DEVELOPING 7mm×7mm QFN PACKAGE WITH LIQUID CRYSTAL

POLYMER

By

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I dedicate this work to my parents and my mentors who I have learned a lot from

and has inspired me at every step of my academics.

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ABSTRACT

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Quad Flat No-Lead (QFN) packages are one of the most widely used and popular packages in the industry. The QFN packages gained popularity in the last decade because of its excellent electrical/thermal characteristics and lower costs. QFN packages are widely used in automotive, defense, handheld devices where space is a constraint and high current circuits require the package is mounted on thick printed circuit boards. This work makes an attempt to develop an economical 7mm*7mm QFN package using Liquid Crystal Polymer (LCP).

The first challenge in this work investigate the different grades of LCP to match the electrical as well as mechanical properties for the package. Different materials were investigated before the LCP with the desired mechanical/ electrical properties was found. Once the organic material was selected the next challenge was to investigate a cost effective fabrication process that can be used for mass production in the

industry. Process such as injection moulding, hot embossing, roll to roll bonding produce shrinkage in the final package. So these conventional process were avoided. The two step process, lamination and laser ablation, is tested in this study. First multi-layer lamination technique is used to laminate 3 sheets of LCP through the bondply. Then this structure is attached to the array of lead frames. Then laser ablation technique is used to generate 7mm*7mm square holes.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

TABLES

Chapter 1

INTRODUCTION AND OBJECTIVE

1.1 Role of Packaging in Micro-Electronics

The semiconductor industry has gone through the continuous development of new and enhanced processes which has resulted in to highly integrated and reliable circuits. One of the widely used process for Integrated Circuit(IC) manufacturing is the complementary metal oxide semiconductor (CMOS). [1].

The typical Integrated Circuit(IC) consist of thin films. Thickness ranging from 100 nm to 1μm, and the substrate. In the CMOS process these films include:

- Semiconductors (as active part)

- Metal interconnects

- Via plugs (as carrier for current),

- Dielectrics (for electrical isolation),

- Passivation layers (for mechanical protection).

The primary function of a substrate in an IC is that of mechanical carrier. The figure1.1 shows the cross-section of a typical IC.
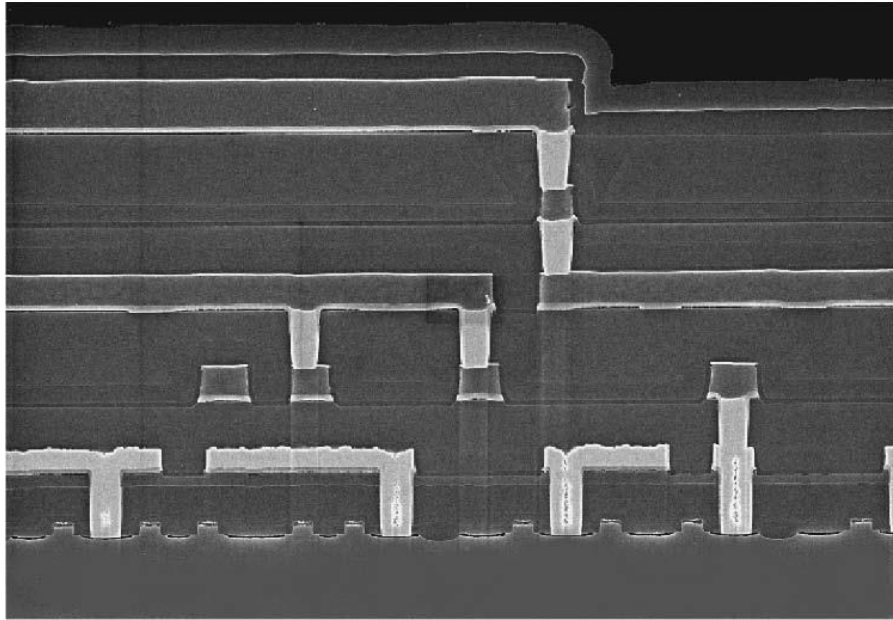
Figure 1.1 Cross section of a typical IC

The next process in the assembly line is the packaging. The primary function of an electronic package is to provide signal and power connection to the active components of an electronic circuit and also protect these components from its environment. It is the whole package that is shipped and not just the silicon. Packaging contributes significantly towards the cost of the package. The primary function of an electronic package in an IC are:

- Allow an IC to be handled for PC Board assembly.

- Enhance thermal and electrical properties of the overall system.

- Power, signal connection to the active components.

- Mechanical and chemical protection against the environment.

Packages can be broadly classified as:

- Through Hole Mount IC Packages

- Surface Mount IC Packages

- Contactless Mount IC Package.

1.2 Quad Flat No-Lead (QFN) Packages

The Quad Flat No-Lead package is a standard size IC package that is specifically designed to avoid the bulky heat sinks and slugs. The QFN package exhibits superior thermal and electrical properties as compared to other packages. QFN is a leadless package. The electrical connections in the QFN package to the printed circuit board (PCB) is made through soldering of the lands underneath the package body [2]. Using the standard PCB assembly techniques the QFN package can be mounted and replaced using standard repair procedures. As shown in the figure 2 the QFN package is designed such that the thermal pad (or lead frame die pad) is exposed to the bottom of the IC. This design of the QFN package provides an extremely low resistance path, which results in efficient conduction of heat between the die and the exterior of the package.

Plastic Mold Compound

IC (Silicon)   **Die Attach (Epoxy)**

Exposed Thermal Pad Located Underneath the Package

Leadframe (Copper Alloy)
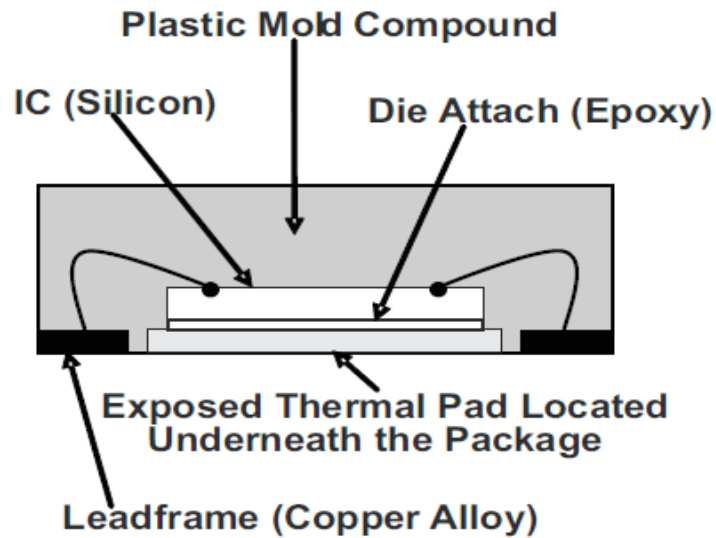
Figure 1.2 Cross section of a typical QFN package

QFN package has gained much of the popularity in the last few years due to the increased trend of miniaturization of the electronic packages in response to the advancement of mobile applications and other handheld devices.

1.3 Objective

The primary objectives of this study are:

(1). To test Liquid Crystal Polymer as a packaging material for 7mm*7mm QFN package for high temperature applications.

(2). To develop a fabrication technique that is stream lines enough for mass production.

There has been a growing trend of miniaturization of electronic packages due to the advancement of mobile applications and other handheld devices. This

4

trend has helped the QFN package gain much of the popularity in the last few years. QFN packages are low cost, compact in size and exhibit excellent thermal and electrical properties.

This study focuses on 7mm*7mm QFN package offered by Texas Instruments. The study aims to develop a stream lined process to develop the QFN package using the Liquid crystal polymer (LCP) as a material.

Chapter 2

LITERATURE REVIEW

Edwin C. Culbertson [3] studied Liquid Crystal Polymer (LCP) laminated to copper foil for high performance applications. He also discussed the balanced properties offered by LCP and how these properties are superior to any other engineering material. Some of these properties are: Low Dielectric constant, very low moisture absorption rate, chemical resistance. He also evaluated the multilayer PCB fabrication with Liquid Crystal Polymer copper clad film. He evaluated peel strength, solder float, moisture absorption, and moisture resistance.

Tadatomo Suga [4] discussed the excellent mechanical and electrical properties offered by LCP and how LCP should be used for electronic circuit boards. They also discussed that LCP is not widely used because of the weak interaction between LCP and Cu. They also investigated the Surface activated bonding (SAB) process to increase the bonding between the LCP and Cu. SAB is done through physical bombardment in vacuum. They established that the peel strength of 800-900g/cm of the laminate prepared by SAB process is achievable.

M. Worgull, A. Kolew [10] discussed about hot embossing and injection moulding being the established plastic moulding processes. These processes has been used to develop a variety of microstructures. Semicrystalline polymers like PEEK and LCP are a good fit for many applications in microfluidics. Precise

setting of temperatures are required for successful hot embossing of these chemicals. They set up the process parameters and the heating conditions for the hot embossing of various polymers such as, LCP, PEEK, FEP and PSU.

N. J. Teh, P. P. Conway[12] discussed the technological and economic impact of the overmoulding technology. Some technical challenges are thermal, electrical and process requirements in the production of highly integrated polymer encapsulated electronics products. They discussed the findings of the experimental work done to find the critical factors for the manufacturing of encapsulated electronic structures.

Chapter 3

LIQUID CRYSTAL POLYMER

The three main factors those are driving the electronics industry are: faster, smaller, and lighter. To satisfy these needs, many laminate materials have been developed in the past. But as the density increases the demand for some of these materials is hitting the limit. So in order to address the needs of manufacturers, it is critical to develop new laminate materials. All of these materials use thermosetting resins of some type. One of the thermoplastic materials that satisfies the requirements of high performance applications is liquid crystal polymers (LCP).

Liquid Crystal Polymer (LCP) offers electrical and mechanical properties unmatched by other organic materials. Some of the advantages offered by the LCP copper clad film include: Low dielectric constant, very low moisture absorption, chemical resistance, flame resistance.

3.1 Material properties of Liquid Crystal Polymer

Liquid Crystal Polymer (LCP) maintains its rigid, rod-like molecules crystalline order even in the liquid phase, this is regarded as one of the primary reasons for the special properties offered by LCP.[3] Ivotropic was the first commercial LCP and DuPont developed KevlarB fiber from it in 1965. [3] Celanese developed Vectra family of resins in 1985. There are different grades of LCP and the properties vary significantly for different grades.

It is the crystalline nature of LCP gives it the unique combination of electrical, thermal, physical and chemical properties. Below is the brief description of some of the unique properties of LCP.

Flame Retardant: LCPs are proven to be extremely flame retardant. The unfilled LCP resin are immediately self-extinguishing and has been rated UL94 V-0.

Radiation Resistance

LCPs are transparent to microwave energy. LCPS are unaffected by exposure to 500 megarads of Cobalt-60.

Moisture Resistance

LCP has been tested to be unaffected by 200 hours of water exposure at 121°C. LCP exhibits only a modest reduction in mechanical properties after 1000 hours of water exposer. The moisture absorption rate for the LCP films used for the production of copper clad laminate is in the range of 0.05%. The moisture absorption rate for the glass fabric filled material is in the 0.10% range.

Low Permeability

The barrier properties exhibited by LCP are superior to any other polymer barrier material. The barrier properties of LCP are not affected by humidity. LCP exhibits good barrier properties for other gases such as, carbon dioxide, nitrogen, argon, hydrogen and helium.

Chemical Resistance: LCPs exhibit resistance to most acids, bases and solvents over a broad temperature range. Table 3.1 lists some of the chemicals tested at different temperature. LCP does not show any significant change in properties after 30 days of exposer to more aggressive chemicals.

Table 3.1 Chemical Resistance of LCP

Table I	CHEMICAL RESISTANCE	
	30 days exposure – no effect[a]	
Solvents		**Temperature, °C**
Acids		
	Formic, 80%	102
	Glacial acetic	118
	Sulfuric, 70%	190
	Nitric, 70%	87
	Chromic, 70%	87
	Hydrochloric, 37%	87
Bases		
	Sodium hydroxide, 10%	87
	Diphenylamine	65
Oxidants		
	Sodium hypochlorite, 20%	87
Organic		
	Acetone	52
	Methanol	52
	Ethanol	52
	Methylene chloride	65
	Trichloroethane	65
	Nitrobenzene	65
	Ethyl acetate	77
	Phenol, 100%	100
	Toluene	111
Others		
	Gasoline	50
	Diesel	50
	10W-30 motor oil	50
	Antifreeze, car 50/50	50
	Hydraulic fluid	50
	Skydrol fluid	71
	Sour gas	50
	Freon	25
	Fluorinert FC-70, vapor	215
	Silicon oil	200

[a] <5% change in mechanical properties and <2% change in weight and dimension.

3.2 Dielectric properties of copper clad films:

The LCP cooper clad films exhibits excellent electrical properties with a dielectric constant of 3.1 and a loss factor of 0.022 at 1 MHz and decreasing to 2.9 at 1 GHz with a loss factor of 0.0025. Figure I shows a graph of the dielectric constant versus frequency for LCP (VECTRAN), PTFE, FR-4, BT, Low DC BT, PPO laminate materials.
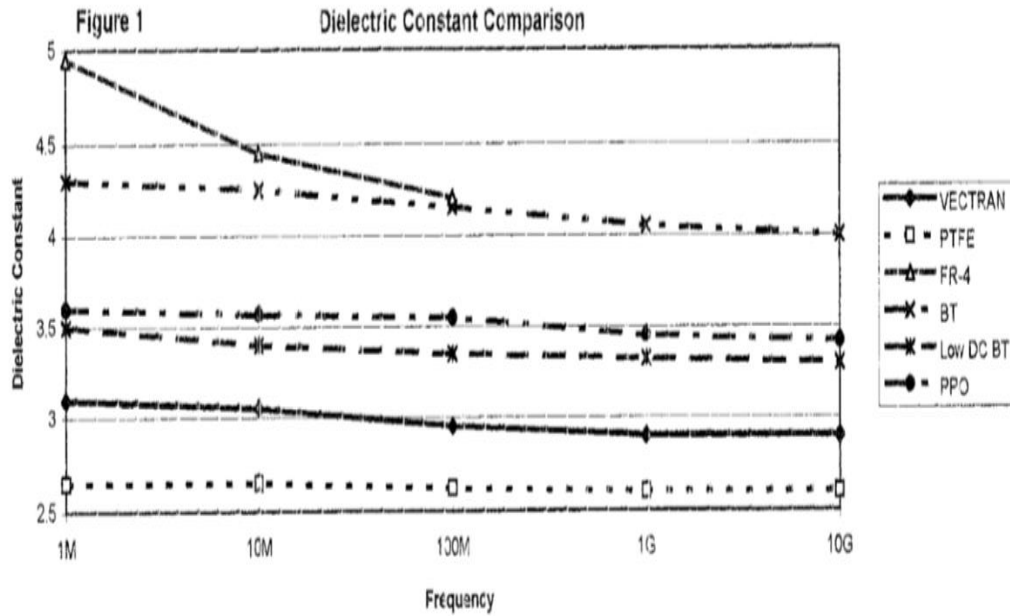

Figure 3.1 specific impedance measurements of LCP with FR-4 and PTFE

These data shows that the performance of LCP reaches that of PTFE, which makes it suitable for high performance application.
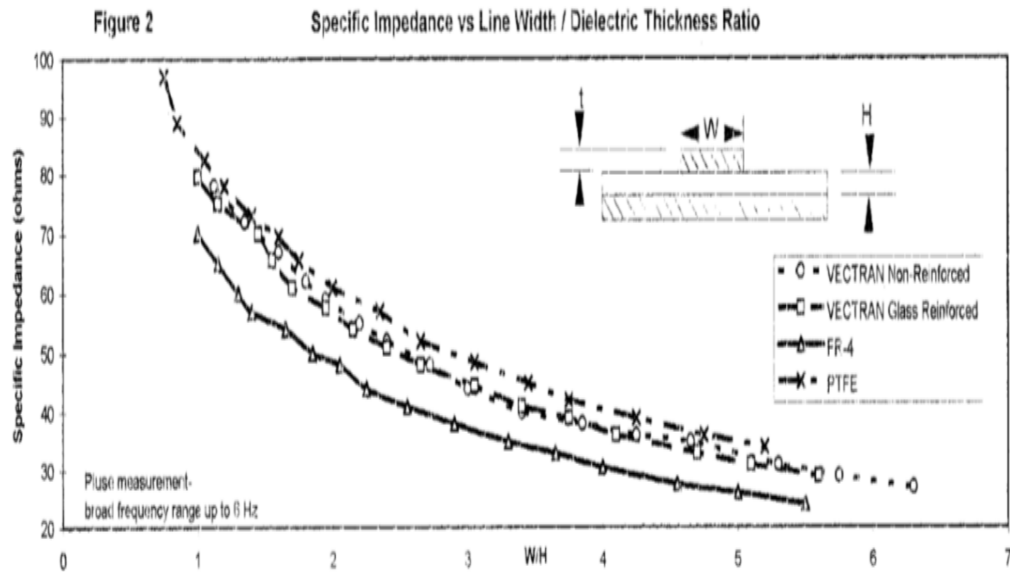
Figure 3.2 Specific Impedance Vs Dielectric Thickness

The interaction between LCP and Cu is very weak. For this reason LCP is not widely used for electronic packaging. To improve the adhesion between the LCP and Cu a rough surface of Cu foil is used in the heat lamination process. However, the rough interface between LCP and Cu is undesirable in the high-speed signal transmission. [4]

The method used for direct bonding between LCP and Cu is widely known as surface activated bonding (SAB) method. This method produces a strong bond with smooth interface between Cu foil and LCP. During this process, Ar beam etching is used to activate the Cu and LCP surfaces and then are bonded directly in vacuum

at room temperature. Fast atom bombardment or radio frequency (RF) plasma sputtering is used to remove the inactive layers of native oxide and contaminants from the surface of LCP.

3.3 Dielectric properties over frequency, temperature, and humidity

Dielectric properties such as dielectric constant, loss tangent, and the stability of these properties are very critical characteristics for the microwave design. [5] Figure 2.3 shows measurement value over frequency for dielectric constant up to 40GHz. These values are compared with adhesiveless polyimide based flex. The comparison shows that LCP can provide nearly static dielectric properties across different frequency range as polyimide. The stable dielectric properties of LCP are believed to be due to the rigid-like aromatic structure and dense chemical structure.

The dielectric properties dependent on humidity are also critical as the moisture absorption in dielectric films can cause significant losses in devices such as antennas, filters, and transmission lines [5]. Water has large dielectric constant, this causes the dielectric properties of the materials to vary as the humidity increases. Using the material analyzer and the environment chamber, the dielectric constant and loss tangent measurements at 1GHz in the environment chamber are investigated in the humid conditions. [5].

Figure 3.4 shows the stability of dielectric constant and loss tangent at 1GHz over humidity up to 100% RH for different materials such as, LCP, polyimide, FR-4,

BT, and PTFE. These graphs show that LCP laminates has stable dielectric properties over humidity. The dielectric properties of polyimide are unstable due to its high moisture absorption.
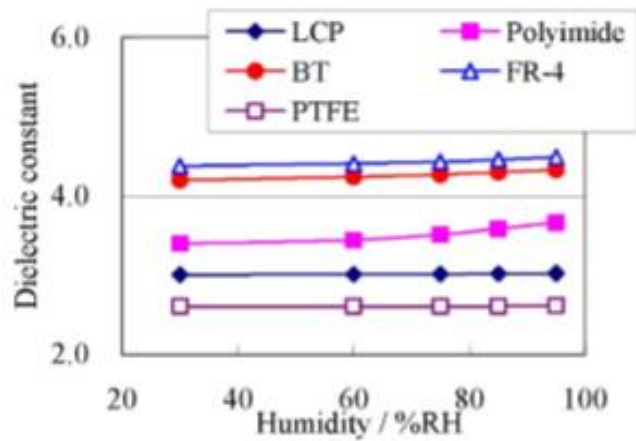
(a) Humidity versus dielectric constant
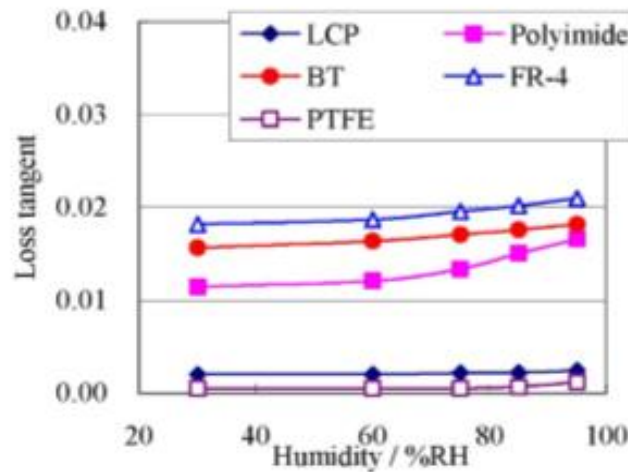
(b) Humidity versus loss tangent

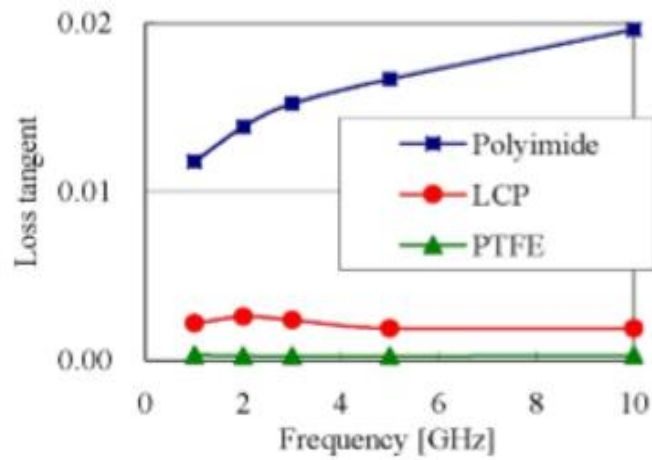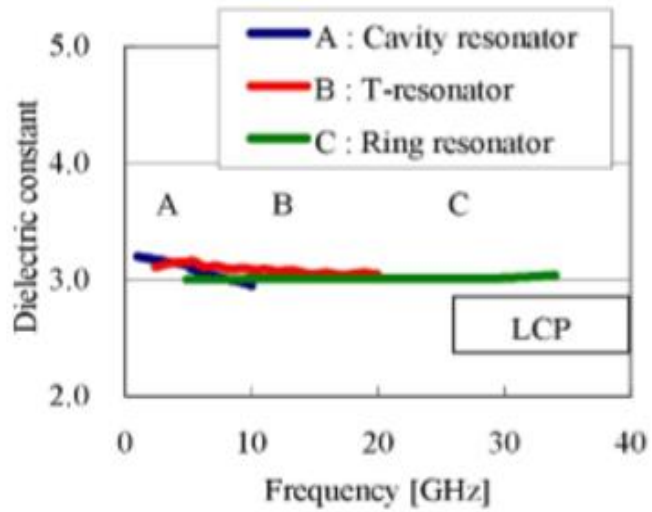Figure 3.3 Humidity VS Loss Tangent

Figure 3.4 Frequency VS Loss Tangent

Electronic packaging technology considers both system and materials considerations. The general trends in the electronic packaging industry are

packages with increased performance, lower price, and a faster time to market. Typical printed circuit boards consist of a substrate and copper foil circuit traces. Circuit laminates are usually made out of FR-4. LCP are high performance materials that combine the properties of polymers with those of liquids. LCPs are the condensed matter between crystalline solids and isotropic liquids. This condensed matter exhibits the combination of physical properties of a liquid crystalline state and specific polymer properties. The ring-aromatic structure that the LCPs are based on are very stable after polymerizing. The liquid crystalline material can have its molecules realigned using magnetic or electrical fields, and in the process acquire the properties of both solids and liquids.

Thermotropic LCPs exhibit variety of properties those are attractive for electronic packaging. But the LCP films developed using processing techniques produce films those exhibit anisotropic in-plane properties.

3.4 Effect of Cu deposition

Unlike metals LCP has an ordered structure. Because the bulk Cu atoms restrict their position to each other, it is difficult for bulk Cu atoms to approach LCP molecules. This results in a weaker bond between bulk Cu and LCP. As opposed to this, the sputtered Cu atom is free from other Cu atoms and Cu-deposition on LCP increases bonding sites. Figure 3.5 shows how the Cu layer deposition helps increase the peel strength. As the figure shows the peel strength increases up to 20

nm and then changes consistently with the increase in Cu layer. This can be explained by the findings of Chopra et al [13]. As per their findings, of 10-2Onm Cu deposited layers requires to cover the LCP surface for the bonding. This value is in line with the result in Figure 3.5. Also the peel strength of the test specimen without annealing increases about 100 g/cm with the deposition of 7mm Cu lay. So the peel strength increases linearly with the increased area covered by Cu deposition.
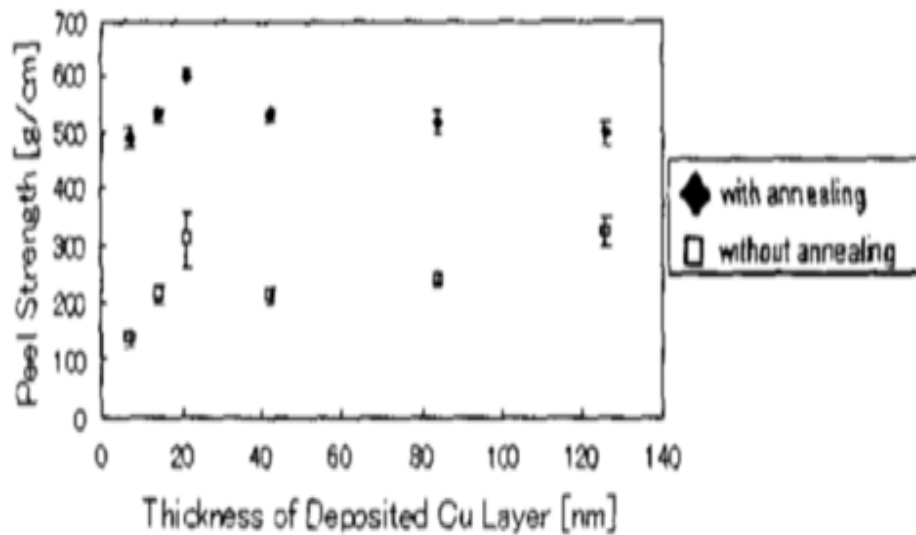

Figure 3.5 Cu Deposition Thickness with annealing

3.5 Effect of annealing

The bonded specimen that is heated at 240°C for 1hr exhibits higher peel strength of 100-150g/cm than that of other specimen. This process of heating the specimen for the specific period of time is called "annealing".

LCP has an extremely solid molecular structure, so LCP does not transforms plastically at room temperature. Cu is ductile so during cold rolling significant shear stress can occur the bonding interface. The bonding specimen without annealing curls because of the difference of expansion between LCP and Cu. The bonding specimen after annealing is flat because of creep. Stress relaxation is one of the main outcomes of annealing. The glass transition (Tg) temperature is when the movement of molecular chains in polymer are activated. Annealing at glass transition temperature promotes the restructuring and strengthening of binding between the molecular chains. Greater amount of peeled LCP observed in annealed specimen proves the stronger LCP/Cu bonding due to annealing.

Manufacturer, but they are currently available in a variety of unfilled, glass-filled, mineral-filled, carbon fiber reinforced, and glass fiber-reinforced grades which allow for numerous options in melting points and other key properties. LCP is a promising material because it has exceptional properties that make it well suited for use as a substrate material. The unique properties of LCP's have led to increasing interest and development in the field. The combination of polymer specific

properties together with properties specific to the liquid crystal phase has led to a multitude of new prospective that are not possible for conventional materials. LCP's have a high modulus, high melting temperatures, and good impact strength as a result of the fibrous nature of liquid crystal morphology. They are unaffected by acids, dilute bases, and organic solvents over a broad temperature range and demonstrate minimal dimensional changes after exposure to a wide range of solvents. Strong concentrated bases at elevated temperatures hydrolyze LCP's. This is convenient for molded circuit board applications and as a method of promoting copper adhesion to LCP's. Other important properties relative to electronic packaging include a low coefficient of thermal expansion, flame retardant, low moisture absorption, and the ability to resist attacks by solvents used in defluxion and cleaning printed wiring boards. On the other hand, LCP's are extremely difficult to align in devices, and they tend to be more viscous than low molecular weight liquid crystal materials. LCP's also have high anisotropic mechanical properties.

There is good processability and a high flowability in the melt state, but in the flow direction the properties are quite different compared to those perpendicular to the flow direction. Exceptional barrier properties make LCP's well suited for use in packaging applications. LCP technology can replace materials such as ceramics, metals, composites, and other plastics due to outstanding mechanical properties such as: strength, resistance to virtually all chemicals, extreme temperatures, and

weathering to name a few. The properties of LCP's discussed are practical relevant for current packaging concerns. These concerns involve addressing heat removal with a higher thermal conductivity, lower thermal expansion materials to better survive thermal stresses during temperature cycling in a system, and alternatives to solder lead content issues. Currently, polymers are widely used in electronic packaging as adhesives, encapsulates, insulators, dielectrics, molding compounds, and conducting elements for interconnects. These are typical applications requiring resistance to high temperatures and chemicals, and where thin walls, dimensional stability, strength, and rigidity are essential. The thermal analysis data presented will show the need for LCP in future electronic packaging applications.

LCP Properties and Applications LCPs are so called because their molecules can be mutually aligned and organized (crystal), yet the bulk LCP can flow (liquid) in the molten state. This behavior is unlike ordinary polymers which are randomly configured in the melt or in solution. The liquid crystal state results from the rigid nature of segments of the LCP molecules (Figure 1). When the LCP flows in the liquid crystal state, the rigid segments of the molecules align next to one another in the shear flow direction, creating locally oriented domains. The domains in turn create macroscopic oriented regions. Once the oriented regions are formed, their direction and structure persist, even when the LCP approaches the melt temperature, because of the long relaxation time of the stiff chain LCP molecules.

Chapter 4

FABRICATION PROCESSES

4.1 Injection Molding:

In simple terms injection molding can be described as a cyclical process that forms plastic into a pre-determined geometry by forcing high- temperature molten polymer resin under injection pressure into a cavity of desired shape. [12] AS shown in figure 4.1 the molten polymer solidifies within the mold, which is then opened and the part is ejected out after a given cooling time. With thermoplastic injection molding process time is faster and no secondary operations are required, which results in to short processing time. Thermoplastics offer higher material yields due to less scrap and reusability. Fundamental process parameters such as: temperature (melt, mold), pressure (injection, holding), time (injection, holding), speed (injection) and molding tool design, influence the quality and repeatability of molded parts. These factors influence both in- and post-mold reactions of plastic part and any flaw in design will result in distortion, such as thermal shrinkage, warpage, under-strength weld lines, sinks or voids in the final product.

The interaction between the molding polymer and the subassembly components (particularly with PWB and electrical interconnection joints) is very critical for the success of this technology. The significant difference or mismatch of material properties can cause thermal shrinkage and shear -stresses at interfacing layers

between these materials and lead to mechanical deformations of the embedded subassembly. So it is crucial to achieve both, optimum molding parameters and materials matching criteria, in order to realize the manufacturability of this encapsulation technique.
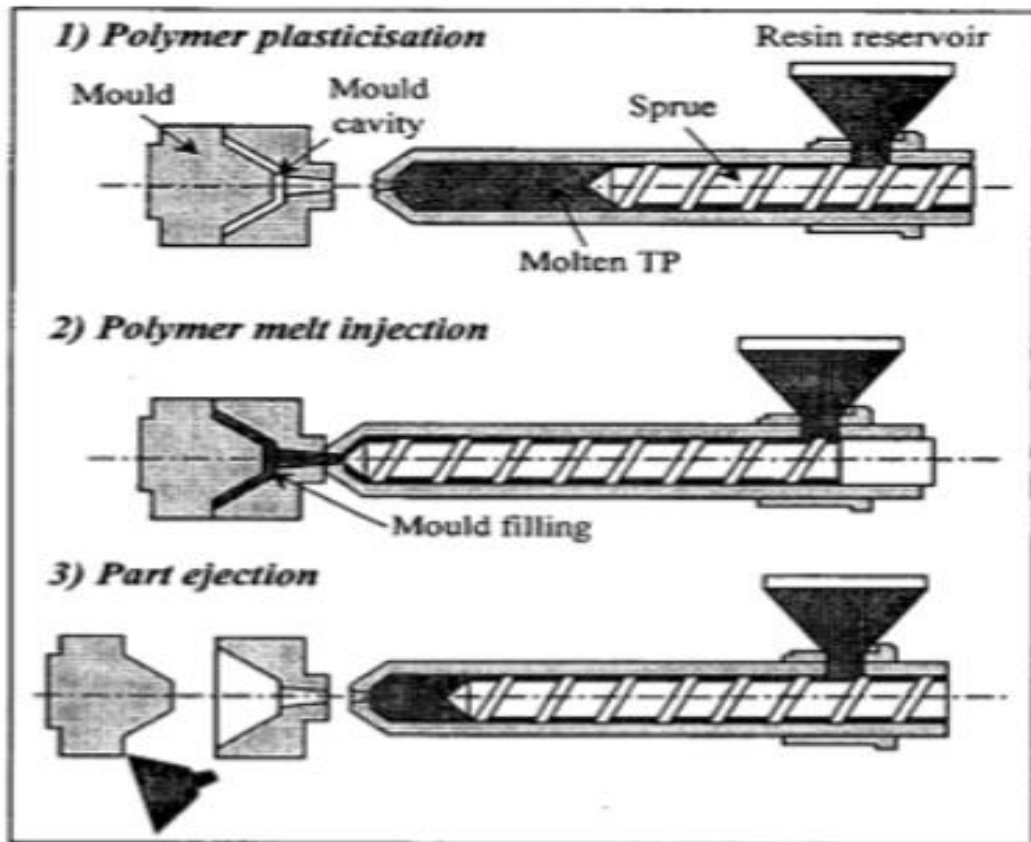

Figure 4.1 Injection Molding

4.2 Injection parameters and module deflection:

Due to the effect of part shrinkage and electronic integrity two levels of injection are chosen. The critical injection parameters are: melt temperature, injection pressure, mould temperature and holding pressure.

Module deflection: The most widely reported issue with injection moulding is that of warpage of intrinsic polymer molding is a well- established and widely reported issue. The common causes being polymer properties, injection parameters and tooling geometry. Another major issue could be the parity of CTE between the molding polymer and substrate laminate. Figure 4.2 shows two samples with different degrees of longitudinal warpage observed.
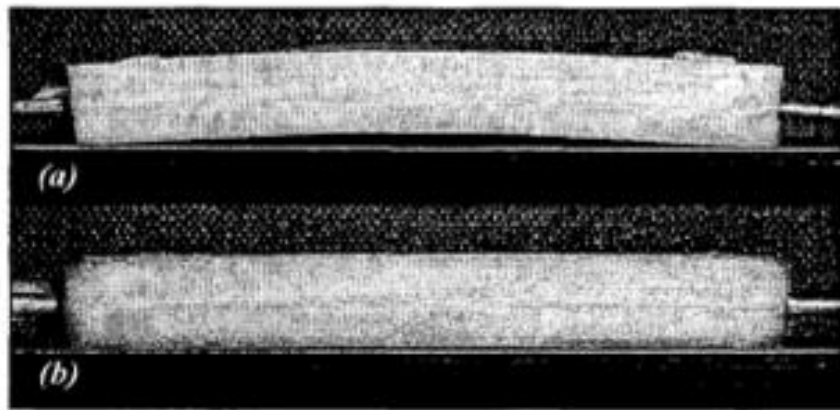

Figure 4.2 Flexure due to injection molding

The glass-reinforced semi-crystalline polymers are observed to show reduced amount of warpage as compared to unfilled polymer.

4.3 Hot Embossing:

Hot embossing is one of the replication techniques for the replication of a microstructured mould insert. The available replication processes are micro reaction injection moulding (RIM), micro injection moulding, micro injection compression moulding, micro hot embossing, micro thermoforming and nanoimprint lithography processes (NIL). Each of these processes has their specific characteristics and advantages. So based of the requirements such as, stress in moulded parts, flow length, number of replications or cost effectiveness the specific process will be selected. [10] Hot embossing is a suitable technique for the replication of various structures with high aspect ratios.

To understand the fundamental of the process, let's take a look at the example of the case of single sided hot embossing. Figure 4.3 represents the principle of a one-sided hot embossing cycle. [10] A polymer foil is positioned between the microstructured mould insert and a metal plate known as substrate plate. The polymer foil is usually thicker than the structural height of the tool. The structured part of the tool is covered by the surface area of the foil. Then the tool and substrate are heated up under vacuum to the polymer moulding temperature. During the heating process as the constant moulding temperature is reached, the two steps of the moulding cycle are initiated. First step, the mould insert and substrate are moved towards each other (in the range of 1 mm/min) until the pre-determined maximum

embossing force is achieved. Second step, the embossing force achieved through the first step is maintained for specific holding time. The relative movement between the tool and substrate has to be controlled in order to generate the constant force. The force is kept constant for an additional time period (packing time, holding time). During the packing time the plastic material flows in radial direction and the residual layer will be reduced under the acting constant force (packing pressure) during this holding time. The thickness of the residual layer decreases with the packing time as the tool and substrate move further towards each other. The temperature is to be kept constant during the moulding time.
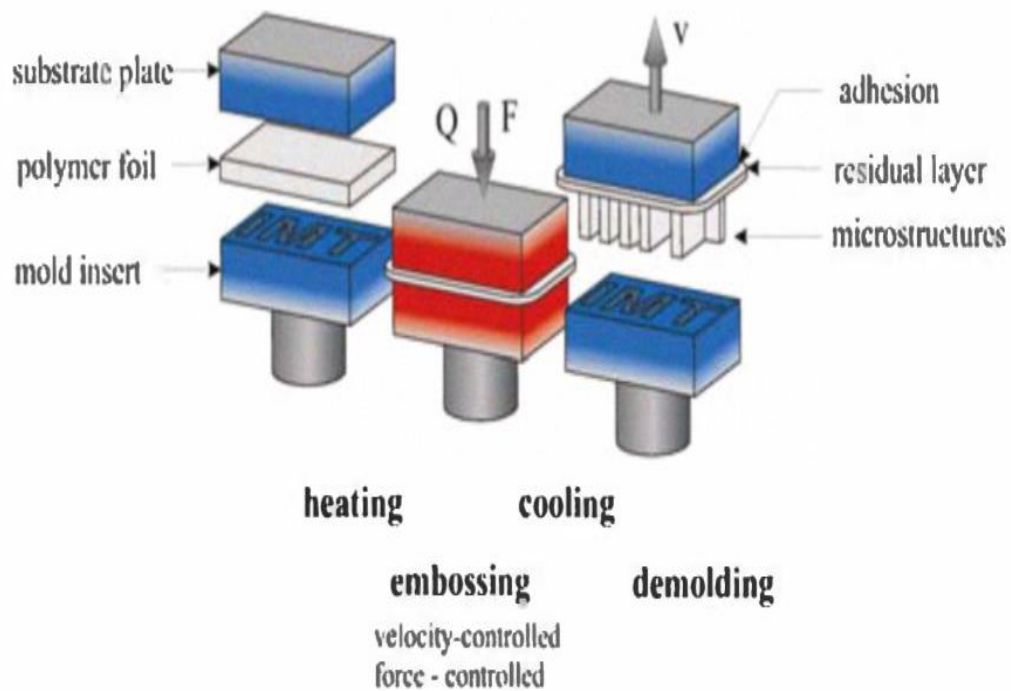

Figure 4.3 Hot Embossing

In order to fill the cavities of the tool completely the isothermal embossing under vacuum is required. Once the packing time is over, the tool and substrate parts are cooled and the embossing force is kept constant. Cooling is continued until the temperature of the moulded part drops below the glass transition temperature of the plastic. Moulded part is demoulded from the tool through the relative movement between the tool and the substrate as the moulding temperature of the polymer is reached. Demoulding only works in connection with an increased adhesion of the moulded part to the substrate plate. This adhesion helps the homogeneous and vertical transfer of the demoulding movement to the moulded part. Demoulding is the most important step of hot embossing.

The accuracy of the embossed microstructures is influenced by the process parameters such as, process temperature, loading pressure and holding time. High loading pressure and high process temperature are preferred in order to improve the fidelity of the embossed microstructures. High temperature embossing comes with certain drawbacks. Some of those drawbacks are, the difficulty in demolding, residual thermal stress due to difference in coefficients of thermal expansion (CTEs) between the mold and polymer used in the process. Due to this the embossed devices suffer from global warpage or distortion because of mechanical stress during demolding and residual thermal stress [14].
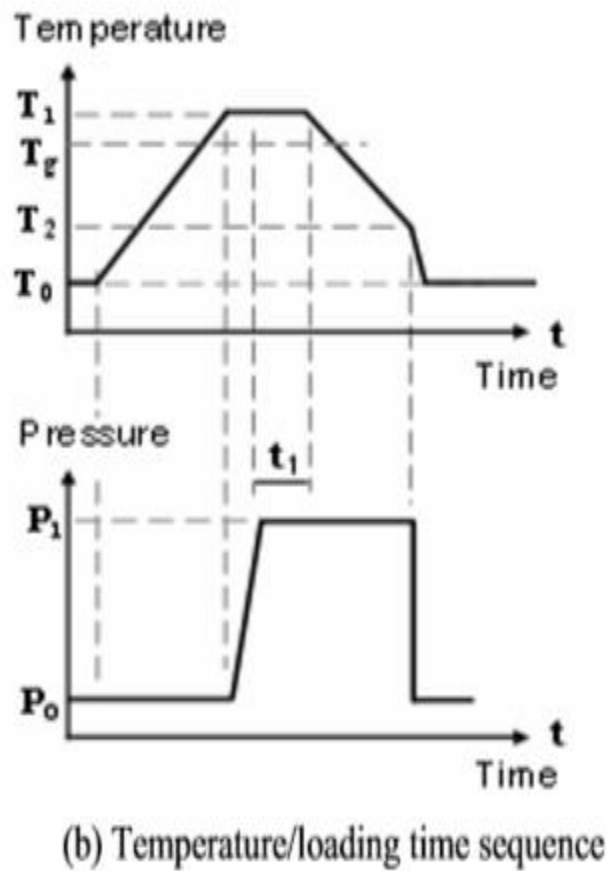
Figure 4.4 Process Description of Hot Embossing

4.4 Hot Embossing of LCP:

LCP (Liquid crystal polymer) is a semicrystalline high temperature polymer. The melting point of LCP ranges between 280°C and more than 300°C. The melting point depends on the modification of the polymer. [10] The high melting point and chemical resistance make LCP suitable for applications such as, microfluidics for high temperature environment, electronic packaging etc. Due to the small zone near

the melting point and the high anisotropy due to molecular orientation, the moulding of LCP by hot embossing is challenging. In addition to this LCP exhibits high adhesion between polymer and mold insert at temperatures higher than the melting point. This makes the demoulding of structures with high aspect ratios difficult. This risk of damage during demoulding requires that the setup of moulding temperature has to be very precise in a range between one and two degrees.

The semi-finished products fabricated by injection moulding of LCP are available in the form of sheets. [10] The thickness of these sheets ranges from one up to two millimeters. These plates are high grade oriented and because of injection molding they exhibit anisotropic flow and perpendicular to the flow direction. Due to the small moulding window the complete relaxation of stress inside the polymer is prevented and this causes anisotropic behavior of molded parts. LCP sheets with a thickness between 50μm to several hundred microns are better suited for hot embossing. These films can be fabricated using hot embossing with small temperature gap in the melting range. The molecular chains become active at the glass transition temperature (Tg). So the temperature range should be over the glass transition temperature and below the melting temperature. Cleaning the cavities after hot embossing process is also very important before using the same substrate plates.

The moulding velocities during the compression step are low as compared to injection molding. This results in to lower shear velocities and which results in to lower shear stress and residual stress as compared to injection molding. Hot embossing is also better suited for structures with high aspect ratio. Hot embossing is highly flexible. The mould inserts and the kind of polymer used can be changed very quickly. Hot embossing is also feasible with double sided moulding and multilayer lamination.

Hot embossing of large area and high aspect ratio structures should be done at lower process temperature. The process parameters that impact the fidelity and accuracy of the microstructures are, process temperature, loading pressure and holding time. High process temperature, high loading pressure are preferred to improve the quality of the microstructure. But high temperature embossing comes with its own disadvantages. Some of these disadvantages are difficulty in demolding, significant residual thermal stress. The residual and thermal stress are due to different coefficients of thermal expansion (CTE) between the mold and polymer used in the process. This results in the embossed devices suffering from global warpage due to the mechanical stress during demolding and residual thermal stress.

As shown in figure 4.4, micro hot embossing process consists of a rigid stamp or mould, which is pressed against a polymer substrate. The substrate is heated up to the glass transition temperature (Tg) of the polymer material. The glass transition

temperature is where the molecular chains of the polymer becomes active. The heat and pressure conditions allow the polymer to flow completely to form the patterns. The heating process is followed by the cooling of the mold tool and the substrate. This is followed by demoulding of the molding tool.
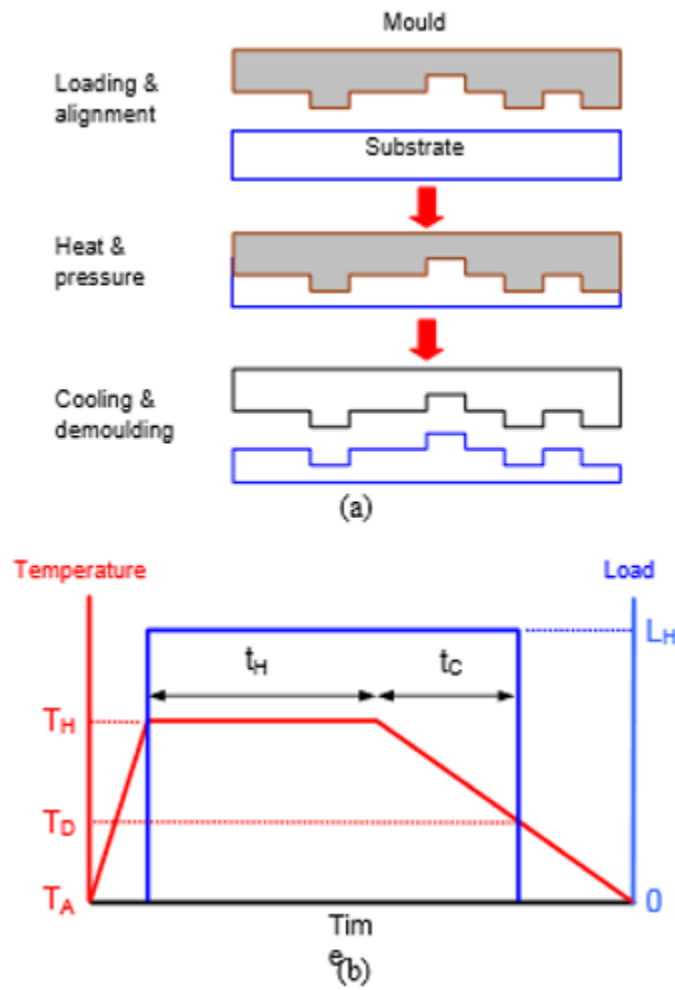

Figure 4.5 Hot Embossing Process Outline

As per the free volume theory as the temperature increases, local motions occur and the molecules start to stretch and bend. As the temperature increases further, the material undergoes a glass transition phase where the modulus of the materials will decrease by significant percentage. After the glass transition phase the molecular chains are free to move relative to each other. Even during this phase the long range molecular movement is restricted. For amorphous polymers like PMMA, further increase in temperature results in melting. All polymers has to go through these transformation stages for manufacturing process. During the micro hot embossing the material is brought from glassy state to rubbery region and back to glassy state slowly. During injection moulding the material is brought to the melting point and back to solid state rapidly.

Chapter 5

LAMINATION PROCESS & LASER ABLATION

The most widely used fabrication techniques such as injection molding and hot embossing are ruled out for the fabrication because of high residual stress, thermal stress and shrinkage. So we tested a new twostep approach: 1. Multilayer lamination. 2. Laser ablation to generate cavity structure.

5.1 Multi-layer lamination:

Multilayer lamination approach is adopted to attach the sheets of LCP to the copper lead frame. The process parameters are as shown in the chart. The lamination process is carried out by hot oil press. To attach the sheets of LCP to the copper lead frame the bond ply is used. Bond ply is the special adhesive for LCP sheets. The process parameters are as per the fabrication guidelines by the suppliers, Rogers Corporation. As shown in figure 5.1 first the temperature is increased up to 260ºC at the ramp rate of 3-4ºC. During this process the pressure is increased up to 50PSI. The temperature is monitored by the thermocouples to ensure the specific temperatures are maintained. These conditions are maintained for about 20 minutes. Then the temperature is increased up to 282ºC at the ramp rate of 3-4ºC. Pressure is increased up to 300PSI during this process. These conditions are maintained for about 30 minutes. Then the cooling begins. The cooling is carried out at the ramp

rate of 3-4 ºC. The temperature is maintained at 100 ºC for 15 minutes during the cooling. The robustness of fabrication is dictated by the ability of the press to achieve uniform platen high temperature.
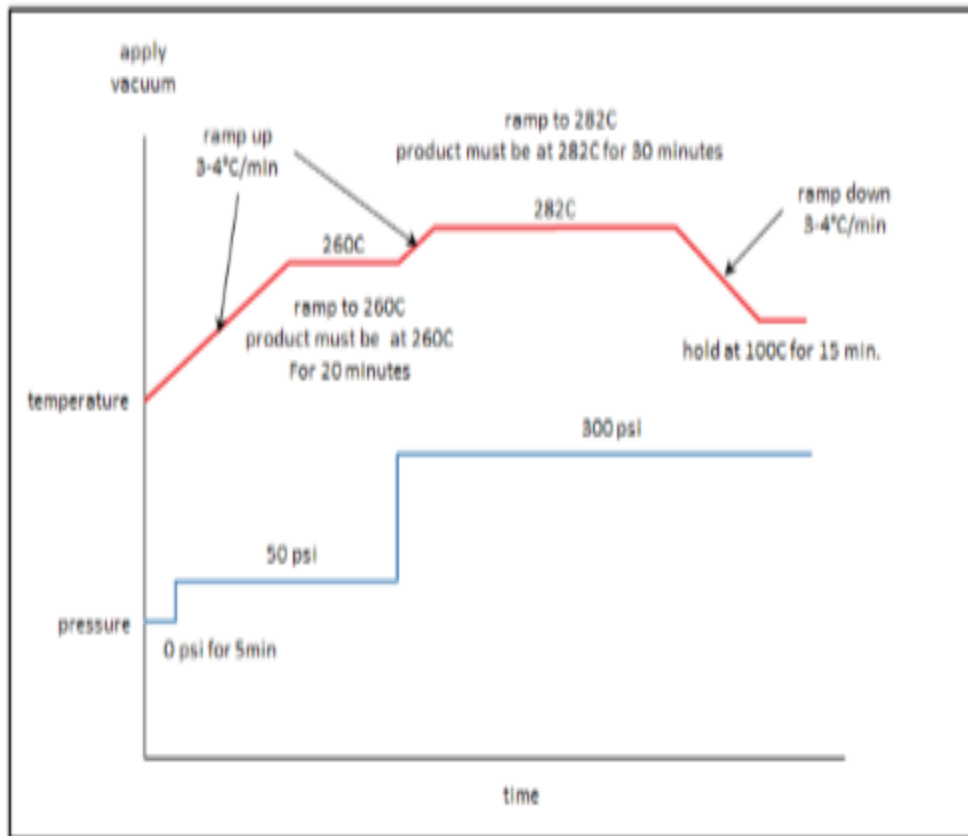

Figure 5.1 Fabrication Process Chart

5.2 Laser Ablation: After the lamination process we have the sheets of LCP attached to the copper lead frame. There are different ways to generate the 3D cavity structure in the lamination structure. Some of these are, mechanical drilling, photolithography, laser ablation. Laser ablation produces the most precise dimensions. For this reason laser ablation was chosen to generate the 3D cavity structure. Figure 5.2 shows the test specimen. In this test specimen the copper lead frame is exposed by 7mm*7mm square hole.
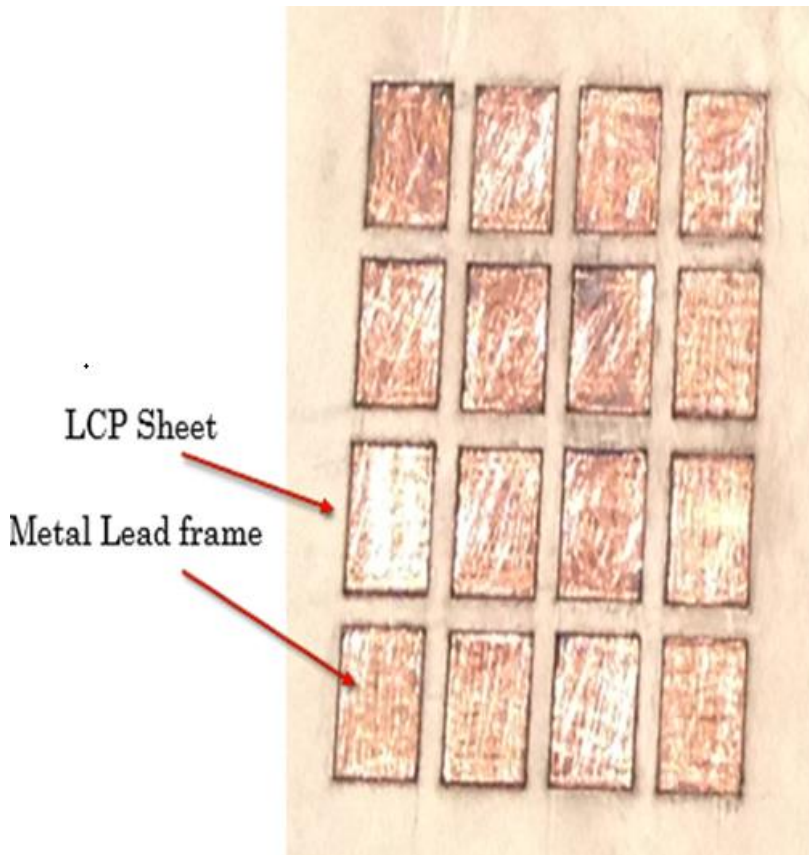

Figure 5.2 Test specimen

Chapter 6

CONCLUSION

As discussed earlier, the packages developed using the conventional fabrication processes such as injection molding, hot embossing are likely to suffer shrinkage. Also these processes produce high residual and thermal stress. The twostep process of multilayer lamination and laser ablation avoids these issue of residual stress and shrinkage. At the end of the study, the 7mm*7mm QFN package is developed through the lamination process and the laser ablation process.

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BIOGRAPHICAL STATEMENT

Mitul Naik received his Bachelor's degree in Mechanical Engineering from the South Gujarat University, Surat, Gujarat, India in the year 2010. Mitul Naik received his Master's in Business Administration (MBA) from the University of Texas at Arlington in the year 2013. He decided to pursue his Master's in Mechanical Engineering by enrolling in University of Texas at Arlington in Fall 13. He worked as a Mechanical Engineering Intern at Daimler Ag for 6 months during the spring of the year 2015. There he joined the Electronics MEMS & Nano electronics Systems Packaging Center (EMNSPC) under Dr. Dereje Agonafer and developed a keen interest in reliability and failure analysis of electronic packages. His research interest includes, electronic packaging, reliability, fracture mechanics, thermo-mechanical simulation and material characterization. During his time, he was an integral part of the SRC funded project where he worked closely with the industry liaisons. Upon graduation, Mitul is highly motivated to pursue his career in the semiconductor industry.