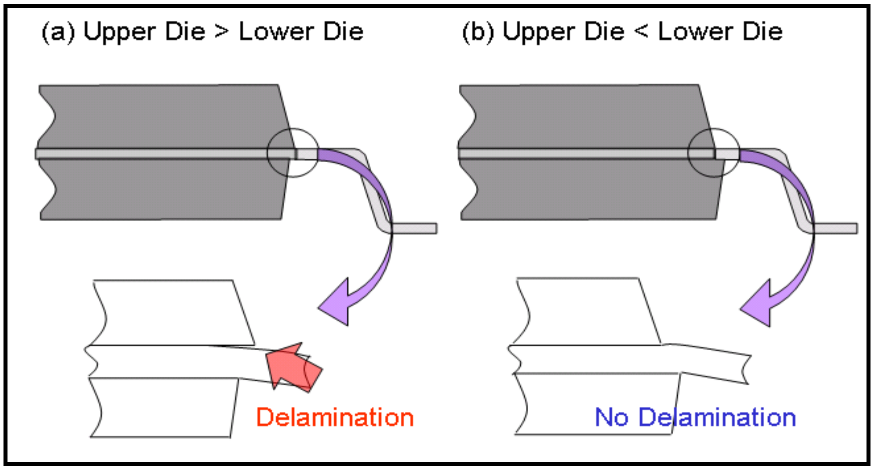

Figure 2.11: Delamination during the Cutting Process

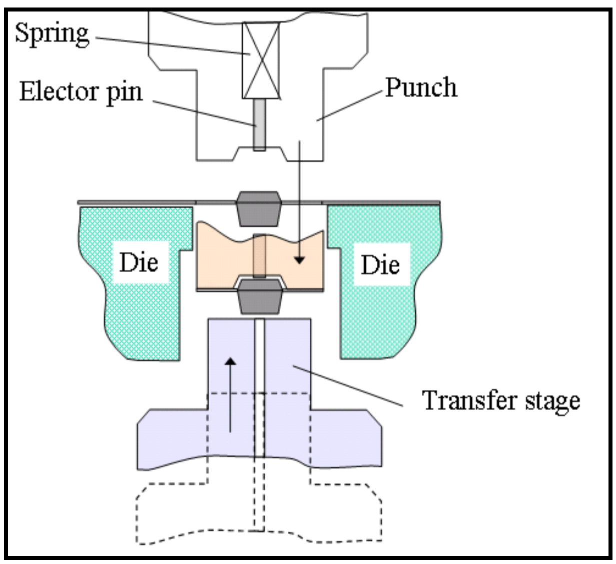

Figure 2.12: Mechanism of the Cutting Process

2.3.2.6 Marking

The purpose of marking process is to identify the product identity and as well as for company reference. The lot number on the product contains its particulars such as the date of production and the machine used. This will allow the detected lot to be detected and tracing the machine that caused the problem will be easier [8]. There are two types of laser marking, which are:

i) CO_2 (Carbon Dioxide)

ii) YAG (Yttrium Aluminum Garnet)

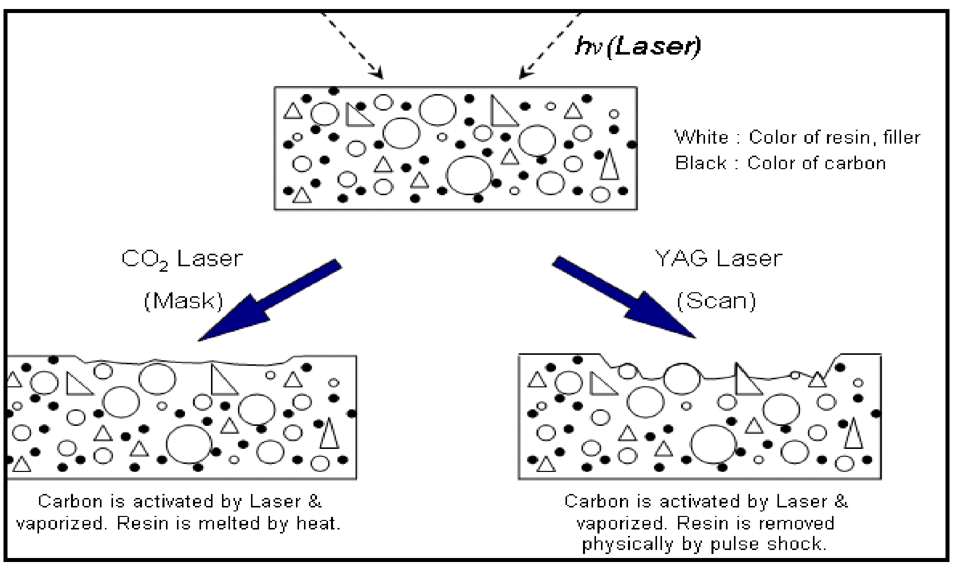

Figure 2.13: Mechanism of the Marking Process

2.3.2.7 Testing

In the testing and sorting process, the product is tested to determine whether it passes (good) or fails (no good). The failed product will be sorted out from the pass product. Normally, the product is tested with its direct current (DC), alternative current (AC) and noise level (NL) characteristics.

In the DC and AC tests, the product is supplied with DC and AC, voltage and current are measured. The results are compared with the product specifications to determine whether the product passes or fails. In the NL test, the product is supplied with power and the noise level is measured. The result will compare with the product specifications to determine whether it passes or fails. A testing system consists of two major components, the handler and the tester. The handler holds the product while the tester carries out the program to verify the characteristics of the product [8].

2.3.2.8 Taping / Bagging

The taping process depends on the customer requirement. Some of the customers prefer the product be shipped in a special form so that their machine can easily handle the product. The common type of taping is paper taping, emboss taping and anti-static tube [8].

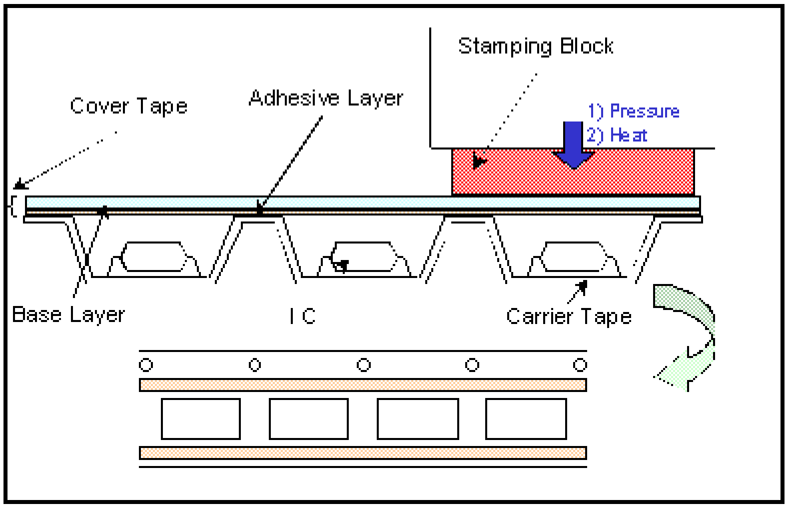

Figure 2.14: Emboss taping

2.3.2.9 Outgoing and Inspection

Before the product ship to the customer, a formal inspection (ILC/OGI) on electrical properties, external appearance and reliability of the finished product are conducted. This ensures that no customer claims occur and increase their confidence in the company [8].

2.4 Production Yield

To survive in such a competitive industry like semiconductor manufacturing, every manufacturer must enhance its own competence in several ways. The four principles for a competitive semiconductor manufacturer are: continuous measurable improvement, statistical thinking, constraint-focus, and people development / empowerment (Armstrong, 1989; Crowder, 1989). Besides, many factors are critical to the competitiveness of a semiconductor fabrication factory, such as sales price, production cost, cycle time, time to market, service quality, financial status, patent right, and research ability. Among these factors, product yield is undoubtedly the most important one to the competitiveness of a semiconductor fabrication factory (Chen, 2007, in press; Chen& Wang, 1999; Cunningham,1990) due to the following reasons:

i) Unlike service quality and research ability, yield is a quantitative measure and is traditionally very important to a semiconductor manufacturer. Besides, compared with financial status, yield is easier to predict in the long term because of its learning property.

ii) Sales price is beyond the control of a single semiconductor manufacturer.

iii) A high average yield represents the good quality of products. More wafers can also survive after fabrication with a high average yield. That drops down the average fixed cost and further the overall average cost as well. Besides, it also reduces the possibility that more wafers have to be released to compensate for the shortage resulted from the scrapped low-yield wafers, which is important for on-time order delivery that is part of service quality.

iv) Yield improvement is a learning process, and the cycle time of a product determines the period of its learning process (Haller, Peikert, & Thoma, 2003). To increase the yield of a product further, shortening its cycle time is always the goal, which not only improves the responsiveness to customers' demands but also pushes forward the improvement of the efficiency of operations.

For these reasons, evaluating the yield competitiveness of a semiconductor fabrication factory by considering the yields of all its products is a reasonable idea. Furthermore, based on the evaluation results, an efficient plan for enhancing the yield competitiveness of the semiconductor fabrication factory can also be made.

2.5 Kobetsu Kaizen

Kobetsu Kaizen uses a special event approach that focuses on improvements associated with machines and is linked to the application of TPM. Kobetsu Kaizen begins with an up-front planning activity that focuses its application where it will have the greatest effect within a business and defines a project that analyses machine operations information, uncovers waste, uses a form of root cause analysis (e.g., the 5 Why approach) to discover the causes of waste, applies tools to remove waste, and measures results.

2.5.1 Introduction of Kobetsu Kaizen

Kaizen is a Japanese word that has become common in many western companies. The word indicates a process of continuous improvement of the standard way of work (Chen et al., 2000). It is a compound word involving two concepts: Kai (change) and Zen (for the better) (Palmer, 2001). The term comes from Gemba Kaizen meaning 'Continuous Improvement' (CI). Continuous Improvement is one of the core strategies for excellence in production, and is considered vital in today's competitive environment (Dean and Robinson, 1991). It calls for endless effort for improvement involving everyone in the organization (Malik and YeZhuang, 2006).

Kaizen originated in Japan in 1950 when the management and government acknowledge that there was a problem in the current confrontational management system and a pending labor shortage. Japan sought to resolve this problem in cooperation with the workforce. The groundwork had been laid in the labor contracts championed by the government and was taken up by most major companies, which introduced lifetime employment and guidelines for distribution of benefits for the development of the company. This contract remains the background for all Kaizen activities providing the necessary security to ensure confidence in the workforce (Brunet, 2000). First, it was been introduced and applied by Imai in 1986 to improve efficiency, productivity and competitiveness in Toyota, a Japanese carmaker company in the wake of increasing competition and the pressure of globalization. Since then, Kaizen has become a part of the Japanese manufacturing system and has contributed enormously to the manufacturing success (Ashmore, 2001). Kaizen forms an umbrella that covers many techniques including Kanban, total productive maintenance, six sigma, automation, just-in-time, suggestion system and productivity improvement, etc. (Imai, 1986).

2.5.2 Review of Literature related to Kaizen concept

The philosophy of Kaizen has kindled considerable interest among researchers because it increases productivity of the company and helps to produce high-quality products with minimum efforts. Several authors have discussed the concept of Kaizen including Deniels (1996), and Reid (2006) etc.

According to Imai (1986), Kaizen is a continuous improvement process involving everyone, managers and workers alike. Broadly defined, Kaizen is a strategy to include concepts, systems and tools within the bigger picture of leadership involving and people culture, all driven by the customer.

Watson (1986) says that the origin of Plan-Do-Check-Act (PDCA) cycle or Deming cycle can be traced back to the eminent statistics expert Shewart in the 1920s. Shewart introduced the concept of PDCA. The Total Quality Management (TQM) guru Deming modified the Shewart cycle as: Plan, Do, Study and Act. The Deming cycle is a continuous quality improvement model consisting of a logical sequence of these four repetitive steps for Continuous Improvement (CI) and learning. The PDCA cycle is also known as Deming Cycle, the Deming wheel of CI spiral. In ‘Plan phase’, the objective is to plan for change predicts the results. In ‘do phase’, the plan is executed by taking small steps in controlled circumstances. In ‘study/check phase’ the results are studied. Finally in ‘act phase’, the organization takes action to improve the process.

Suzaki (1987) explains that CI is a philosophy widely practiced in manufacturing and quality circles. As the name implies, it relies on the idea that there is no end to make a process better. Each incremental improvement consists of many phases of development. Originally used for enhancing manufacturing processes, the philosophy has gained considerable popularity recently, and has been extended to all aspects of business including the software industry.

Wickens (1990) describes the contribution of teamwork to make the concept of Kaizen. The key role and authority of each supervisor as a leader of his team has been described by taking an example of Nissan Motor Plant in the UK. Emphasis is placed on teamwork, flexibility and quality. Teamwork and commitment do not come from involving the representatives of employees, but from direct contact and communication between the individual and his boss.

Teian (1992) describes that Kaizen is more than just a means of improvement because it represent the daily struggles occurring in the workplace and the manner in which these struggles are overcome. Kaizen can be applied to any area in need of improvement. Hammer *et al*. (1993) explain that Kaizen generates process-oriented thinking since processes must be improved before better results are obtained. Improvement can be divided into CI and innovation. Kaizen signifies small improvements that have been made in the status quo as a result of ongoing efforts. On the other hand innovation involves a step — improvements in the status quo as a result of large investments in new technology and equipments or a radical change in process design using Business Process Re-engineering (BPR) concept.

Bassant and Caffyn (1994) define the CI concept as ‘an organization-wide process of focused and sustained incremental innovation’. Many tools and techniques are developed to support these processes of incremental innovation. The difficulty is the consistent application of CI philosophy and CI tools and techniques. As an organization wide process, CI requires the efforts of all employees at every level. Deming (1995) highlights that organizations are evolved at a greater rate than at any time in recorded history. Since organizations are dynamic entities and since they reside in an ever-changing environment, most of them are a constant state of flux. This highly competitive and constantly changing environment offers significant managerial opportunities as well as challenges. To effectively address this situation, any managers have embraced the management philosophy of Kaizen.

Deniels (1995) explains that the way to achieve fundamental improvement on the shop floor is to enable operators to establish their own measures, to align business strategies and to use them to drive their Kaizen activities. The author explains that operators are the experts and once they realize that they are the ones who are going to solve their problems, and then all they need is some direction. He also discusses the role of performance measurement in fashioning the world class manufacturing company. Yeo et al. (1995) describe the viewpoints of various traditional quality management gurus on the concept of ‘zero defects’ and ‘do it better each time’ that these strategies are the important ways to improve quality continuously. ‘Zero defects’ represents CI over quality by detection of defects. A phrase ‘do it better each time’ (DIBET) strategy is associated with constant, conscious and committed efforts to reduce process variation.
They conclude that CI is the most important way to manage business through these strategies.

Newitt (1996) has given a new insight into the old thinking. The author has suggested the key factors to determine the business process management requirements.

The author also has stated that Kaizen philosophy in the business process management will liberate the thinking of both management and employees at all levels and will provide the climate in which creativity and value addition can flourish.

Womack and Jones (1996) refer to Kaizen as a lean thinking and lay out a systematic approach to help organizations systematically to reduce waste. They describe waste as any human activity that absorbs resources but creates or adds no value to the process. Most employees could identify several different types of muda in their workplace, but unfortunately the waste that they identify is only the tip of the iceberg. The authors state that until these employees have been taught the essentials of lean thinking, they are unable to perceive the waste actually present in their environment. They provide an example involving preparing a newsletter for mailing. Most of us would tackle the problem after the printing has been completed by folding all copies of the newsletter, placing stamps on the envelopes, then inserting the folded newsletter into an envelope and finally, sealing all the envelopes. When examining this process, it is not readily apparent to the observer that the newsletter is picked up four times. We compartmentalize and attempt to group tasks without looking at the flow. It would reduce muda if newsletter has been folded, inserted into the envelope, stamped as stacked. When explained, this opens up a new world of operation to those studying manufacturing processes. The process of Kaizen carries many other benefits as well.

Ghalayini *et al.* (1997) describe that Kaizen is characterized by operatives on the shop floor, identifying problems and proposing solutions—the epitome of spontaneous, bottom-up change. Small scale tuning of a system, by its very nature, is likely to lower the cost, generated from an intimate knowledge of a small part of the system. Progress is likely to be largely outside the control of management who are not the sponsors of change but only play, at most, a supporting role. Even though the aggregate effects may be significant, there is an obvious danger that the process may be erratic and fragmented.

Imai (1997) describes that the improvement can be divided into Kaizen and innovation. Kaizen signifies small improvements as a result of ongoing efforts. Innovation involves a drastic improvement as a result of large investment of resources in new technology or equipment. The author also explains that in the context of Kaizen, management has two major functions: maintenance and improvement. Maintenance refers to activities directed towards maintaining current technologies, managerial and operating standards, and upholding such standards through training and discipline. Under its maintenance function, management performs its assigned tasks so that everybody can follow standard operating procedure. Improvement, meanwhile, refers to activities directed towards elevating current standards.

Williamson (1997) highlights the target costing and Kaizen costing concept, one of the manufacturing techniques, which has been developed in Japan. Target costing is a process, ensuring that the products are designed in such a way that the company can sell them cheaply and still make a fair profit. Kaizen costing focuses on the value and profitability of the manufacturing phase, both of new and existing products. Kaizen costing activities should be a part of a process of business improvement continuously, with improvements in quality, product functionality and service jointly. Kaizen activities and targets may vary depending on the type of cost. Combining target costing and Kaizen costing provides a basis of the total life-cost management, managing cost throughout the product life cycle. Cheser (1998) explains that Kaizen is based on making small changes on a regular basis - reducing waste and continuously improving productivity, safety, and effectiveness. While Kaizen has historically been applied to manufacturing settings, it is now commonly applied to service business processes as well.

Kim and Mauborgne (1999) call incremental improvement as ‘imitation’ and not ‘innovation’. According to them, companies should focus on a proactive strategy, which focuses on the creation of new customers as well as sustaining existing customers. They refer this strategy as ‘value innovation strategy’ where the emphasis is on value and customers and to a lesser extent on the competition. The focus on value innovation pushes managers to go beyond continuous incremental improvements of existing products, service, and processes to new ways of doing things.

Williams (2001) highlights that CI techniques are the recognized way of making significant reduction to production costs. Quality Function Deployment (QFD) is a well-known technique for translating customer requirements for a product into functional specification. Data suggests that the best opportunity for significant reduction in the overall cost of manufacturing a product is at the design stage of the new product development program.

Doolen *et al.* (2003) describe the variables that are used to measure the impact of Kaizen activities on human resource. These variables include attitude toward Kaizen events, skills gained from event participation, understanding the need for Kaizen, impact of these events on employee, impact of these events on the work area, and the overall impression of the relative successfulness of these events.

2.5.3 Summary of Kaizen Concept

From the literature, it can be summarized that there is a reasonably vast literature available on Kaizen philosophy, which gives a broad view of past practices and researches carried across the globe. But as Kaizen is a widely accepted philosophy in manufacturing industries, more research work is required in this field. The authors feel that Kaizen philosophy can also be applied to different areas like business, service, commerce, etc. So a great scope of research is available for new researchers in this field. Success stories reveal that it requires team efforts involving every employee in the organization to fully implement the system. However, awareness among employees regarding different strategies that are involved in Kaizen philosophy, various principles behind these strategies and the use of these strategies in different circumstances plays an important role. So more research is required which could improve the awareness aspects, as these factors are highly important for the success of the Kaizen philosophy in most of the manufacturing industries across the globe.

2.6 Conclusion

Literature Review is more focused on previous journal, reference books or any other related articles based on this title of Research Project. The main elements studied in this paper are Semiconductor Process Flow, Production Yield Improvement and Kobetsu Kaizen Techniques. As for the title itself emphasized the term “Yield Discrepancy”, unfortunately, this topic is still new and there is no previous research or surveys have been done.