

สำนักหอสมุดกลาง พระจอมเกล้าลาดกระบัง

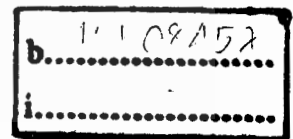
**A LEVEL SET METHOD FOR THE SIMULATION OF THE SOLDERING
PROCESS AT HGA LONG TAIL**



E076499



เลขหมู่.....**76499**
เลขทะเบียน.....
วัน,เดือน,ปี...**25 ส.ค. 2557**



**A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENT FOR THE DEGREE OF
MASTER OF ENGINEERING IN DATA STORAGE TECHNOLOGY
COLLEGE OF DATA STORAGE INNOVATION
KING MONGKUT'S INSTITUTE OF TECHNOLOGY LADKRABANG**

2013



COPYRIGHT 2013

COLLEGE OF DATA STORAGE INNOVATION

KING MONGKUT'S INSTITUTE OF TECHNOLOGY LADKRABANG

This material is reserved for educational use only, not allowed for commercial use.

Forbidden to modify the content, and cite the document when use.

ชื่อหัวข้อวิทยานิพนธ์:	แบบจำลองเพื่อวิเคราะห์ตะกั่วบัดกรีที่ใช้ในการเชื่อมต่อ หัวอ่าน-เขียน ของฮาร์ดดิสก์
นักศึกษา	นายอังการ ทองสุขใส
รหัสประจำตัว	51068912
ปริญญา	วิศวกรรมศาสตรมหาบัณฑิต
สาขาวิชา	เทคโนโลยีการบันทึกข้อมูล
พ.ศ.	2556
อาจารย์ที่ปรึกษาวิทยานิพนธ์	ผศ.ดร.ศิริเดช บุญแสง

บทคัดย่อ

ในการทำวิทยานิพนธ์ครั้งนี้ นำเอาวิธี เลเวล เซท มาประยุกต์ใช้เพื่อวิเคราะห์ปัญหาของของไหลในระบบของแบบจำลอง ประกอบด้วยอากาศและของเหลว ซึ่งของเหลวนั้น กำหนดให้เป็นตะกั่วในสถานะของที่ถูกหลอมละลายแล้ว คุณสมบัติความหนาแน่นของของไหลสองอย่างนี้ มีความแตกต่างกันเป็นสิ่งที่เรานำมาใช้ในการวิเคราะห์พฤติกรรมการไหลของตะกั่วในรูปแบบของของไหลแบบนิวตันเนียน ที่ใช้ในกระบวนการเชื่อมต่อระหว่างหัวอ่าน-เขียนและแผงวงจรแบบจำลองสามทิศทางเพื่อใช้ในการวิเคราะห์การกระจายตัวของตะกั่วที่พอเหมาะกับความต้องการในช่วงเวลาที่เหมาะสม และแบบจำลองสองทิศทางใช้ในการวิเคราะห์การถ่ายเทความร้อนของระบบเพื่อนำมาซึ่งการกำหนดกำลังไฟฟ้าที่ใช้อย่างเหมาะสม ผลที่ได้จากการทดลองแบบจำลองสามทิศทางเวลาที่เหมาะสมคือ 25 วินาที ที่กำลังไฟฟ้าที่ใช้ 110 วัตต์

Thesis A Level Set Method for the Simulation of the soldering process at HGA Long Tail

Student Mr.Angkhan Thongsuksai

Student ID. 51068912

Degree Master of Engineering

Program Data Storage Technology and Application

Year 2013

Thesis Advisor Asst.Prof.Dr.Siridech Boonsang

ABSTRACT

In this Thesis, a level set method is applied to the fluid flow problem of a molten solder at Head Gimbal Assemblies (HGA) Long Tail (LT) and Flex Circuit Board (FCB). The system constituted by air and molten solder is considered as a domain composed by two fluids which have different densities. In particular, a fluid-like constitutive behavior is assumed for solder as well as a Newtonian one. The 3D model simulation is used for predicting the solder mass towards HGA LT layer. And the 2D model simulation is used for Heat transfer that relates to the volume of power applies. The simulation results from 3D model indicate that the optimum time setting of a molten solder is 0.25 seconds at 110 Watt, the power apply.

Acknowledgements

I had the opportunity to have Ass. Prof.Dr.Siridech Boonsang as thesis advisor; He introduced me to the world of A Level Set Method and develops soldering process in Head Stack Assembly operation. I was able to enjoy the numerical calculation techniques design my graduate study at College of Data Storage Innovation, KMITL.

This paper was supported financially by a grant from Western Digital (Thailand) Company through Master program fellowship at DSTAR KMITL. The additional funding was received through DSTAR-KMITL and NSTDA for Research Unit on Finite elements and Mechanical Engineering.

I would also like to thank my supervisors, K.ChaiyaTho, K.Prasopsuk D. and K.Pricha L. for their helping during my research publication.

Finally, thanks to my friend who is a wonderful partner and gives such a good feeling during studies.

For whatever goodness arises from this thesis. I would like to give to family, for whom I have a great love and respect. And respect all to teachers of you who have the ultimate knowledge.

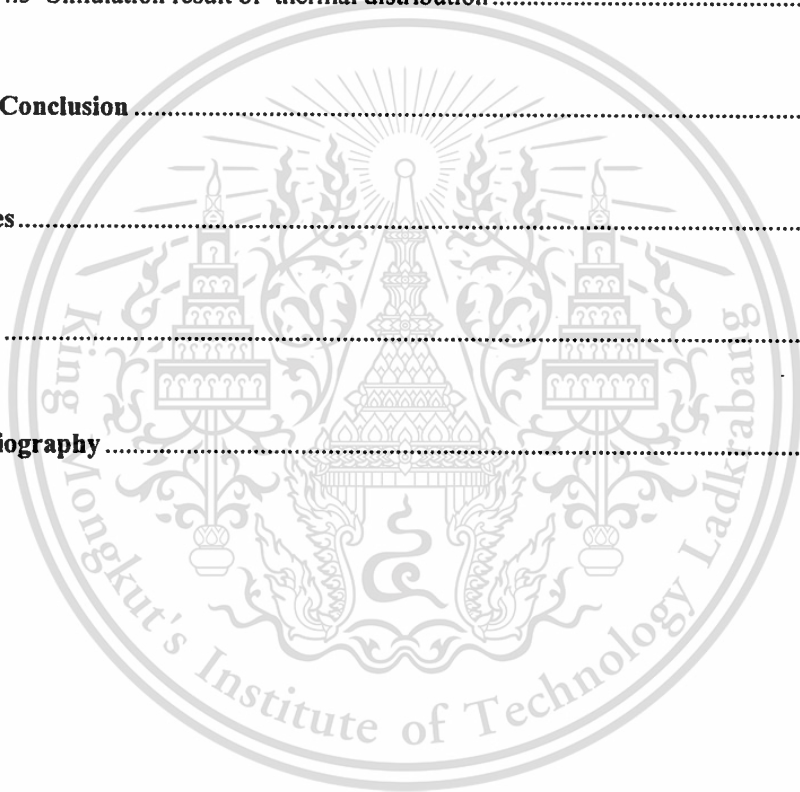
Angkhan Thongsuksai

Contents

	Pages
Abstract (Thai)	I
Abstract (English)	II
Acknowledgement	III
Contents	IV
List of Tables	VI
List of Figures	VII
Nomenclatures	X
Chapter1 Introduction	1
1.1 Background and Significance of the problem	1
1.2 The aim and objectives of the study	7
1.3 Hypothesis	7
1.4 Theory or conceptual used in this study	8
1.5 Scope of research	8
1.6 Thesis Structure	8
Chapter 2 Theory	9
2.1 Literature review	9
2.2 Fundamental of Fluid flow	18
2.3 Fundamental of Level Set Method	19
2.4 Fundamental General Heat Transfer	20
Chapter3 Methodology Set Up	23
3.1 The modeling for solder joint shape without HGA LT	23
3.1.1 Physical set up	23
3.2 Experiment set up of water droplet	26
3.3 The modeling for solder joint shape with HGA LT	27
3.3.1 Physical set up	29
3.4 Methodology set up of thermal distribution	33

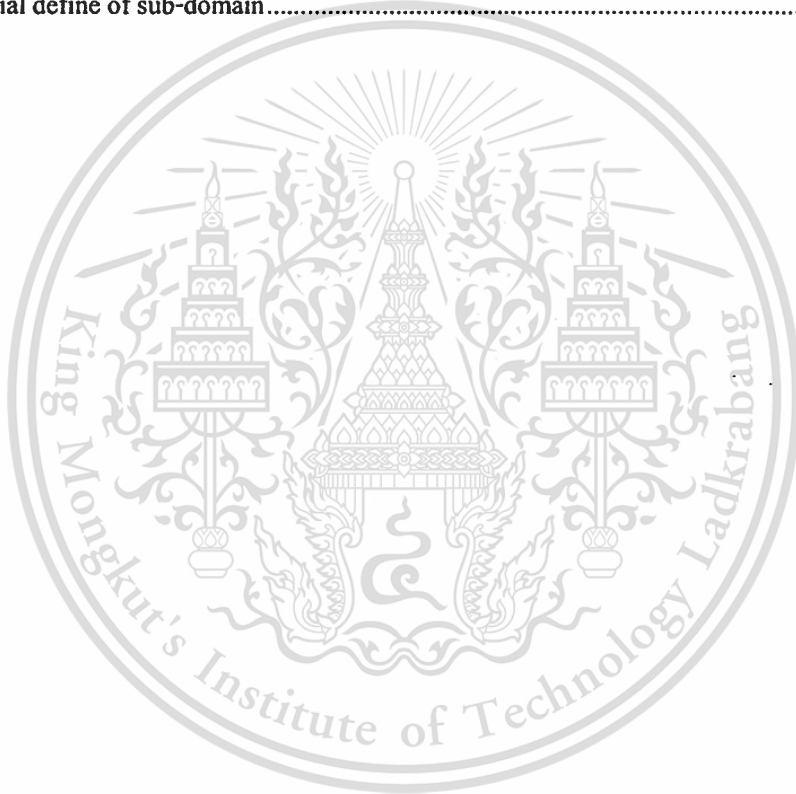
Content (Cont)

	Pages
Chapter 4 Result and Discussion	38
4.1 Simulation result of solder joint shape without HGA LT.....	38
4.2 Experiment result of water droplet	41
4.3 Simulation result of solder joint shape with HGA LT.....	45
4.4 Validation of solder joint shape with HGA LT model	58
4.5 Simulation result of thermal distribution	61
Chapter 5 Conclusion	65
References	67
Appendix	70
Author Biography	74



List of tables

Tables	Pages
3.1 Sub-Domain setting of initial mode	24
3.2 Boundary setting of initial model	25
3.3 Sub-Domain setting of finally model.....	28
3.4 Boundary setting of finally mod	29
3.5 Geometry dimension of each model	31
3.6 Material define of sub-domain.....	35



List of figures

Figures	Pages
1.1 Hard Disk Drive component	1
1.2 Head Stack Assembly and zoom in Head Gimbals Assembly 2 heads	2
1.3 Head Stack Assembly and zoom in Head Gimbals Assembly 10 heads	2
1.4 APFA and HGA before assemble	3
1.5 Diagram of an ultrasonic wire bonding system	3
1.6 Feature designs for FCB and LT.....	4
1.7 Laser beam direction at bonding process.....	5
1.8 Good result after past bonding process.....	5
1.9 The result is not good after past bonding process.....	6
2.1 A molten solder spreading on a substrate	10
2.2 Computer generated images of aluminum droplet before and after impact.....	11
2.3 Solder patterns applied in this investigation	12
2.4 Droplet impact on an unheated surface droplet impacting	13
2.5 Contact angle on difference surface roughness of copper material	14
2.6 Contact angle and surface roughness.....	14
2.7 In-situ temperature measurement setup	16
2.8 Assemble locations between FCB and LT before bonding process.....	16
2.9 The geometry model of FCB with pre-solder and LT key hole.....	17
2.10 Show detail of component layer at LT and FCB	17
2.11 The Level Set function at difference time.....	20
2.12 Show direction of laser beam attacked on Pre-Solder	21
3.1 Model navigator of level set Method	23
3.2 Geometry of Initial model.....	24
3.3 Experimental apparatus for the high speed video for water droplet	26
3.4 Overall dimension of HGA LT	27
3.5 A dimension details of HGA LT and FCB	28
3.6 Geometry of finally model.....	28
3.7 Factorial design of variation value.....	30

List of figures (Cont)

Figures	Pages
3.8 Model navigator of general Heat Transfer	33
3.9 Geometry and sub-domain of general Heat Transfer.....	34
3.10 Sub-domain setting of general Heat Transfer	34
3.11 Absorption of X- laser in material	35
4.1 Meshing result of solder joint shape without HGA LT model	37
4.2 The traces of solder joint shape without HGA LT at the stated time.	38
4.3 The experiment results of Water droplet experiment	40
4.4 Comparison of high between water droplet and simulation result	41
4.5 Comparison of spreading area between water droplet and simulation result	42
4.6 Comparison of wetting angle between water droplet and simulation result.....	43
4.7 Meshing result of joint shape with HGA LT model	45
4.8 The traces of solder joint shape with HGA LT at the stated time.....	45
4.9 Comparing of solder high result between with and without HGA LT.....	48
4.10 Comparison of solder spreading area result between with and without HGA LT	49
4.11 the Wetting angle flow direction result of with HGA LT model.....	50
4.12 Comparison of solder wetting angle result between with and without HGA LT	51
4.13 Show the perfect liquid t solder mass movement on HGA LT.....	52
4.14 Dependence time liquid sliders mass movement until hit the edge of Polymer Layer.....	53
4.15 Main effect plots for final height of solder	55
4.16 Main effect plots for spreading area	55
4.17 HGA LT and FCB before cross section	56
4.18 Cross section of specimen.....	56
4.19 Zoom in cross section of specimen.....	57
4.20 Simulation result at the gap between HGA LT and FCB equal 0.045 mm	58
4.21 Comparison of cross section result and the result of solder mass movement dimension	58
4.22 Mesh result of hest transfer model mesh consist of 1858elements.....	59
4.23 Temperature distributions contour of laser beam	60
4.24 Temperature power profile of laser beam.....	61

List of figures (Cont)

Figures	Pages
4.25 Temperature power incident trajectories at pre-solder surface.....	61
4.26 Dependence of power level HGA LT.	62



Nomenclatures

Latin capital and lowercase letters

ρ	Density (kg/m^3)
u	Velocity (m/s)
p	Pressure (Pa)
F	Gravity force
C_p	Specific heat capacity at constant pressure ($J/(kg \cdot K)$)
T	Absolute temperature (K)
k	Thermal conductivity ($W/(m \cdot K)$)
Q	Contains heat sources other than viscous heating (W/m^3)
ϕ	Level set function $\phi(x, t) = 0$
x	Area coordinates
HSA	Head Stack Assembly
APFA	Actuator Pivot Flex Assembly
FCB	Flex Circuit Board
HGA	Head Gimbals Assembly
LT	Long Tail

Chapter 1

Introduction

1.1 Background and Significance of the problem

The modern technology for electronic device connection within Hard Disk Drive (HDD) for and the near future are far more in complexity and smaller which cause of the two forcing factors they are the products of HDD and digestion criteria is to prepare the new procedure to assembly all devices together and also encourage high capacity hard disk products which more 2 terabyte. First topics for which we have to give more consideration is the connecting of all fraction devices for signal launch. It must be low resistance and gratifying bandwidth together .



Figure 1.1 Hard Disk Drive component

Figure 1.1 shows HDD and its component when the cover is open the highlight and obviously parts as such case is the black square box which protect and supported all compartments within, Disk is a big brown circular plate on which data is storage. Head stack assembly taper to a pointed triangle which is colored white, It holds the reading head and writes all data in the disk and VCM half circulate plate like, if will control the moving of H SA on the disk

When the size of HDD is small size the other compartment is also smaller by design. The compartments as such read and write heads while there are in the same properties or better the more reading heads means less of the area between connector which smaller than the old ones. These make more complexity for the works of assembly.

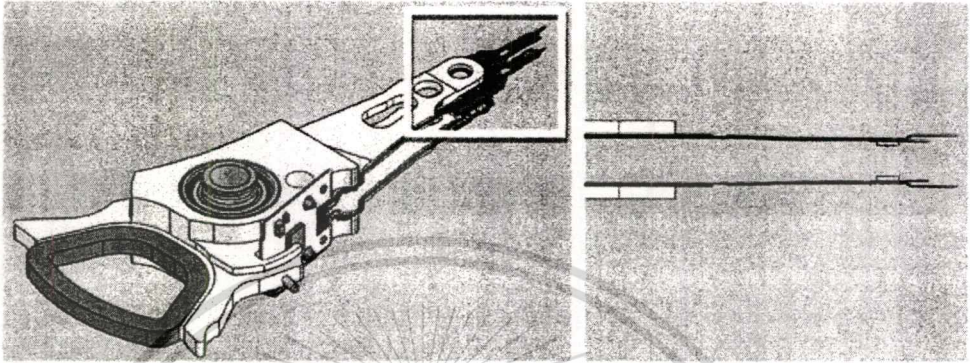


Figure 1.2 Head Stack Assembly and zoom in Head Gimbals Assembly 2 heads

Figure 1.2 shows the H SA, the original design HDD Technology which is not the same complexity that show H SA feature at left side of figure. The quantity of HGA has only 2 heads that show the head feature at right side of figure

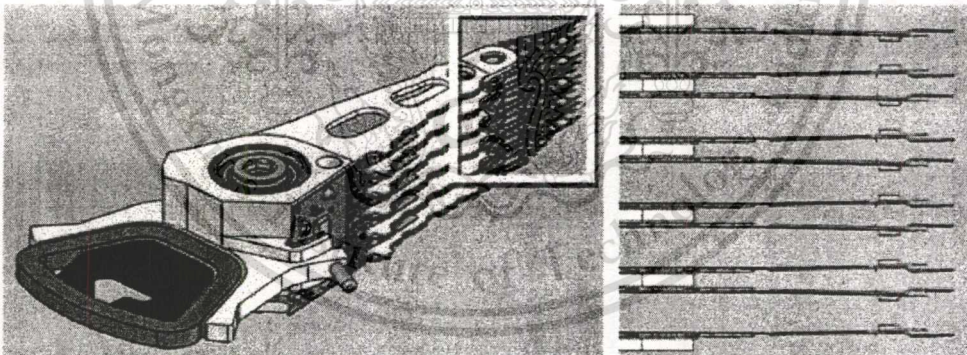


Figure 1.3 Head Stack Assembly and zoom in Head Gimbals Assembly 10 heads

Figure 1.3 shows the H SA, the modern design with far more complexity that show H SA feature at left side of figure. The quantity of HGA has an addition of 10 heads that show the head feature at right side of figure In designation, There are a number of compartments but with the size of APFA and its density are still not different, thus if must be redesigned in order to size smaller HGA, where its properties are in the same.

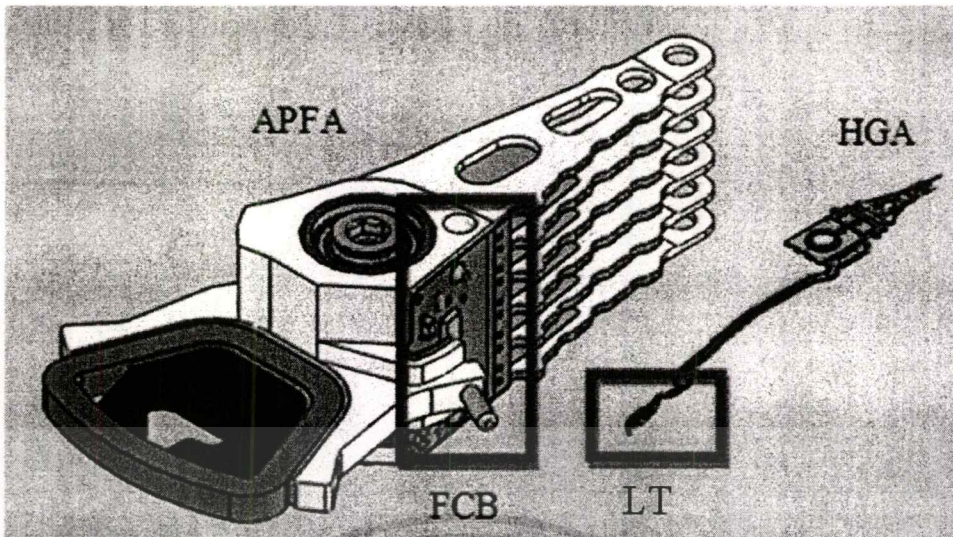


Figure 1.4 APFA and HGA before assemble

Figure 1.4 shows the APFA and HGA, Assembly of the two parts by the procedure called Swaging process and then, It shall be into banding process in order to conjoin the FCB (Flex Circuit Board) where a piece of APFA, to couple with long tail (LT), which is a tail of HGA

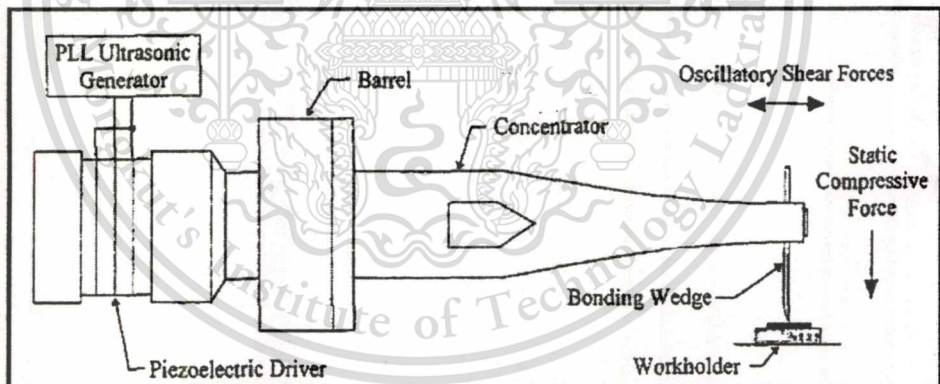


Figure 1.5 Diagram of an ultrasonic wire bonding system [1]

Figure 1.5 shows the diagram of an Ultrasonic wire bonding system. The observation of its workings are considered, the work piece to be bonded, will be placed on the workholder, in these research, the bottom of these work pieces will be FCB and lay down on it with LT, then pressed with bonding wedge. These pressing forces are called static compressive force, while LT will be crushed with shake forces called oscillatory shear force to generate from piezoelectric drive and transfer force by concentrator.

The bonding materials that fixed a piece of FCB and LT are pieces of small and tin brass. This bonding procedure was in the production epoch called bonding process. As said above, the modern procedure is ultrasonic wire bond and pressed the ceramic pin (Bonding Wedge) on goal layer at LT where placing on the FCB. When the sheer force and compressive force at the end point of the banding wedge shall hit and rubbed together, then it's a cause of heating on its surfaces and melting to each other's (See in figure 1.5)[1].

Changing in designer of LT and became smaller, The following results are able to place LT on FCB, better than the old pattern, while there were in the same expanded of FCB. There changing could be responsible to the high capacity of HDD. The smaller of LT wide and reformations, itself then could be utilized the primeval bonding called ultrasonic wire bond, any more.

From the study of bonding development for LT and FCB by using of the media substance, the is lead bonding, it became the moistest popular substance in electronic factories, Using of laser in bonding process are performed by laser for bonding formations (See figure 1.5) There concept is to use high challenge and geometrical corroborate of LT. The importance of the aments of banding and laser, is that the operational factors for the new bonding process shall be better.

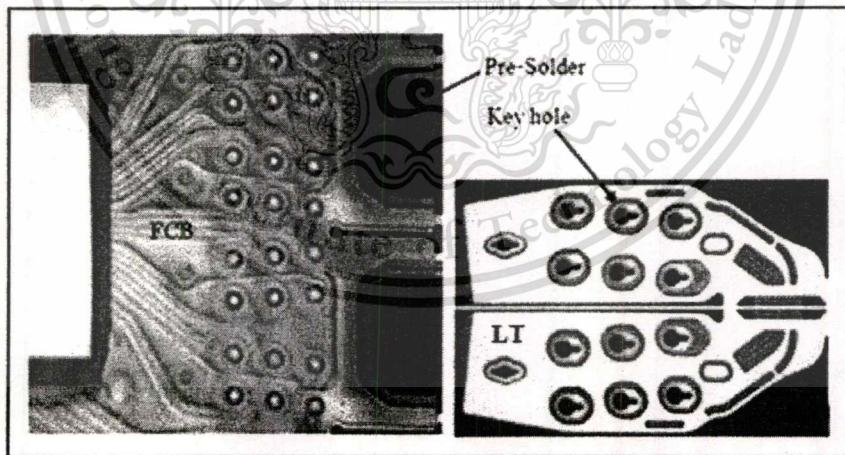


Figure 1.6 Feature designs for FCB and LT

Figure 1.6 shows the picture of the real FCB and LT, before assemble. On the left side is the FCB where installed with APFA, The procedure of assemble can see in figure 1.4 as seen in the picture, the dots are pre-solder, It comes with FCB. On the right side it's LT, where a tail

pieces of HGA, and can see its position from figure 1.4. And the hold as seen, called key hole. It will be used with pre-solder, as seen in the left side of figure 1.7.

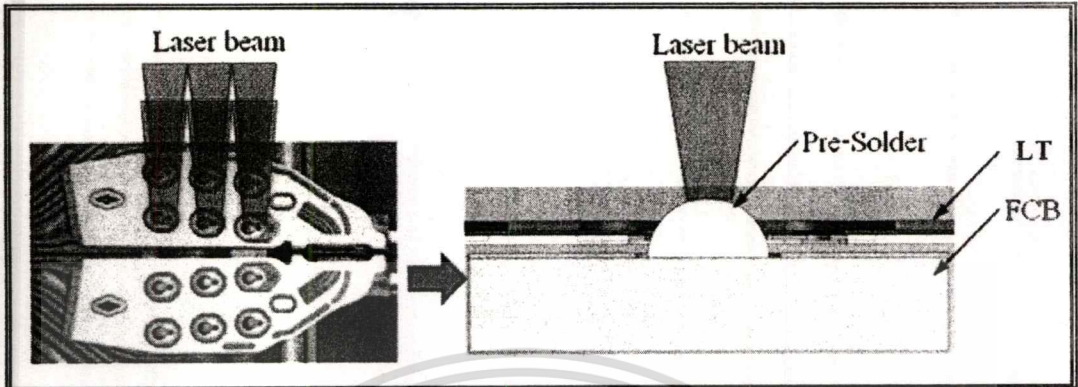


Figure1.7 Laser beam direction at bonding process

Figure 1.7 shows the assembly of FCB and LT before bonding process and refluxing position of laser beam. In the working duration, on the left it shows the real component part after assemble and location of laser beam. On the right shows it the detail of FCB and LT layer after assemble.

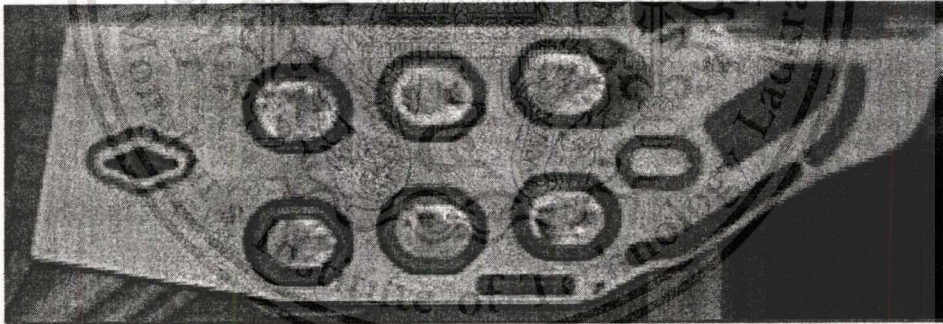


Figure1.8 Good result after past bonding process

Figure 1.8 shows LT and FCB after past bonding process by laser beam. The result is good well because of perfect melting of pre-solder, where seen from the flat plate of solder joint after Solidification and disperses in specific areas, the layer of leads where placing and covering on the key hold in gratifying volume, not reach the outer rim, which is made of a stainless steel layer.

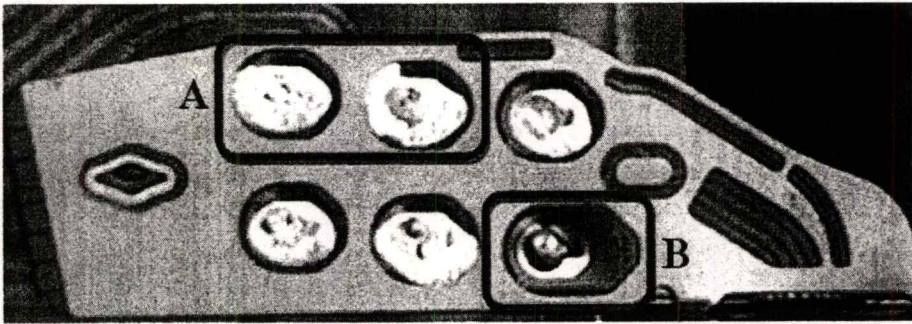


Figure 1.9 The result is not good after past bonding process

Figure 1.9 shows LT and FCB after past bonding process by laser beam, the result is not good, from figure 1.9 we found issue for two cases, first, the dispersion of lead layer was not in an undesirable areas, it reached the outer rim, which is made of stainless steel layer with. It would be the cause of short circuit issue. (See in figure 1.9 A marking) Secondly, Solder joint melting was not complete .It would be the cause of circuit not connect issue. (see in figure 1.9 B marking)

The primary assessment of solder joint, firstly (See figure 1.9 A marking) we can divide it for two parts, they and temperature consideration in melt with acceptable period. The main topics are also capable melting of bonding leas which not burn the other layer of LT [5]. Component part means also the control of volume of Pre-Solder by examine of height and width of its basement from the result. It might consider that there were over of solder volume, the second problems (See in figure 1.9 B marking) as in the same leys, If divide it for two parts, they are melting process, a position of laser beam where's not pointed in the centre of Pre-Solder, then there're not heating anymore and also not melting. It must be preciously controlled to the real points. And might be cause of punctuation between laser focus and pre-solder, was not in the right position of working range, thus have to be well control all focus length in the period of bonding. Component part from the result might be from the less of solder volume the layer lead cannot flow into the key hole of LT, in order to cover it. With these two problems, the patterns of lead layer in dispersion after bonding process were changing in an unacceptable pathway which undesirable by their process.

The Study of final of solder joint shape, after join or mend with solder could be practices by cutting at the solder point and inspection with high power microscope, due to not inspected all internal structure with natural human eyes, by all means these transaction must have highly cost and time consumption.

Model formation by computer program is another ways to prediction all aspect of solder joint shape after past bonding process and also prevailing method which decrease time and cost. This study was exploited COMSOL software to operate the model inquiry. Which divide into two parts, Firstly the modeling of solder joint shape prediction by use of the level set method, And when using of simulation result to analyses for solder joint shape predication of solder It's also describe another factors which affected to the solder joint shape in final stage. Second model is thermal distribution.

Within HGA LT, there are only laser studying in bonding area. The result of these examine for heat transfer from laser beam, The original sources, which sufficient power enough to melt per-solder with acceptable condition with in the Transformation periods form liquids into solid. Consideration form the following parameter, there are temperate and melting time. We used general heat transfer of COMSOL program in order to analyze heat transfer's problems of LT and FCB

1.2 The aims and objectives of the study

1. Establish 3D simulation model, by reference with the real size of works in order to predictions the shape of pre solder after melts and became solid.
2. Establish 2D simulation model in order to study systematic temperature which affected to the change of pre solders shape.

1.3 Hypothesis

1. The simulation model which used the level set method capable to predict the final solder joint shape after past bonding process.
2. The simulation model which used the level set method exposes the gratifying volume of pre solders and also uses this value as a standard control of pre-solder.
3. The simulation model which used the general heat transfer capable to clarify acceptable temperature and time from the real situation, with in the step of bonding process.

1.4 Theory or concepts used in this study

In this studies, Level set method shall predict the final shape of coupler and also study all factors which affect the process of bonding which well developed for scrutinize the evolution of bonding properties at the surface that means ability of changing explain in case of, could not specify the different list or anything else. The highlights of geometrical properties of the surface which can be directly calculate from vertical functions. Due to the pattern of beat transfer within HGA LT and metal sheet solder the examiner of power transformation rate in term of heating which establish within. It might occur between the two systems or between one's system and environments, when there were different in terms of temperature. It no need have to transfer to be a thermal power or several type of it when the different of temperature in the system caused the power up from beat transfer from high temperature to the laser. At the slope temperature where derived from the dispersion of temperature. And when the dispersion of temperature are recognized, It could be searching for heat transfer rate. There are 3 types of Thermal exchanges, heating transfer by the law of Fourier, heat conductions. Law of Newton, release and remove the heat by prostrate of thermal radiation Law of Stefan-Boltzmann.

1.5 The Scope of research

1. Establish 3D and 2D simulation by model COMSOL program this design have to reference with the real size of works.
2. Experiment of 3D simulation model by Level Set Method.
3. Experiment of 2D simulation model by General Heat Transfer.

1.6 Thesis Structural

This thesis is divided into content, which consists of 5 chapters.

Chapter 1. Background and Significances of the problem

Chapter 2. Theory and Literature review

Chapter 3. Modeling setup

Chapter 4. Result and Discussion

Chapter 5. Conclusion Acknowledgement

Chapter 2

Theory

This study examined the physical of behavioral change on the surface movement If is vary requisites to concurrence the environment which affected to the physical change, either the changes which acceptable or not analysis of the variables which affected to the moving of liquids, is the most prevailing procedure with the basically to the change which abundance result, thus manage and controls these result then we can definite the changes into the acceptable pathways and all these occurring were measure for the concluded results.

With these basically practices shall be apply within this study, in order to analyses the variables which affected to the alteration of liquid solder. A piece of read and write heads which a part of HDD Form bonding process by solder joint. The results of the study indicated that there are many topics where couldn't clarified with the external aspects as such liquid solder dispersion in melting periods and shape of solder joint on the bottom side of LT after solidified. And finally interesting are thermal transferring within the LT.

2.1 Literature review

The Study begins with studies the other qualified and completely researches for implementation of the approved studies. This study used and apply the families researches. Next mention of literature reviews have underscored the perspectives of studies in this research and also pleasant to comprehend by the reader this study also clarity the above 5 researches in details, as following.

2.1.1 Research of Y X. Gao. *et,al* [2]

Present solder profile with two factors those are surface tensions and gravity field by the principle of kinetic law. In order to predict the physical change of molten solder and, also basically to predict the physical change of solder it was recommended to examine the wetting angle and spreading area. And the both changes were depending on time, and also influence to solder shape and movement at the linkage of solid, liquid and gas, which move the surface tensions and gravity field.

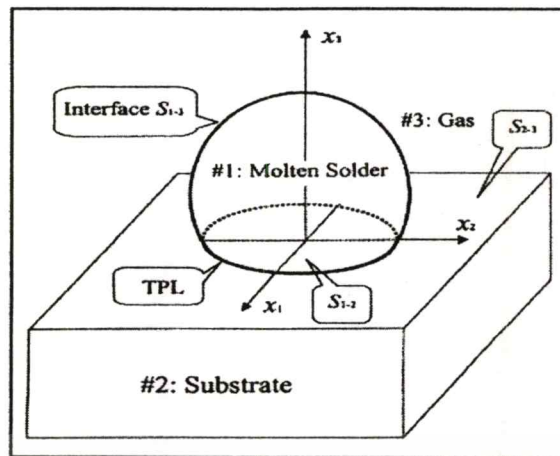


Figure 2.1 A molten solder spreading on a substrate [2].

Figure 2.1 shows the elementary dispersion of liquid solder on the surface. The three materials appear in this picture # 1 Molten solder # 2 Substrate and # 3 Gas Interface meaning is jointing point between three materials solid liquid and gas.

Solder profile could be calculated by arithmetic method by comparative changing approach of wetting angle and spreading area in different time. It indicated that the step of dispersion of soldering leads at first shall be quickly disperse and then slow down profile where's not symmetry in dispersion with the principle of Kinetic Laws, that is the study of changing behavior for two factors. Firstly, solder profile is solder height when considerate from simulation result, from the highest point and then decrease. Second, the movement at the linkage point of TPL that is continuous decreasing of wetting angle and rush-up till the lowest point, thus, It's continuous constant.

2.1.2 Research of Tanai L. *et, al.*[3]

It is the best example and coincidence with this research, because they're establishing his stimulation model by COMSOL program, in order to predict the dispersion liquid aluminum on the face of stainless steel. 2D study were occurring, in symmetrical axial by level set Method, to explain the motion of free surface in the state of liquid and used COMSOL to study convection and conduction heat transfer for dropping of liquid aluminum on the surface of stainless steel.

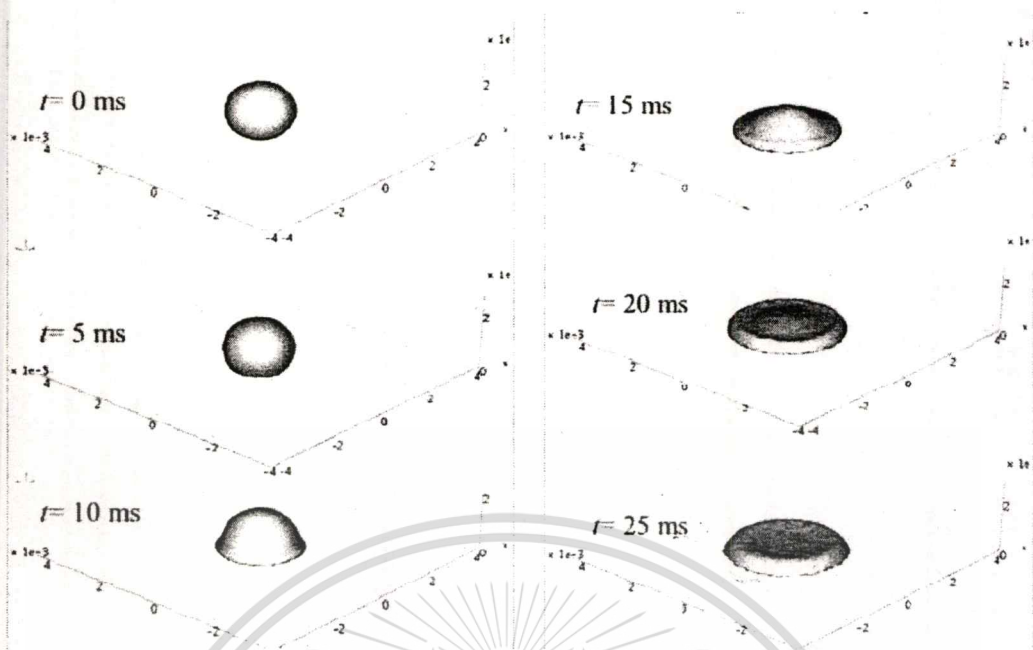


Figure 2.2 Computer generated images of aluminum droplet before and after impact [3].

Figure 2.2 shows the result from simulation model for shape prediction of aluminum droplet on an experimental time, from zero to 25 mill-Second (ms), gathering form the span of time, at 5 milli-seconds (ms). The dispersion of aluminum liquid is visible at the three axial (x,y,z) a circular shape which trends to be bigger from the origin and reach the biggest point at $t=25$ ms. By the lay , the changing in Z axial, Originated from the highest point at $t= 0$ ms. It means the circum diameter of aluminum droplet shall be decreasing and run to the lowest point at $t= 25$ ms

When considerate the result from Tanai L. et, al. In summary, COMSOL could be predict the shape of dispersion of aluminum droplet on the surface liquid aluminum droplet on the surface of stainless steel, but need have to rectify on boundary conditions at the interface such as the contact angle between the liquid and the substrate

2.1.3 Research of Kwang-Lang Lin et, al. [4]

They present the study of leads soldering linkage. The topics, they'd concerned with were the solder thickness and spreading area after soldering process. The factor which affected to both topics are the reflow of temperature, solder volume, Soldering forces and location of devices where installation on substrates.

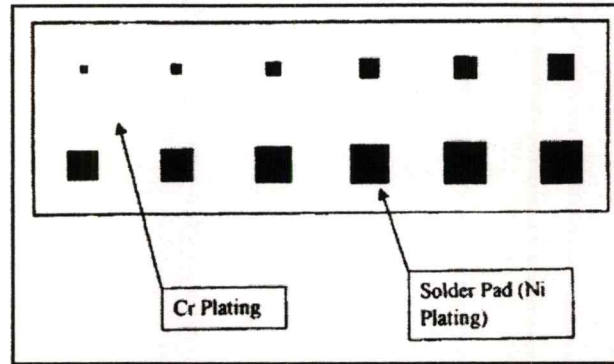


Figure 2.3 Solder patterns applied in this investigation [4].

Figure 2.3 shows the experiment of solder pad for width 5 cm long 12 cm. material is copper alloy. To made square hole dimension is 30 x30 micron until 150 x 150 micron. The depth is 100 micron totally 12 holes

In experimentation, apply 95Pb – 5Sn of leads and melting by controlling temperature at 330-360°C. With 4 steps, drop the liquid leads on the silicon sheet where's already bore different 12 holes, which out on copper alloy plate with nickel as a substrate. The amount of droplet liquid leads were 0.005-0.020 ml with 4 levels, for 10 times and measured a solder thickness of each points, then used these thickness data of each experiments to find the means of each point. It's about 10% approximately. These results indicated that there was no changing in the shape among the solder thickness, especially in the small areas. Because the gravitational forces are far more influence than the surface tension of soldering leads and solder thickness where derived from solidified of leads were relatively with the areas of the holes [4]

The information which Kwang-Lung Lin. Et.al presented should be regulated and concurrence with this study there are;

1. The area of the holes on the sheet, when comparing with this study, it is polyamine layer on FCB.
2. The amount of leads which assed, comparing with this study, is pre-solder on FCB.
3. Size of the pattern, including with thermal changes, comparing with this study, is the temperature within LT which derived from laser beam, which used to melt the Pre-Solder.

2.1.4 Research of S. G. Kandlikar, *et,al* [5]

The present of this paper work and reports an experimental study conducted to characterize the contact angle variation as a function of the heater surface finish, heater material, and heater surface temperature prior to impact. It is seen that the dynamic advancing contact angle extends beyond the equilibrium advancing and receding contact angles during the motion of the interface. Since the droplet spreading is influenced by the dynamic advancing contact angle, it is proposed to use the dynamic contact angle measurements in the available models for maximum spreading ratio. The experimental results obtained on the maximum spreading diameter indicate the validity of this approach.

Objective of the research is the understanding of various phenomena associated with advancing and receding contact angles of a liquid-vapor interface, the present work focuses on experimentally measuring the contact angles at various stages as a liquid drop impinges on at heated surface. The effects of surface roughness, surface material, and surface temperature on dynamic advancing and receding contact angles are studied.

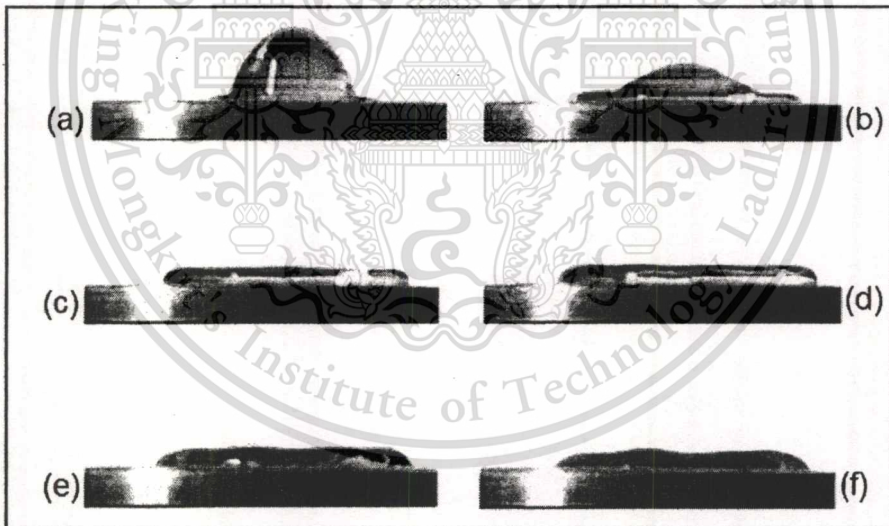


Figure 2.4 Droplet impact on an unheated surface droplet impacting [5]

Figure 2.4 shows droplet impacts on an unheated surface droplet impacting on three surface materials are copper, stainless steel, and the silver stone. The copper and stainless steel are both polished using the one-micron slurry.

They have a surface roughness of 0.0002 mm for the copper surface and 0.0001 mm for the stainless steel surface. The silver stone surface was tested using the factory finish with a surface roughness of 0.00135 mm.

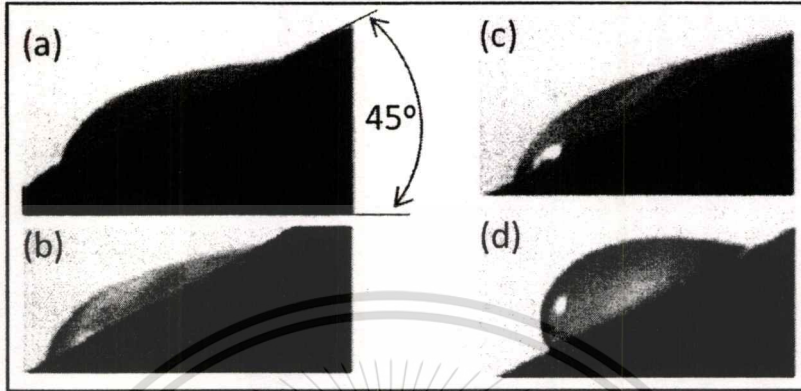


Figure 2.5 Contact angle on difference surface roughness of copper material [5]

Figure 2.5 shows experiment set up of contact angle on difference surface roughness. The droplet is gently placed on the surface using the needle. The advancing contact angle was measured on the downhill or left hand side and the receding contact angle was measure don the uphill or right hand side. To check whether the angle is the true advancing and receding angles, the surface is tilted further to 45 degrees. The angles remained nearly constant indicating that these are representative of the advancing and receding contact angles respectively.

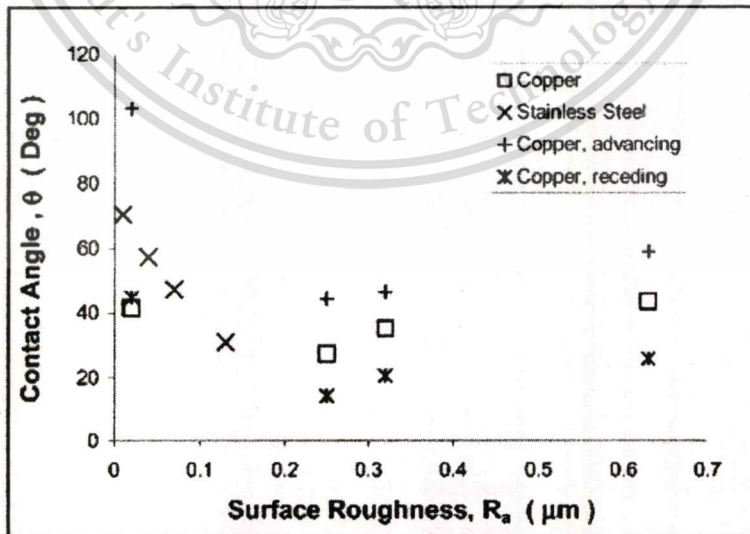


Figure 2.6 Contact angle and surface roughness [5]

Figure 2.6 shows contact angle and surface roughness equilibrium, advancing, and receding contact angles for horizontal unheated copper and stainless steel surface. These contact angles for different surface roughness values for copper surface.

The effect of roughness is seen to be important for advancing contact angles near very low roughness values. As the surface becomes smoother, the advancing contact angle becomes higher. For higher roughness values the contact angles seem to remain almost constant, although some increase is noted at higher roughness values. It is also noted from Figure 5 that the equilibrium contact angle lies somewhere between the advancing and receding contact angles. Since the equilibrium contact angle depends on the history of the interface.

One knowledge to interacting from this research is the effect of temperature on dynamic advancing and receding contact angles is seen only around temperatures between 140-150° C. At this temperature it is suspected that the rapid evaporation near the liquid-solid contact region influences the dynamic contact angles and both dynamic advancing and receding contact angles become almost equal to each other. The experimental results show that the dynamic advancing contact angles are significantly higher than the equilibrium contact angles. Furthermore the equilibrium contact angle is not a unique measurement as it can vary between the static advancing and receding contact angles. Since the spreading phenomenon is affected by the actual dynamic contact angle. It is recommended that this value be used in the modeling of spreading characteristics of impinging droplets.

2.1.5 Research of Tamas Hurtony. *et,al.* [6]

This study presents the procedure of electronic devices linkage by laser soldering, Familiar with our study. Due to the linkage of small and complex component parts thermal controlling which derived from laser beam to get along with the need is very important for bonding. The main factors which have to pay more attention is the temperature from laser beam, it must be standing on the gratifying conditions. Due to the different of melting point for component part and solder as a media of conjoining at approximately 100 Celsius thus the main topics which have to regard in laser soldering process ware solder melting and no burning at another component part. These researches used finite element method to establish the simulation model. To study the temperature distribution of solder structure by considers from reflection, absorption and transmission a well as the Gaussian energy distribution of the laser beam. Design upon which this experiments used the properties of ND: AG Laser (Wave length 355 nm). Type

of determination for simulation model of laser beam, for the role of solder parameter was based on plus energy average power, soldering time and laser beam intensity. Temperature distribution result from simulation model compared with the results of the real temperature where measure by the pyrometer.

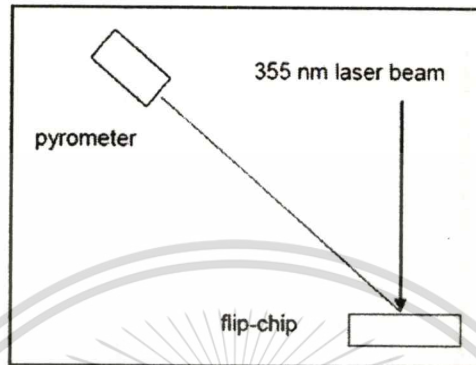


Figure 2.7 In-situ temperature measurement set up [6]

Figure 2.7 shows temperature measurements by pyrometer on flip chip surface the origin of heating power is laser beam at wavelength 355 nm. The arrowhead in seams focusing points of laser beam and also the measuring point of pyrometer these studies were highly reliability, due to its simulation model can works well and acceptable predicts the temperature distribution and also supported the measure of suitable heating for the real working and validated the result form simulation model with experiment by compare temperature from the result form simulation model with experiment by comparing temperature from the results it was apparent that they were indistinguishable trends of changing, thus it support and confirm the efficiency of the model

The other researches as mentioned above was utilized and could verify the establish of simulation model by COMSOL programs 3 in modes of level set method to predict the solder shape after past bonding process.

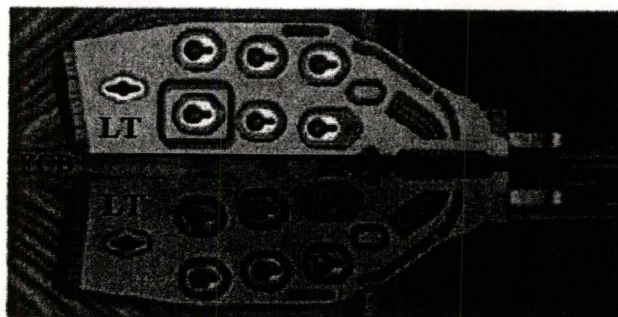


Figure 2.8 Assemble locations between FCB and LT before bonding process

Figure 2.8 show the assembly between FCB and LT before bonding process at red box marking on figure. It is weighty points between FCB and LT. Pattern of liquid solder in distribution were in the same ways, then single point manipulate was utilized to establish simulation model and also behavioral analyze, to make clear and uncomplicated to conceive by the readers. As exhibit, the area of FCB with pre-solder and FT key hole at figure 2.9

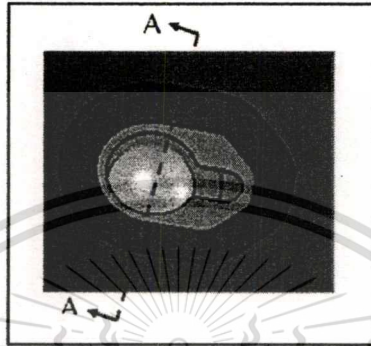


Figure 2.9 The geometry model of FCB with pre-solder and LT key hole.

Figure 2.9 show the model at FCB with pre-solder and LF key hold, which could be looking for more details of component part that associated with FCB and LT and know , what's compost within form figure 2.10 cross section through A-A section.

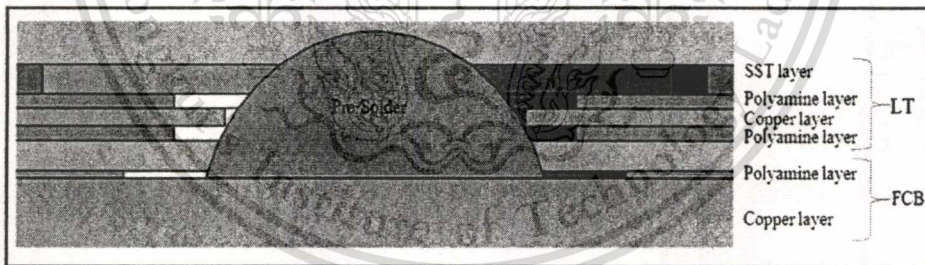


Figure 2.10 Show detail of component layer at LT and FCB

Figure 2.10 show a detail of component part layer at LT and FCB. By the way, LT constitute with 4 layers, from upper to lower. The first layer is stainless steel for strengthens of LT. second signal transit and polyamine layer for electronic insulation. Second is copper layer for electronic signal transit and Per-Solder, an intermediate media which used as a coupler between FCB and LT

Form the literature reviews; it shall explain the all theories by computer programs that are COMSOL 3.5. There were relatively factors, first is fluid flow. It's illustrating the flowing

patter of liquid solder, by the equation of Navier –Stoke [6-7] second is level set. It will explain the change of contact surface or the linkage between the three materials, there're liquid, solid and air [8], Liquid, in the case means Liquid Solder which movable or dispersion on the solid surface. They are FCB and LT. The last is heat transfer; it will explain the energy transfer, where in temp of heating within the system. It is constitute with laser beam, the origin, and thermal transfer by distribution on the surface of Per-Solder [2]

As mentioned above the theories reveal the perspective of this study and facilitate to understand the four theories in details.

2.2 Fundamental of Fluid flow

The Study of variables which affected the change of environments. It could let to predict the possibility of changing levels. As in the same way, If we're don't want to change, it must be well control the variables which the causes of these change.eg. The motion of liquid, the variables is a solid as such surrounding surface, and also the air around. Each variable shall have got its properties, itself, thus necessary to learn what it could be controls and then controlling them as in this research, it has been studied the calculation principles of Fluid Flow, With the equation of Nervier-Stokes. The main reason is, to use this equation of to make concurrence with the equation of COMSOL Program. This research, also studied the variables which affected to the flowing rate of Liquid solder on the surface of FCB and LT, firstly, the dispersion of liquid solder could be measured from its height and areas of disperse. In this study flowing solder of liquid and surrounding gas, as seen in figure 2.10, the areas around pre solder are empty, then liquid solder and air can be moving around, thus simulation model were established in order to study the motion behavior of liquid-solder and gas, Where reference from the flowing equation of incompressible laminar flow [6-7]

$$\rho \frac{\partial u}{\partial t} - \nabla \cdot u (\nabla u + (\nabla u)^T) + p(u \cdot \nabla) + \nabla p = F \quad (1)$$

$$\nabla \cdot u = 0 \quad (2)$$

From equation 1 and 2 ρ is the density (kg/m^3)

u is the velocity (m/s) is time (s)

p is the pressure (Pa)

F is gravity force

From first equation we can explain in four separate parts. First part $\rho \frac{\partial u}{\partial t}$ meaning is accumulation of moment per unit volume. Second part $\nabla \cdot u (\nabla u + (\nabla u)^T)$ meaning is shear stress. Third part $p(u \cdot \nabla)$ meaning is rate of momentum. Fourth part ∇p meaning is pressure force. Last part F meaning is gravity force.

In summary, the study used Fluid flow to contemplate behavioral motions of Liquid solder on the surface of FCB and LT.

2.3 Fundamental of Level Set Method

The second theory is level set method. The cause of this study was for the need of coincidence with the operating equation for COMSOL Program. This study examined the variables which affected the solder joint shape after past bonding process, that's the continuous results of Liquid's motion. It said the shape of pre-solder to be changed liquid by laser beam and turn back to solid again. Level set Method is numerical techniques which development to study the evaluation on interface of surface. The highlight is capability to specify the change of contact surfaces, in case of unable to explain with another procedures such as the broken of contact surface or combination of contact surface. Another highlight is geometrical properties of contact surface which directly calculated from level set function such as the right angle direction to the contact surface which derived from equation 3 [6-7]

$$\frac{\nabla \phi}{|\nabla \phi|} \quad (3)$$

Figure 2.11 Changing of t time. Position of contact surface was prescribed X value and then,

$$\phi(x, t) = 0 \quad (4)$$

Where ϕ level set function and x is an area coordinate

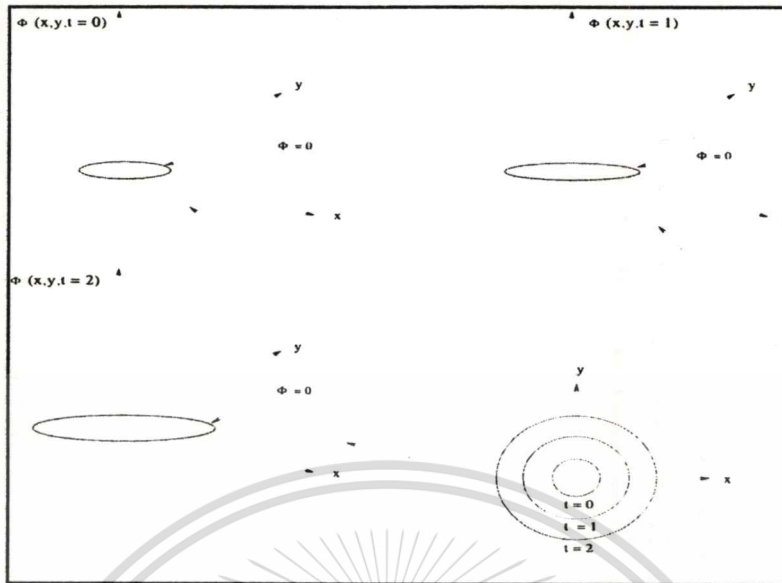


Figure 2.11 The Level Set function at difference time

Figure 2.11 shows a level set function at difference time with chain law and equation 3-4, then level set equation obtain

$$\phi_t + F |\nabla \phi| = 0 \quad (5)$$

Where F is motion velocity of contact surface.

In summary, the study used level set method to predict the final shape of solder joint shape after past bonding process.

2.4 Fundamental General Heat Transfer

From the last theories, the motion on the surface of liquid solder can be analyze the behavioral motions by the equation of navier-stokes and solder joint shape after past bonding process. It can predict from level set method for the both methods provided the hypothesis as the situation which occurring in the melting periods of slider. It means liquefying to liquid at the optimum temperature, but in practice it could not be 100% at all time. In this case, the thermal energy means laser beam. Position and direction of laser beam on pre-solder were illustrated in figure 2.9

The study of heat transfer's theories was a result of coincidence in purposes with the calculation of COMSOL Program, in the same way this research examined the variable which affected to the melting of soldering at bonding process.

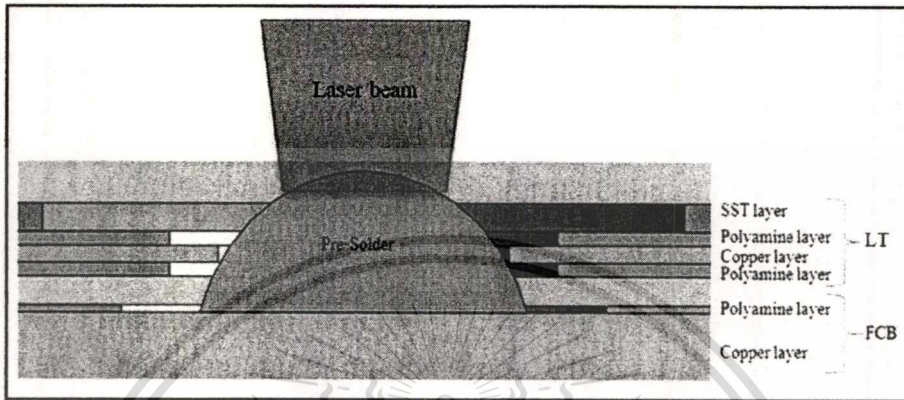


Figure 2.12 Show direction of laser beam attacked on Pre-Solder

Figure 2.12 shows direction of laser beam attacked on Pre-Solder and component part layer to prevent light reflex on other materials. If necessary to regulate the positions and diameter of light .By the Hypothesis. Laser beam diameter should be less than diameter of pre-solder and hole of SST, Polyamine layer (first and second layer of LT) form the model. It was found that the size of laser beams were smaller than the hold of SST, Polyamine layer, by the assumption.

This was the study of energy transfer in temp of heating which derivation within the system. It might be occurring between the both systems or within one system and environments when temperature were dissimilarity, without alteration of energy from high temperature to the lower, or another said, temperature gradient was created from temperature distribution. It shall be recognize the ratio thermal transfer per Area. Heat Transfer could be consideration for 3 examples there are induction Heat transfer by the law of Fourier conduction heat transfer, by Newton's law of cooling. Radiation heat transfer by the law of Stefan-Boltzmann.

Simulation model experiment by COMSOL Programs of this was utilized the temperature distribution. With applying the equation 6 to calculate heat transfer of the system

$$\rho C_p \frac{\partial T}{\partial t} + \nabla \cdot (-k \nabla T) = Q - \rho C_p \mathbf{u} \cdot \nabla T \quad (6)$$

Where,

ρ is the density (kg/m^3)

C_p is the specific heat capacity at constant pressure ($J/(kg \cdot K)$)

T is absolute temperature (K)

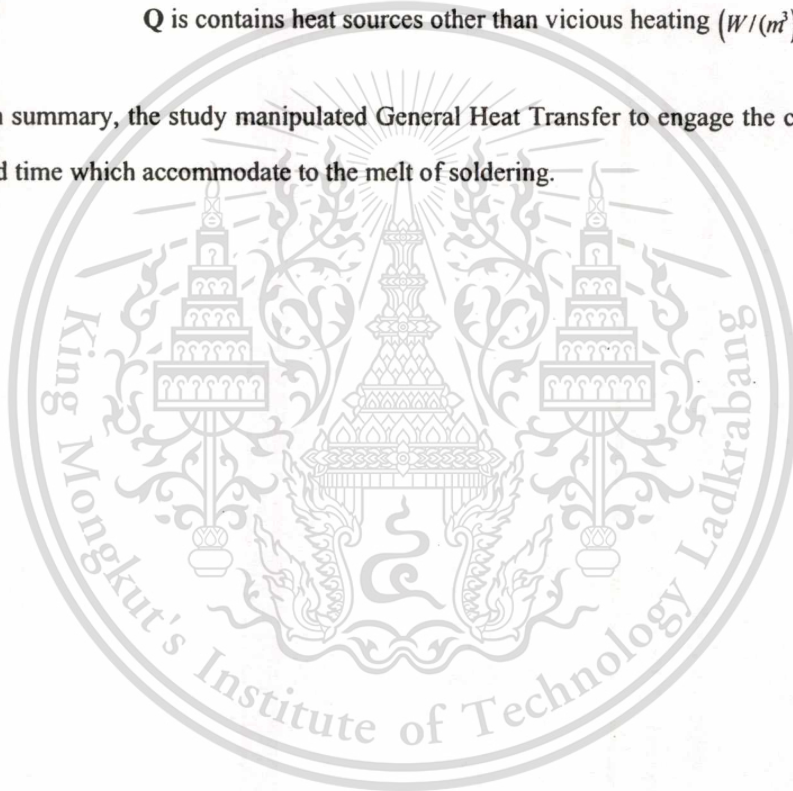
k is the thermal conductivity ($W/(m \cdot K)$)

\mathbf{u} is the velocity (m/s)

p is the pressure (Pa),

Q is contains heat sources other than vicious heating (W/m^3)

In summary, the study manipulated General Heat Transfer to engage the column of heat energy and time which accommodate to the melt of soldering.



Chapter 3

Methodology Set up

This chapter will illustrate all equipment and methods of experiment these experiments were classified for four where divided for several topics in order to make clear for the reader.

3.1 The modeling for solder joint shape without HGA LT

Firstly, experimentation was the establishment of stimulation model by COMSOL Program, by use of level set method mode to establish simple stimulation model the result from this experiment is the guideline to establish a perfect simulation model in the third experimentation, and use the result from this model to validate with the second experimentation in order to study the behavioral motion of liquids on the smooth surface. At the beginning by the level set mode, this could be set up as the following step.

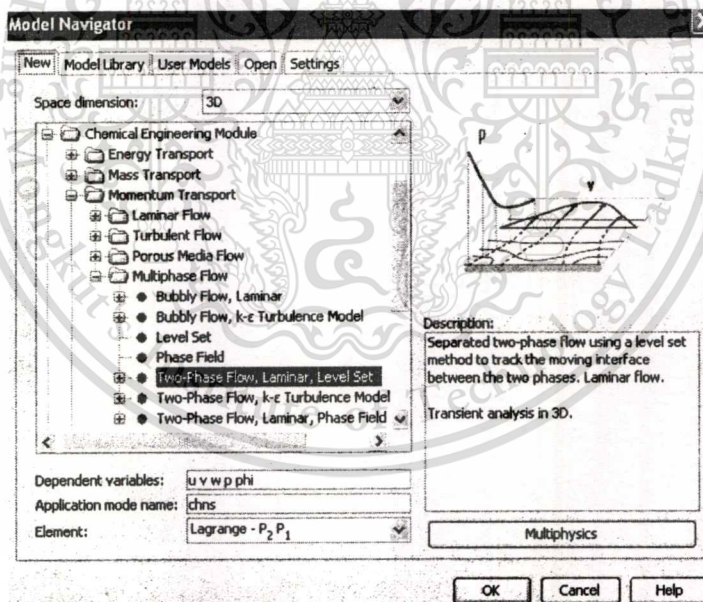


Figure 3.1 Model navigator of level set Method

From Figure 3.1 show model navigator of Level set Method we follows with step a two.

After that, continue to draw the model by used dimension (See figure 3.2-3.3)

- Go to the model navigator and select 3D in the space dimension list
- In the list of application modes, then open the COMSOL metaphysics

- Chemical Engineering Module
- Momentum transport
- Multiphase flow, on the list we select follows with as below
- Two Phase flow, Laminar, Level Set

c) Click to accept at multi physics bottom then click add bottom.

We have to separate two models for level set method. First is initial model for simulation guide line (see figure 3.5). The geometry including rectangle air room box (w-0.7mm-0.8mm, H - 0.25mm) and pre solder (dome shape 0.115mm) Second model is finally and the figure overview follow with figure 3.2 and 3.3

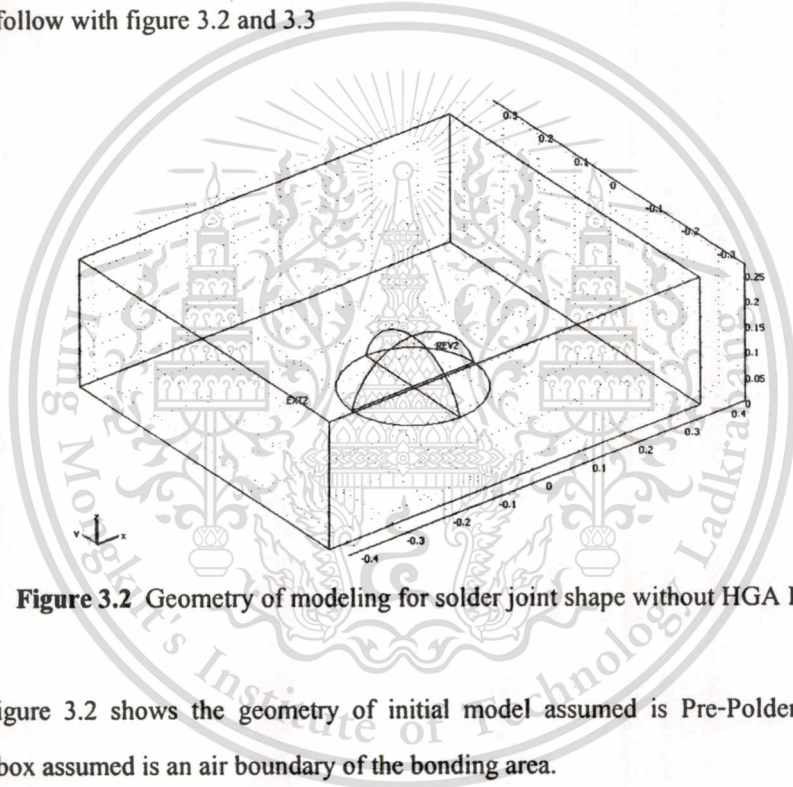


Figure 3.2 Geometry of modeling for solder joint shape without HGA LT

Figure 3.2 shows the geometry of initial model assumed is Pre-Polder on FCB the isometric box assumed is an air boundary of the bonding area.

3.1.1 Physical set up

3.1.1.2 Sub-Domain Setting

Table 3.1 Sub-Domain setting of initial model

Sub-Domain number	Material define	Initial fluid
1	Air	Fluid1
2	Solder, 60Sn-40Pb	Fluid2

Table 3.1 shows Sub-Domain setting of initial model which used for set up the model for this work, has two Sub-domain, first defines air and second defines solder

3.1.1.2 Boundary Setting

Table 3.2 Boundary setting of initial model

Boundary number	Boundary type	Boundary condition	Remark
1,2,5,14	Wall	Wetted wall	Vertical wall of four side
4	Inlet	Pressure, no vicious stress	Top wall
3,6,8,10,12	Wall	Wetted wall	All of bottom wall
7,9,11,13	-	Initial fluid interface	Surface of dome surface

Table 3.2 shows boundary setting of initial model used for set up the model all of them are 14 boundaries. We defined boundary by refer with the real situation which existence on bonding process lintel is the hydrostatic pressure; It gives the pressure at the inflow boundary. In this model setting to pressure, no vicious stress Wetted wall is the boundary condition. It's suitable for solid walls in contact with a fluid interface.

The expectation results of this experiment was the change of pre-solder in term of height, means the change of wetting angle. The results of this experiment will validate with the next experiments.

3.2 Experiment set up of water droplet

The second experiments are water droplets on surface by study of behavioral motion of liquids on smooth surface and then take these results to compare with the first experiment. This topic can explain by three characters, as following

3.2.1 Equipment of experimental

There are seven pieces of apparatus within these experiments, as by figure 3.3 the equipments have got their own responsibilities as follow.

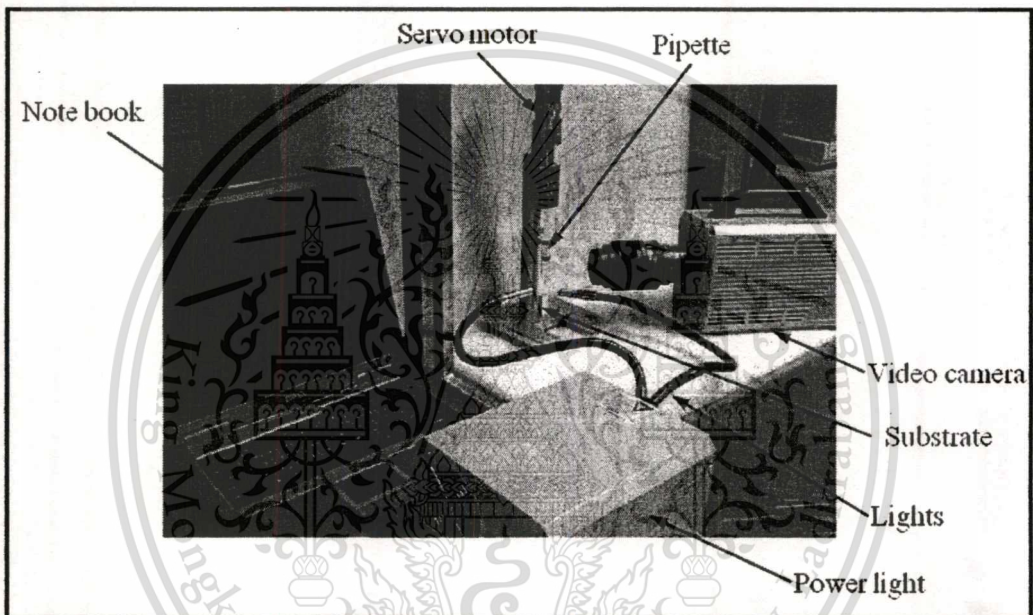


Figure 3.3 Experimental apparatus for the high speed video for water droplet

Servo motor with linear guide used bushing cylinder rod of pipette. We set speed of motor at 0.5 mm per second.

Transparency plastic pipette with capacity size 5 milli-lite. and with end point at 4 mm will make the same size droplet of latter.

Use stainless steel as a substrate with area equals 10 mm^2 of regular surface to support water droplet from the end of pipettes.

Video camera used to record the photo of water droplet this system is a high speed video camera which is able to record 60.000 shot per second.

Light make more luminous droplet especially at both sides of water droplet.

Manipulate the computer to manage motor and recording the video data.

Figure 3.4 shows the geometry of HGA LT bonding areas at section R-R is top view, Section U-U is under side and Details T show zoomed in at stop view of key hole, Details V that show zoomed in at underside of key hole including demission of geometry. In one HGA composed with 6 key holes, but in term of model forming. We used only one of them, for the behavior, where establish in bonding process as in the same way for the six portions, which its details of size will establish the simulate model where present in figure 3.5.

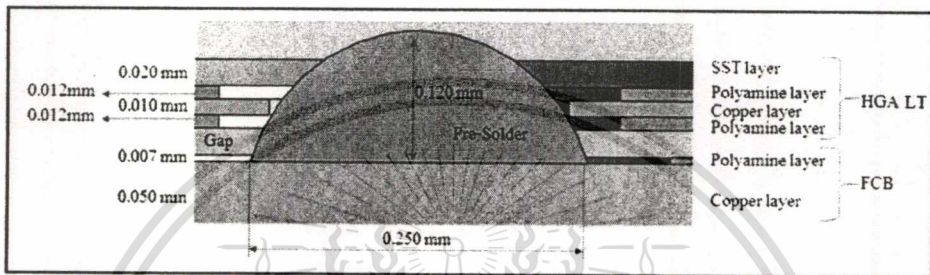


Figure 3.5 A dimension details of HGA LT and FCB

Figure 3.5 shows model in the region of FCB with pre-solder and HGA LT key hold which can be observed for more particular component parts which assemble with FCB and HGA LT. Cross section along the line of A-A Section reference from figure 2.11. And adding more detachment of density in each layer and pre-solder size which its details of size will be establish the simulate model where present in figure 3.6 .

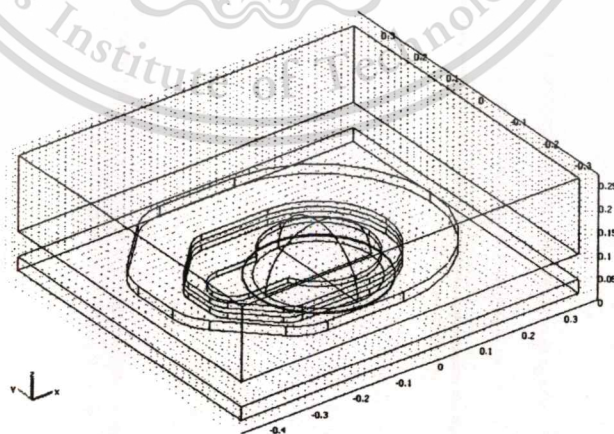


Figure 3.6 Geometry of modeling for solder joint shape with HGA LT

Figure 3.6 shows geometry of finally model assumed is HGA LT assembly on PBC. The entire geometry step key shape assumed to HGA LT. The isometric box on the key shape assumed is air boundary of the condign area.

3.3.1 Physical set up

3.3.1.1 Sub-Domain setting

Table 3.3 Sub-Domain setting of finally model

Sub-Domain number	Material define	Initial fluid
1	Air	Fluid1
2	Solder, 60Sn-40Pb	Fluid2

Table 3.3 shows Sub-Domain setting of final model used to setup the model. For this work has 2 Sub-domain. First defined to be air and second define to be soldered. (Dome shape in figure 3.6)

3.3.1.2 Boundary setting

Table 3.4 Boundary setting of finally mod

Boundary number	Boundary type	Boundary condition	Remark
1, 2, 9, 68	Outlet	Velocity	Vertical wall of four side
8	Inlet	Pressure, no vicious stress	Top wall
49, 51, 59, 62	-	Initial fluid interface	Surface of dome surface
Remaining wall	Wall	Wetted wall	-

Table 3.4 shows boundaries setting of initial model used for set up the model. All of them are 68 boundaries. We are define boundary by refer with real situation which occurred in bounding process wetted well is the wetted wall boundary condition it suitable for solid wells in contact with a fluid interface. It sets the velocity of component normal on the wall to zero. That is outlet is the pressure which equal to zero, it equal to the pressure at the top them in flow boundary. Because it is an out flow boundary we needn't have to set any condition on the level set function.

This material is reserved for educational use only, not allowed for commercial use.

Forbidden to modify the content, and cite the document when use.

In establishment of experimentation, In order to analyze the factors which affected solder joint shape after past bonding process? We used statistical transactions to from simulation model. That in the DOE (Design of Experiment) to make clear for all readers, to appreciate the meaning of DOE, we shall explain as briefly as we can. The primary purpose of DOE is to empirically encourage knowing what we should have to control the changing of each factors on its process in one process. There're a number of factors, one of them in we could not control it. Even so, it is a cause of a result which affect to the process, however, we sometimes have to neglect or let it go naturally. In experimental design we call these factors "NOISE" but some of them we could not let it change its nature, since it has more an effect to the process than noise. We must control the changing of these factors in the right position and period which less affect to the process, and we call it Key Process Input Variable (KPIV) after all, we also know the performance or sequence of the process by using the indicator, as in one process, it might be measured by one indicator or more. The method of measurement can be accomplished by devices which present continuous values called Quanta dative variable. And if we practice by counting and/ or ostentation which present non continuous values or qualitative variable by all means, We cannot measure the output of all process. Only the variable which represents the best effectives or results (Output) which occurring in the process we call this selected variables that" Key Process Input Variable (KPIV)

In bounding process Experimental design from deviation values which are occurring in production process of its component. There are five factors, where we used MINITAP Program in order to changes its value which could be occurring in the process of productions. We used Full Test in order to establish 32 simulation models (See in figure 3.7) and then, analyze the results and searching for the factors which affected to solder joint shape after pasted bonding process.

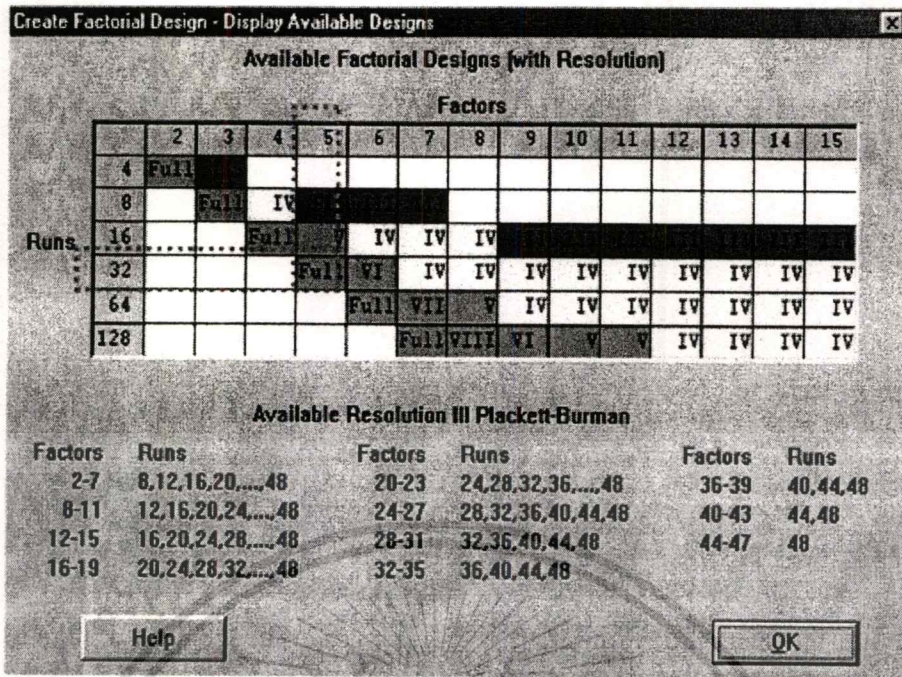


Figure 3.7 Factorial design of variation value

Figure 3.7 shows a guide line in conduct model where concentrate at solder high and density of each layer which affected to solder shape after past bonding process.

Table 3.5 Geometry dimension of each model

Tolerance& Model name	Solder high (mm)	Polymer layer On FPC (mm)	Polymer layer under copper (mm)	Copper layer(mm)	Polymer layer on copper (mm)
Nominal size	0.120	0.007	0.012	0.010	0.012
Negative tol.	0.115	0.005	0.010	0.008	0.010
Positive tol.	0.135	0.010	0.014	0.012	0.014
Model 01	0.115	0.005	0.010	0.012	0.010
Model 02	0.135	0.005	0.014	0.008	0.014
Model 03	0.135	0.010	0.014	0.008	0.010
Model 04	0.115	0.010	0.014	0.008	0.010
Model 05	0.135	0.005	0.014	0.008	0.010
Model 06	0.115	0.005	0.014	0.012	0.010
Model 07	0.135	0.010	0.014	0.012	0.010
Model 08	0.135	0.010	0.010	0.012	0.010
Model 09	0.115	0.010	0.014	0.012	0.010
Model 10	0.135	0.005	0.014	0.012	0.010
Model 11	0.115	0.010	0.010	0.008	0.014
Model 12	0.135	0.010	0.010	0.012	0.014
Model 13	0.115	0.010	0.014	0.008	0.010
Model 14	0.135	0.010	0.010	0.008	0.010
Model 15	0.135	0.010	0.014	0.012	0.014
Model 16	0.135	0.005	0.010	0.012	0.010
Model 17	0.135	0.005	0.010	0.008	0.014
Model 18	0.115	0.005	0.010	0.012	0.014
Model 19	0.115	0.005	0.014	0.008	0.010
Model 20	0.115	0.005	0.010	0.008	0.010
Model 21	0.125	0.007	0.012	0.010	0.012

Table 3.5 Geometry dimension of each model (Cont)

Tolerance& Model name	Solder high (mm)	Polymer layer On FPC (mm)	Polymer layer under copper (mm)	Copper layer(mm)	Polymer layer on copper (mm)
Model 22	0.115	0.010	0.010	0.012	0.010
Model 23	0.115	0.005	0.010	0.008	0.014
Model 24	0.115	0.010	0.014	0.008	0.014
Model 25	0.115	0.005	0.014	0.012	0.014
Model 26	0.135	0.010	0.014	0.008	0.014
Model 27	0.115	0.010	0.010	0.012	0.014
Model 28	0.135	0.007	0.014	0.012	0.014
Model 29	0.135	0.010	0.010	0.008	0.014
Model 30	0.115	0.007	0.014	0.008	0.014
Model 31	0.135	0.010	0.014	0.008	0.010
Model 32	0.115	0.010	0.014	0.012	0.014

The density of each layer for HGA LT and FBC, with attention to what will happen. In the process of production, there are three types of consequences, that said, the values of nominal size, negative and Positive, Then we should have to use statistical inference to random for a thickness of each layers in production process with different 32 models and utilize these values to set up the size of each models

3.4 Methodology set up of thermal distribution

One of the important studies, we do is the thermal within the process, on the other hand. The study of heat transferring behavior and use to apply with the volume controls of temperature at the bonding areas, the interesting things we study the temperature at the bonding areas. The intersection things we study is the temperature which make a perfect melting of solder leads and hot brining another work pieces. The main factors are also, first, the volume of heating which derived from watt feeding to the origin of laser generator and soldering time. Second. At the initial stage we choose the general Heat transfer mode to set it up.

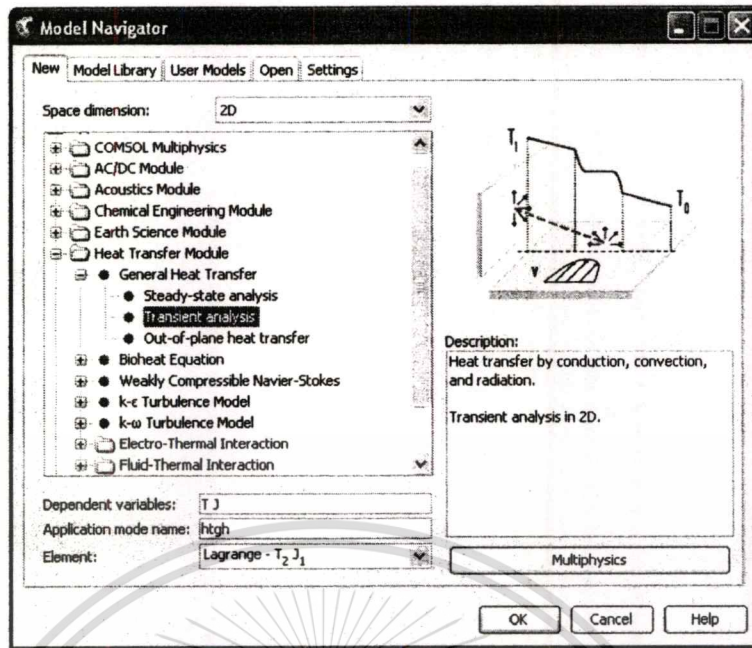


Figure 3.8 Model navigator of general Heat Transfer

Figure 3.8 shows model navigator of general heat transfer, we follow with step a to d step follow topic 3.2.2 after that continue to draw the model by used dimension.

- e.) Go to the model navigator and select 2D in the space dimension list.
- f.) In the list of application modes, Open the COMSOL metaphysic
 - Heat Transfer module
 - General Heat Transfer
 - Transfer analysis
- g.) Click to accept at Multi-Physics bottom, then click Add bottom.
- h.) Click to accept at OK bottom.
- i.) Continue to draw the model by used dimension from figure 3.2.
- j.) Define the properties of Sub-domain.

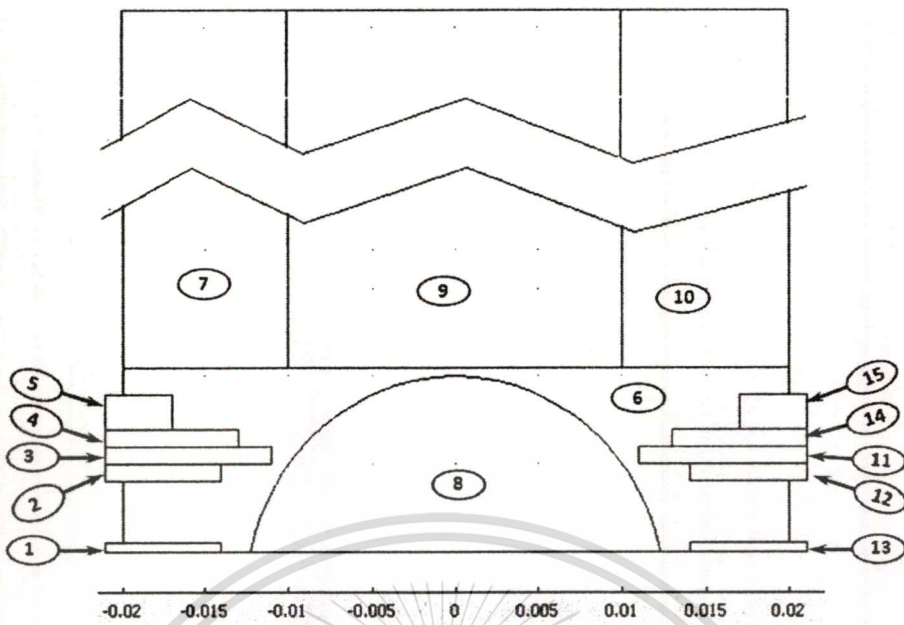


Figure 3.9 Geometry and sub-domain of general Heat Transfer

Figure 3.9 shows the geometry model and sub-domain number we get after draw the model. The amount of sub-domain shall depend on our areas divided in these study was design the property of sub-domain as in table 3.6, with solicitude to the real situation of bonding process in the stage of melting time.

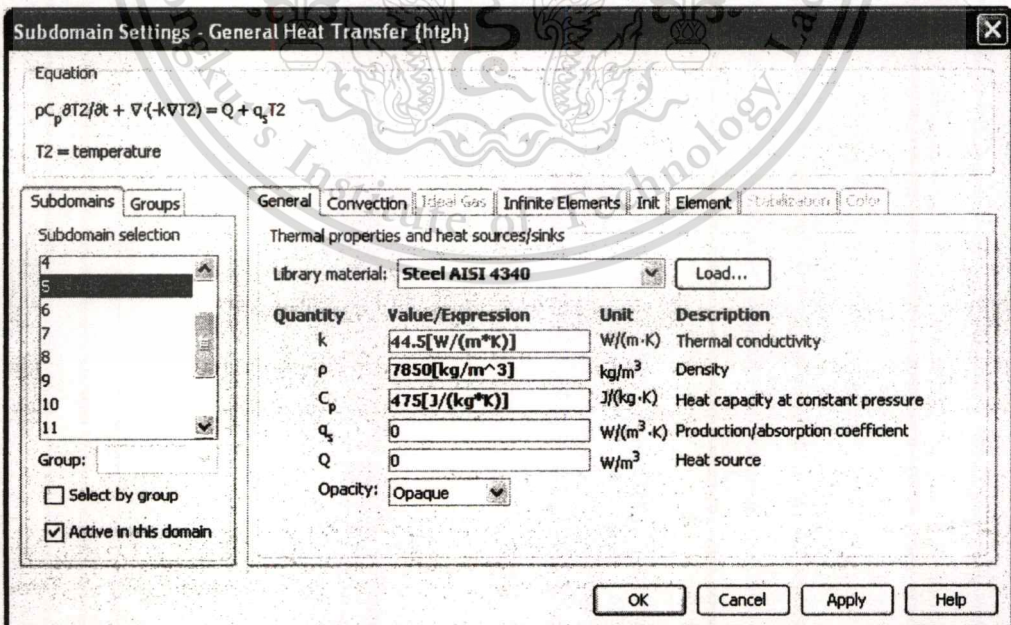


Figure 3.10 Sub-domain setting of general Heat Transfer

Figure 3.10 shows sub-domain setting guide line of general heat transfer model. General set up are thermal properties and heat source of material we load the property from library material by following with table 3.6

Table 3.6 Material define of sub-domain

Sub-domain number	Material define	Absorption coefficient
1,2,4,12,13,14	Polyamine	2
5,15	Steel	1.0
6,7,9,10	Air	1.5
8	Solder	0.5

Table 3.6 shows boundaries setting of sub-domain setting of general heat transfer that used for set up the model. All of them are 14 domains and we define five material properties. Adoption coefficient derived from the equation of Beer-Lambert law.

The defining equation for the mass attenuation coefficient is essentially a different way to write the Beer-Lambert law. The Beer-Lambert law is normally written.

$$I = I_0 e^{-\mu l} \quad (10)$$

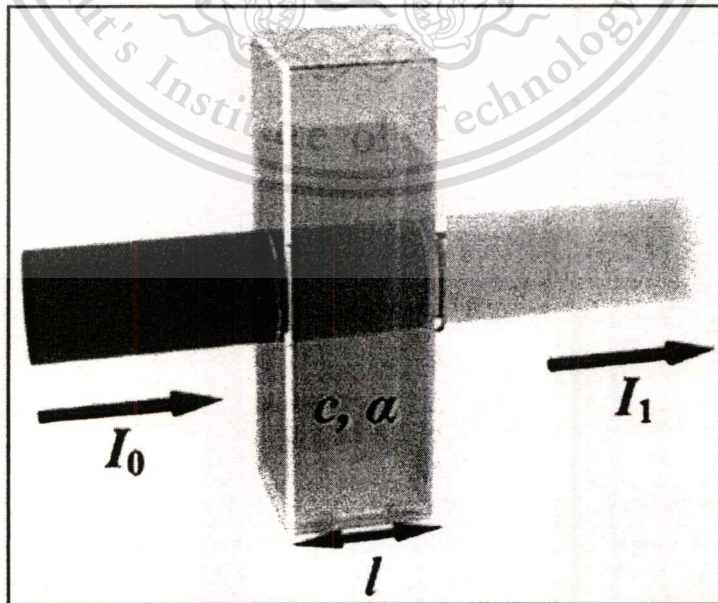


Figure 3.11 Absorption of X- laser in material

Where

- I_0 is the original intensity of the beam
 I is the intensity of the beamer distance l into the substance.
 e is Euler's number, about 2.718,
 μ is the attenuation confident

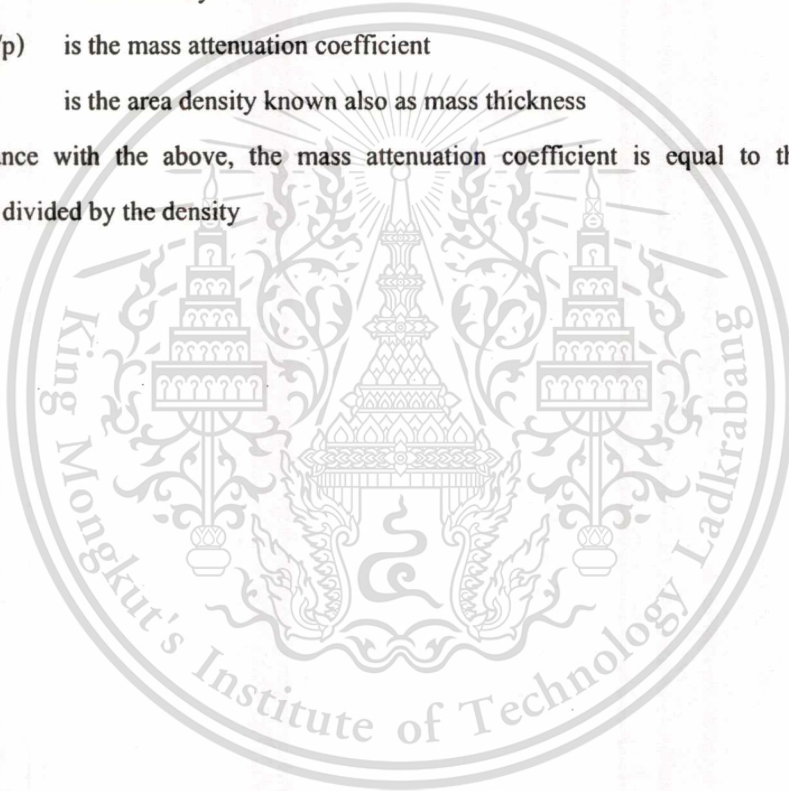
When discuss the mass attenuation coefficient, this equation is rewritten

$$I = I_0 e^{-(\mu/\rho)\rho l} \quad (11)$$

Where

- ρ is the Density
 (μ/ρ) is the mass attenuation coefficient
 ρl is the area density known also as mass thickness

In accordance with the above, the mass attenuation coefficient is equal to the attenuation coefficient divided by the density



Chapter 4

Results and Discussion

In this chapter, we present the all results and analyze results with five topics, as following details.

4.1 Simulation result of solder joint shape without HGA LT

To create simple for an exponential forming and be a guide line to establish a testing form, then simulation model were established. In order to make a comparative between its result and another approval studies as such. Y.X. Gao. *et, at* with the principle of kinetic law to forecast the changing form of melt solder and uncomplicated to forecast the change of solder. With recommendable studies and appreciate with the wetting angle and spreading area. The both changing are depending on time and shall be affect to solder shape, and movement of soldering point of solid, liquid and GAS which drive surface tensions and gravity field [7].

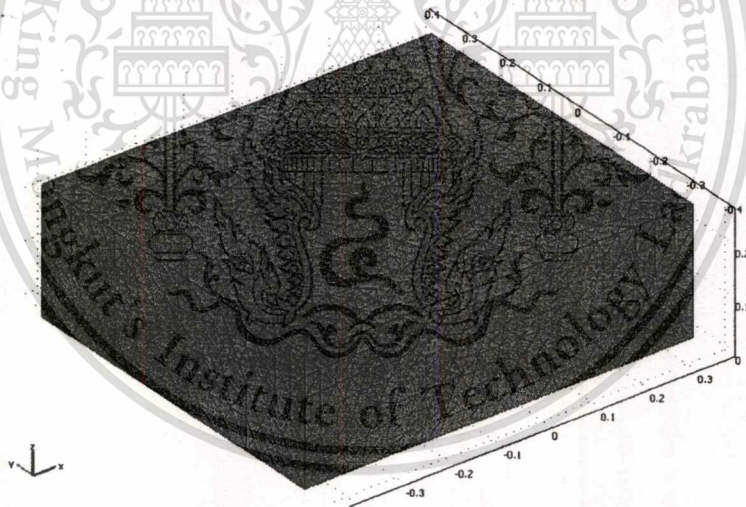


Figure 4.1 Meshing result of solder joint shape without HGA LT model

Figure 4.1 shows the changing form trails of solder shape and movement of the three soldering points. Liquid, Solid and Gas (LSG) as b specified time (t/t_0) during the evolution of change. It's very distinctiveness, the height solder will origin from elevated point to the highest point and slow down into constant point the movement of the three soldering point will be rush-up [7]. At the origin of dispersion will be short-term, as seen at D to E, then it will be slow down before it extend the constant and symmetry.

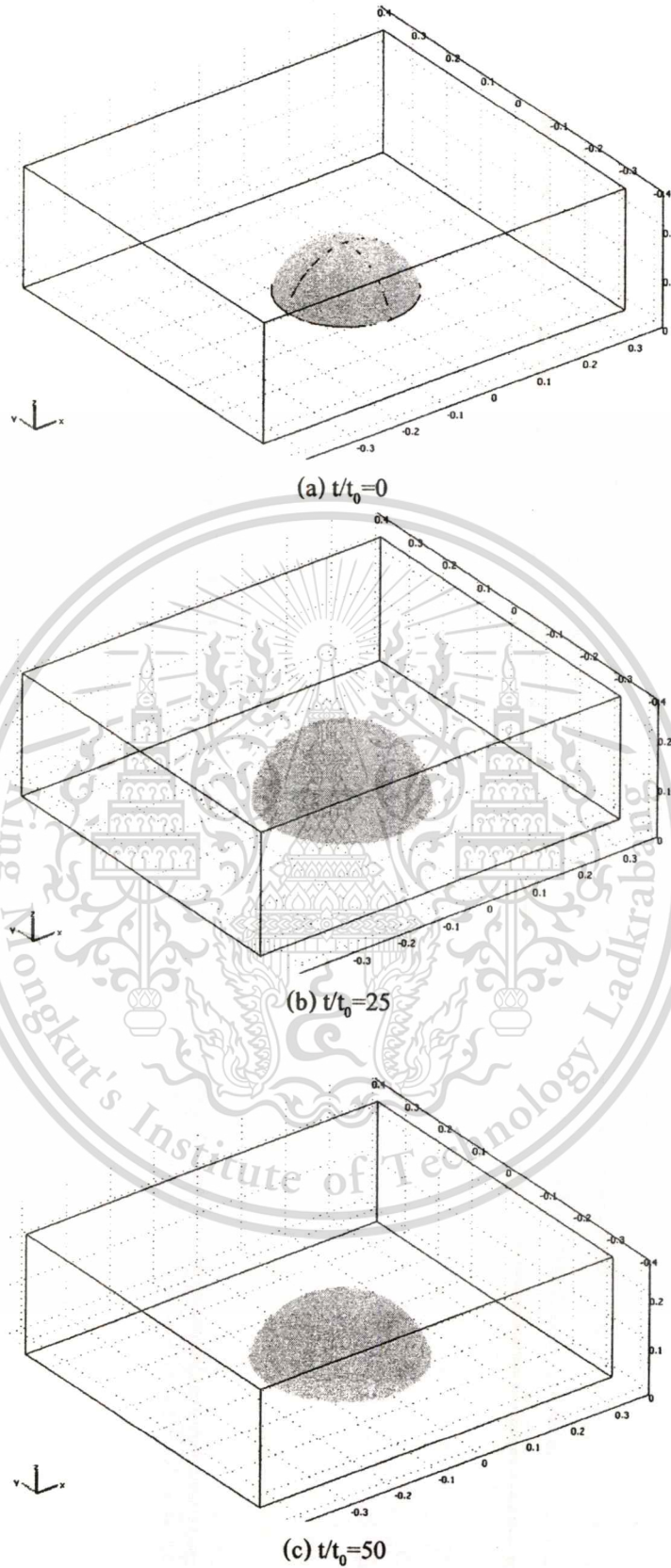


Figure 4.2 The traces of solder joint shape without HGA LT at the stated time

This material is reserved for educational use only, not allowed for commercial use.

Forbidden to modify the content, and cite the document when use.

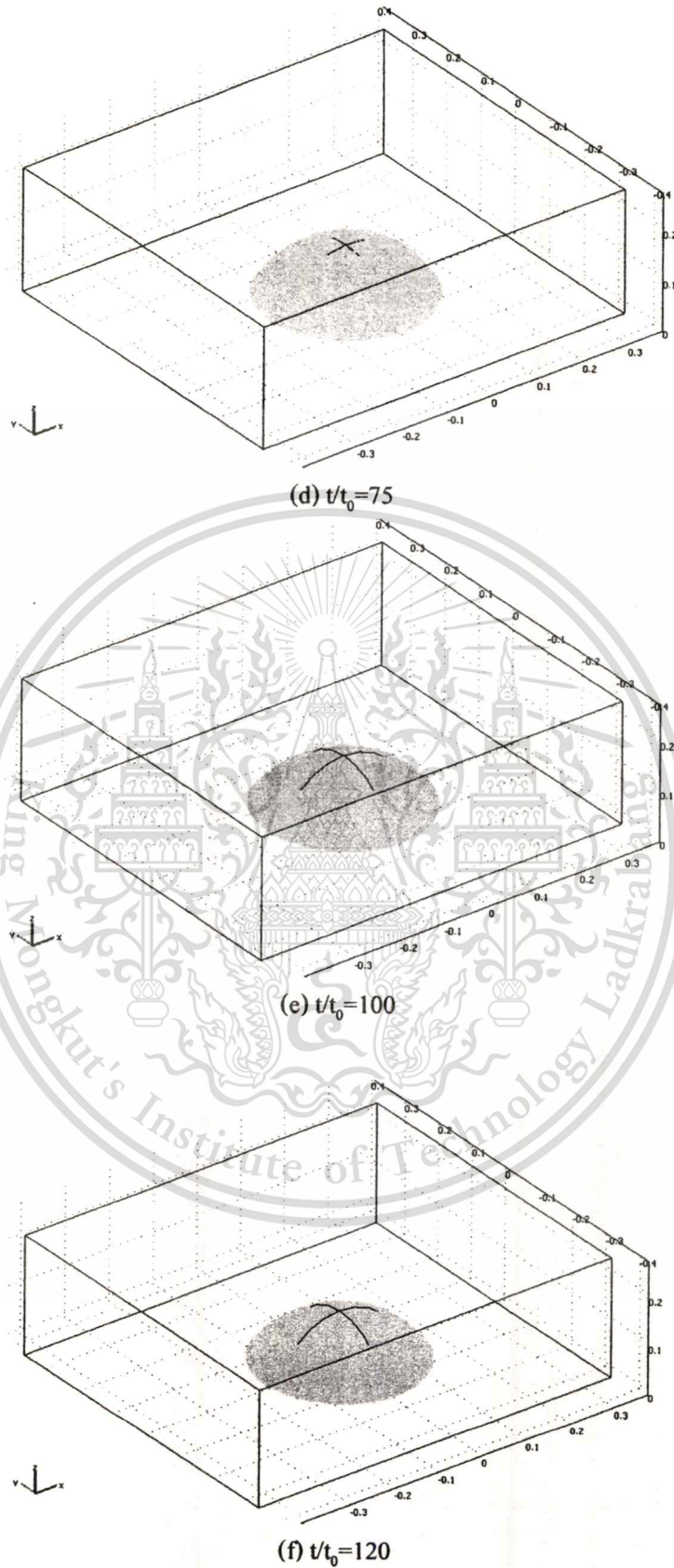


Figure 4.2 The traces of solder joint shape without HGA FL at the stated time (cont)

Figure 4.2 shows simulation result of solder joint shape without HGA LT. The results of changing form of solder shape from simulation result at $t/t_0=0$, until $t/t_0=120$, by measurement of the solder height and spreading area, we used COMSOL to measure the height, by extra grid in setting mode. The value of solder height can be directly illustrated of the height; it shall be present in term of line graph. The change at several times can be seen in figure 4.4 after that, the value of spreading areas derived from the width of solder shape in the axed of X and Y, then are calculated which present in term of line graph. It can be seen from figure 4.5. For the measure of wetting angle change could be done by import the pictures into solid work a program by sketch mode which make the line by angle of solder shape, then follow with measurement of size, which can be seen in figure 4.6

4.2 Experiment result of water droplet

The related propose of this experiment was to determine behavioral motion of liquid on the smooth surface and use the results to compare with results of the first simulation model. In this, topics can be divided for three parts. Equipment method and result as following as

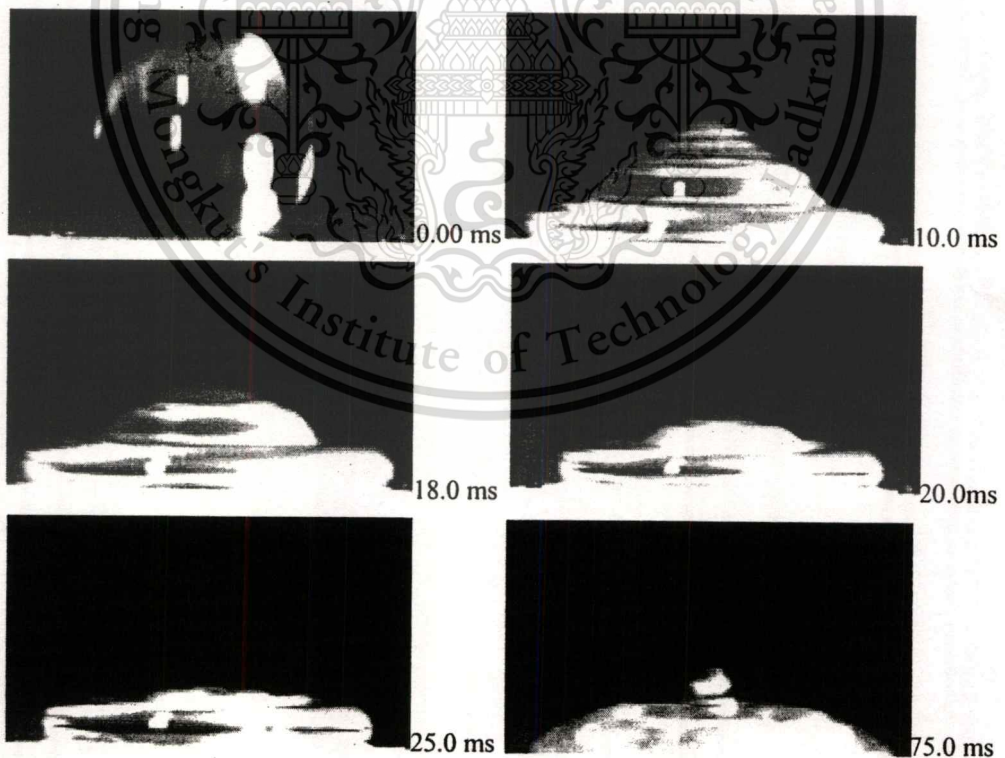


Figure 4.3 The experiment results of Water droplet experiment (ms=Millisecond)

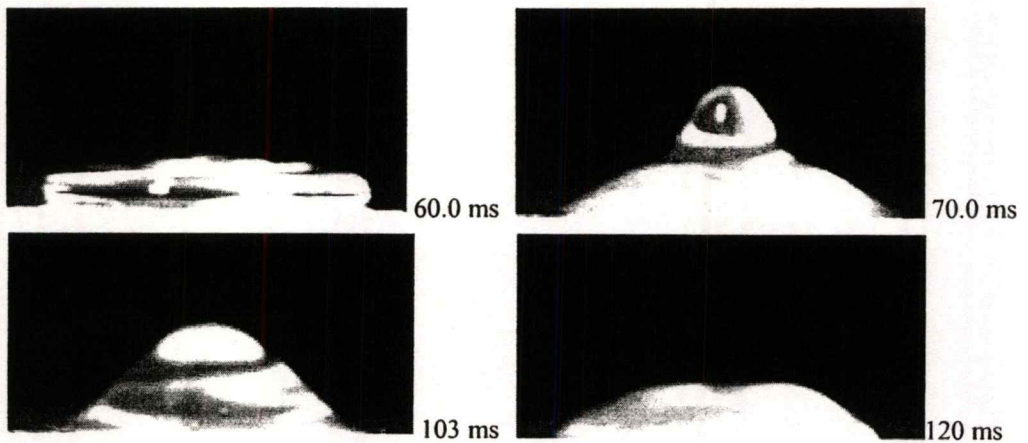


Figure 4.3 The experiment results of Water droplet experiment (ms=Millisecond) (cont)

Figure 4.3 shows water droplets on solid substrate at room temperature in transaction of water droplet was to study the changing form of water droplet, there were three interesting topics. Firstly, result is high measurement by the distance between solid surface and top surface of water dot, the result show at figure 4.4. Second, result is spreading area measurement by diameter of later dot and the result show at figure 4.5 Third, results is wetting angle and the result shown at figure 4.6 the result was explained in tern of line graph. Changing behavior and comparison of the both results they're the water droplet and simulation result from without HGA LT model, as the following detail.

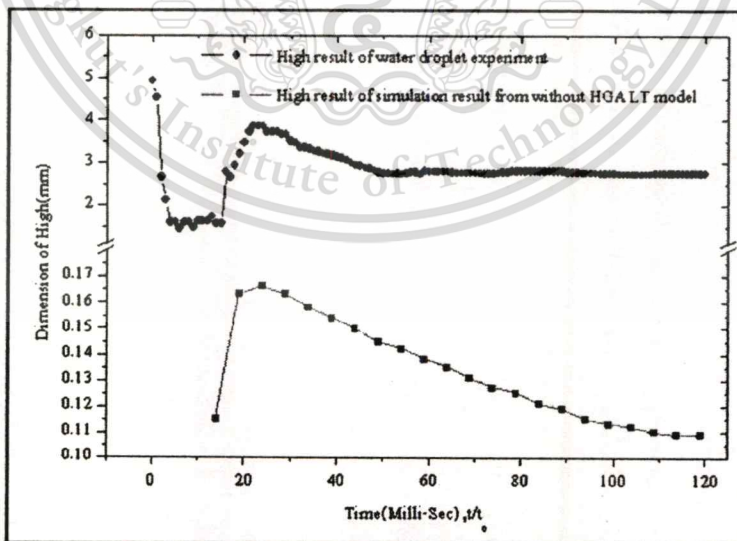


Figure 4.4 Comparison of high between water droplet and simulation result

Figure 4.4 shows comparison of high between water droplet on solid substrate and simulation result from without HGA LT model. In the axes of Y. present the high of water droplet and simulation result within millimeter (mm.) unit, in the axes of X present consumption time of experimentation and simulation, within Millisecond (ms.) unit. Per comparison of changing behavior for the high, in this case, high means height measurement of water droplet, by placing the zero at the surface of solid substrate as same as the modeling. Comparison between the both substance are initially from $t=10$ ms the reason why it doesn't start with comparison from $t=0$ ms. Since the gathering data for simulation model. We originated at the semi sphere and make it as per-solder which placing on the FCB, data gathering of water droplet originated from the reflexive time of solid substrate and when it over about 10 ms the shape of water droplet became semi sphere. We moved the original of comparison at $t=10$ ms to 15 ms, that is 15ms. There were rapidly changes of highs, which the trend of the both change were in the same way. After that, there were continuous change, for 5ms ($t=25$ ms) until it reached the peak of high in hemisphere shape and continuously decrease until it reached the point of no changing. The difference which occurs in the experiment and simulation model at $t=50$ ms. the result of water droplet experimental shall be terminated and discontinued, till the time is over. On the other hand, Simulation model from the peak of solder high at $t=25$ ms the changing of solder high was continuously decreased until $t=110$ ms. After that there were no more changes, till the time was over. The reason of differentiation for the both results might be the causes of insufficient set up model, but most of these result were in the same way as the following details.

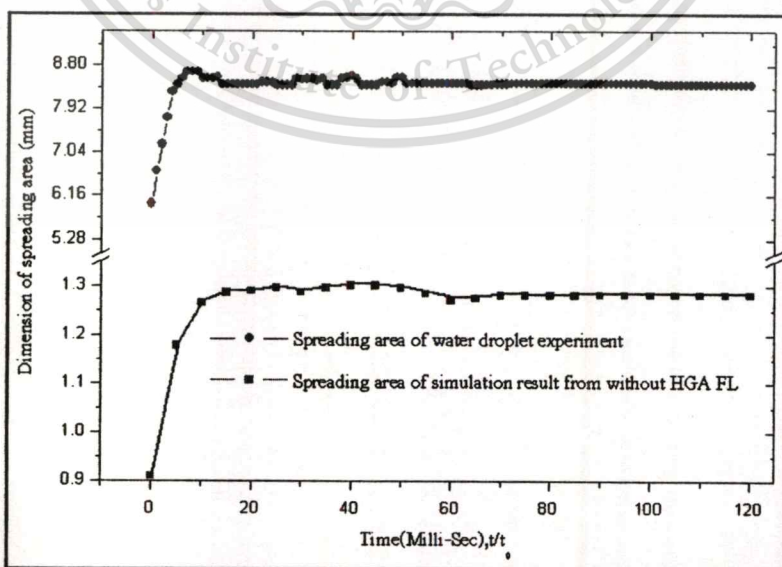


Figure 4.5 Comparison of spreading area between water droplet and simulation result

Figure 4.5 shows comparison of spreading area between water droplet on solid substrate and simulation result. In the axes of Y. show the dispersive area of water droplet and simulation result. In the axes of X show the operational time and time consumption in simulation. The consequence from this comparatives is the behavioral changing of area for the both experimentation which indistinguishable to each others in term of direction. The changing was originated at $t=0$ millisecond of the both graph, with rapidly until approximate $t=10$ millisecond. After that, the dispersion shall be continually decreased until it reaches the point of no change from these disperse behaviors, It could be explained in the scope of science, that the reason of rapidly dispersive changing in the early period was originated from the weight of water droplet and velocity of impact that a cause of an internal pressure within the mass of water droplet, make dispersion and the reason of water contraction, as for the surface tension was greater than the internal pressure. By all means changing behavior of spreading area shall be gratifying with the behavior of high and wetting angle which shall be explain in the next graph. And if also found that, related with the graph of figure 4.5 when the height summit point, shall be causes of decreasing in dispersive area, and when the height is declining, shall be causes of expanding of dispersive area [18]. The behavior of the both changing shall be related with wetting angle which shall be explained in the next graph.

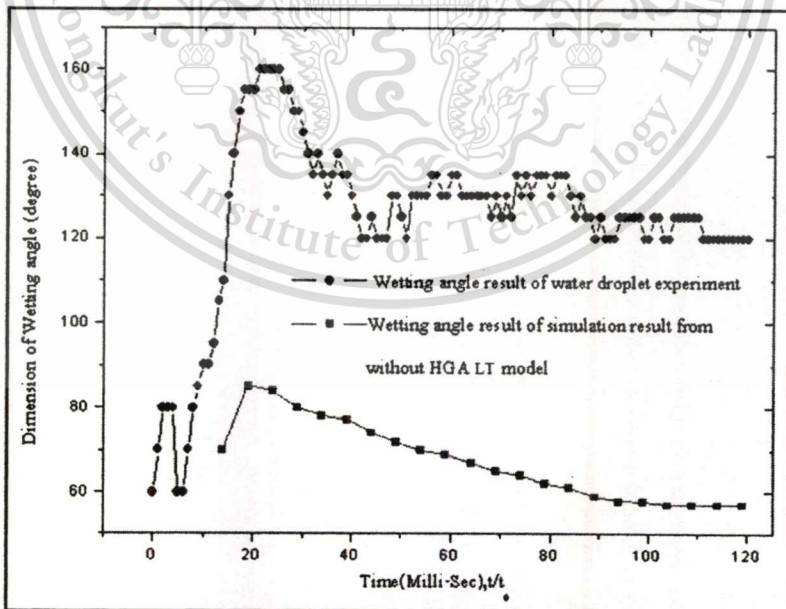


Figure 4.6 Comparison of wetting angle between water droplet and simulation result

Figure 4.6 shows comparison of high between water droplet on solid substrate and simulation. In the axes of Y present wetting of water droplet and simulation result. In the axes of X present the consumption time in the experiments and simulation, comparison of the changing behavior of wetting angle. By placing the centre of degree on surface of solid substrate as in the modeling, Comparison originated when $t=7$ millisecond with the same reason with illustrate of figure 4.5, Changing behavior from the graph the degree of hemisphere like a shape of pre-solder on FCB. Originate from arises of model at 70 degree and rapidly increase till the highest point at about 90 degree at $t=20$ millisecond and then continuously decreasing into the point of no change. For the changing behavior of water droplet, originate when $t=7$ millisecond. The origin of wetting angle was approximately 105 degree at that time, with rapidly increase into the highest point at about 160 degree at $t=20$ millisecond. Then constant and rapidly decrease into 120 degree, after that there is decrease and increase with inconstantly feature. If we considerate at the trend of changing, as same as the above mentions.

The relationship of wetting angle with the spreading area and high, at wetting angle almost 90 degree for both positive and negative values. It's cause high of water droplet much more and makes more hardly dispersing because there is more surface tension.

From the comparison of experimental results and simulation result of without HGA model, believing that the modeling can be utilize to predict the changing behavior of pre-solder after pass bundling process.

4.3 Simulation result of solder joint shape with HGA LT

From the experiment of water droplet and result of solder joint shape without HGA LT. We can preliminary conclude that we can predict the changing behavior of Pre-solder after pass bonding process, thus we take the modeling of solder shape without HGA LT to develop the real works by adding geometry of HGA LT and accomplish the simulation test, the results are presented as the follows.

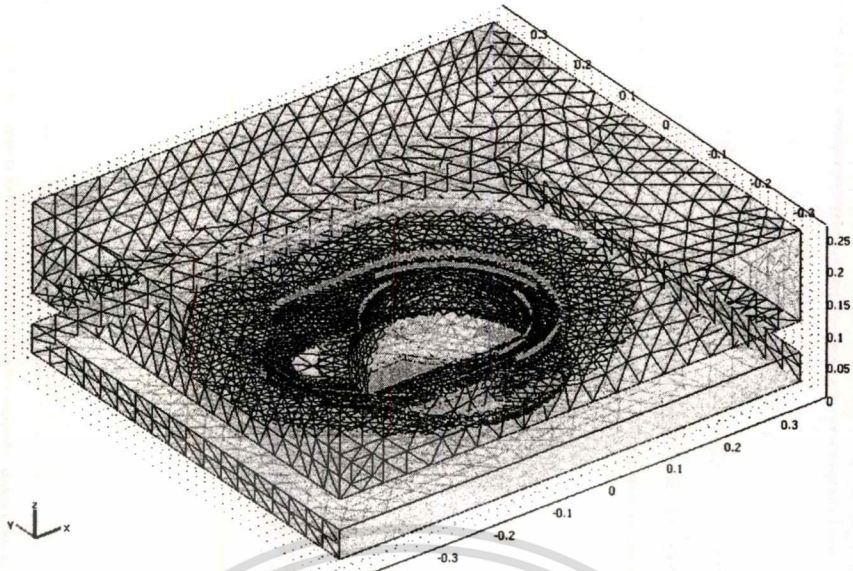


Figure 4.7 Meshing result of joint shape with HGA LT model

Figure 4.7 shows the meshing result of final model with triangle mesh and it consists are .51982 elements. Due to the component of real works are 50 complicatedly and make more surface for a rhombus, the outside of edges are the area of air which considerate to be gratify with the work site and it affected to the scope of prediction for liquid solder dispersion. We disclose the results in 3-D character, as see in figure 4.8(a) to (e). If will verity the dispersion behavior as punctuation of time at $t/t_0 = 25$. We also maintain 3 interesting data; they're, solder height, Spreading area. Wetting angle, then use this data to compare with the result derived from the modeling of solder joint shape without HGA LT

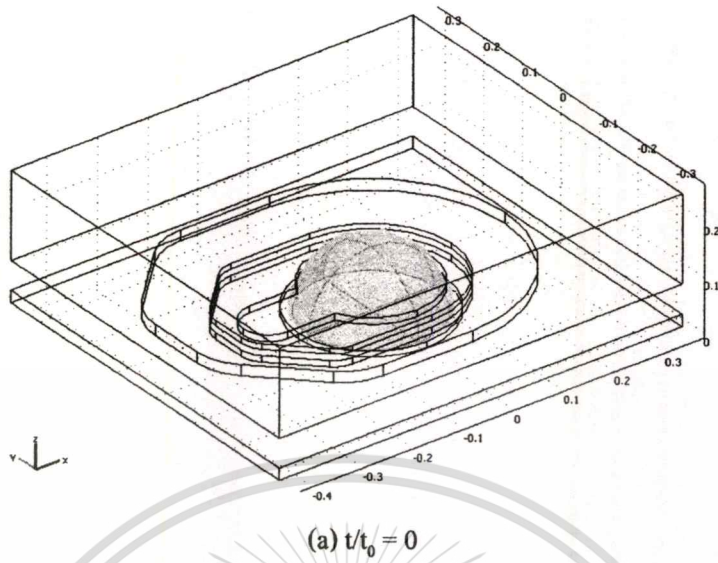
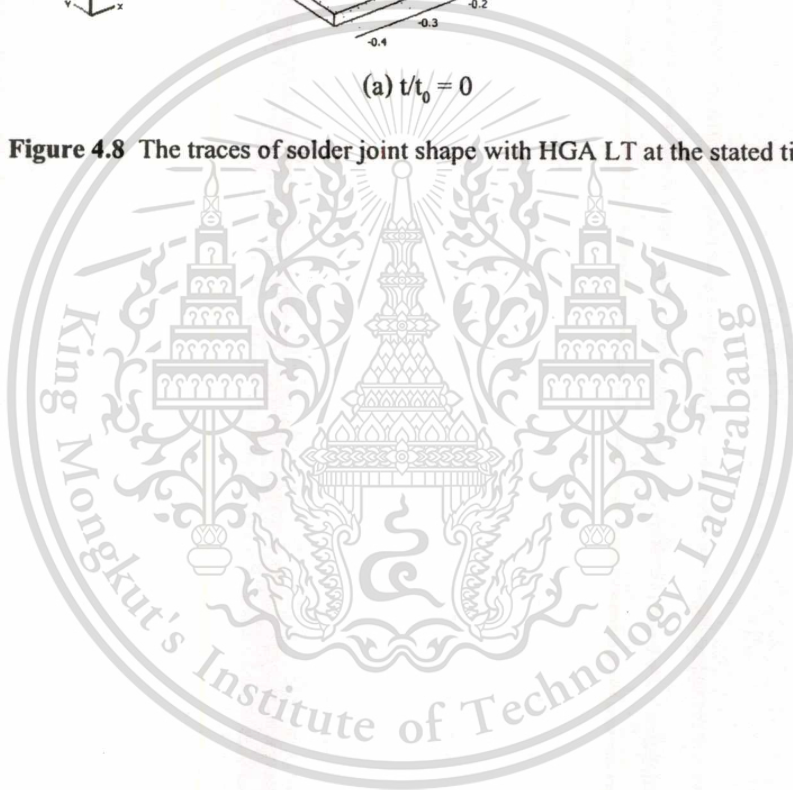


Figure 4.8 The traces of solder joint shape with HGA LT at the stated time



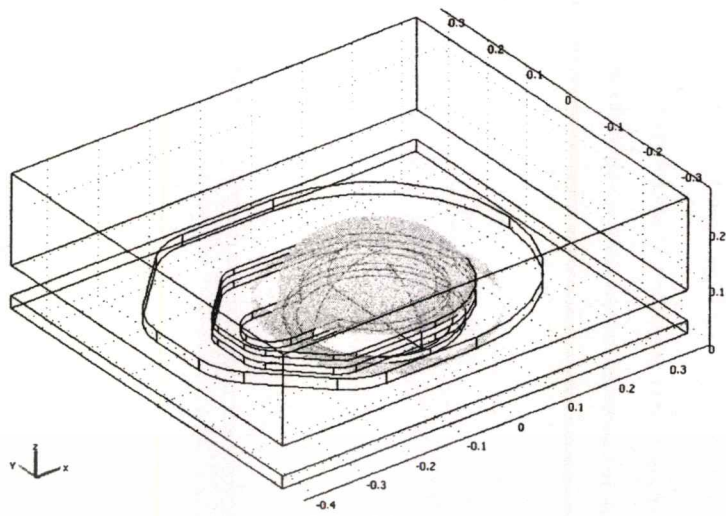
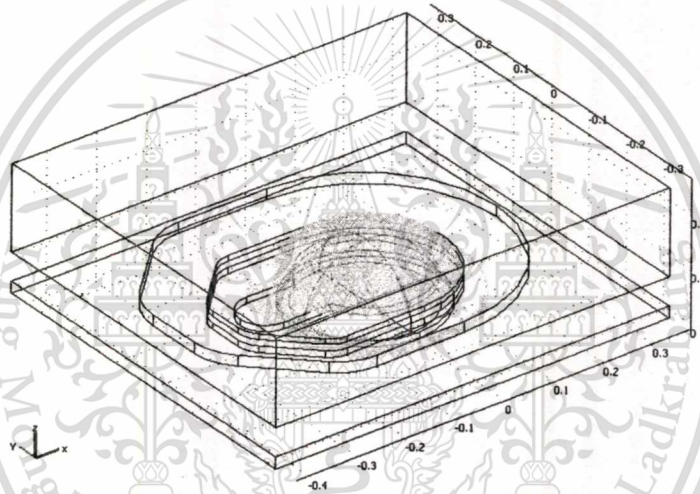
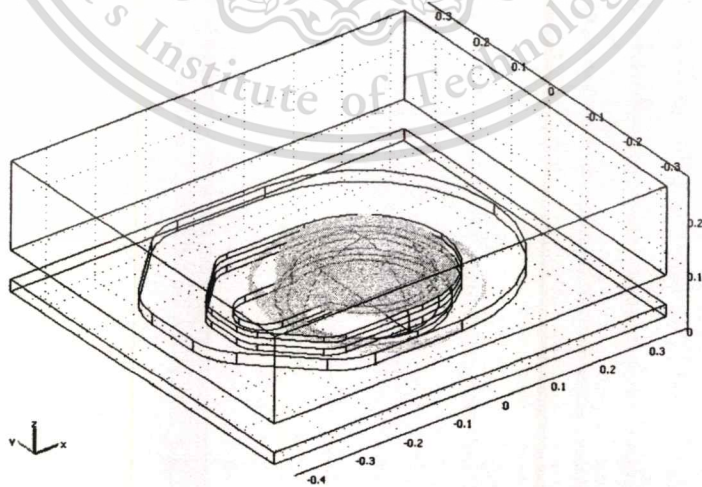
(b) $t/t_0 = 25$ (c) $t/t_0 = 50$ (d) $t/t_0 = 75$

Figure 4.8 The traces of solder joint shape with HGA LT at the stated time (cont)

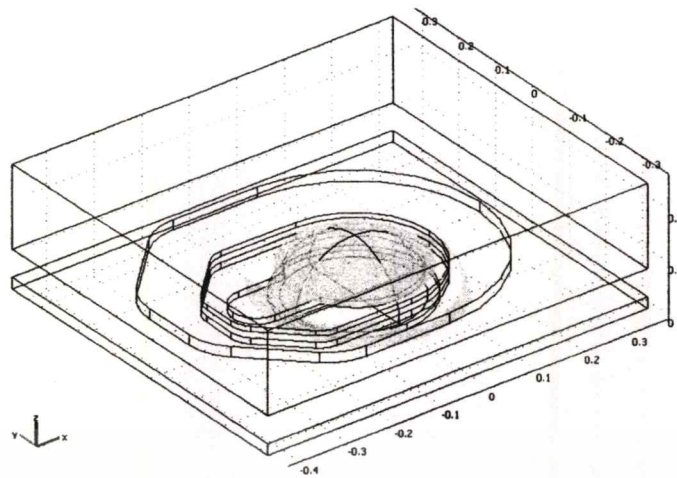
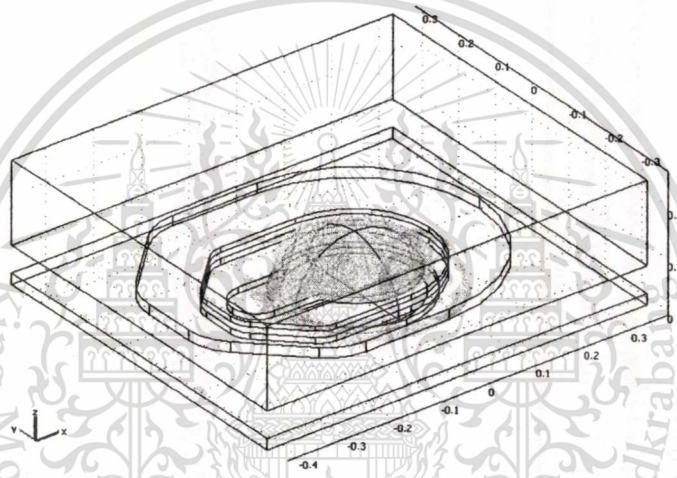
(e) $t/t_0 = 100$ (f) $t/t_0 = 120$

Figure 4.8 The traces of solder joint shape with HGA LT at the stated time (cont)

Figure 4.8 shows simulation result of solder joint shape with HGA LT originate from $t/t_0 = 0$ (a), till $t/t_0 = 120$ (f), by size measurement of solder height spreading area and wetting angle, Then data gathering by the same method of modeling of solder joint shape without HGA LT. Its present on term of line graph, and also, and see it from figure 4.9 to 4.11, by all means, it shall difference at the adding of wetting angle for two surfaces. It can see in figure 4.12 At the surface 2 and 3, in order to covering the study of dispersion behavior of liquid solder at the upper and lower part of surface which present in term of line graph, as some as the dispersion behavior of liquid solder for both models from level set method which derived from the same set-up distinction in term of complexity shape. The changing of shape which altercated by the shape of

actual works. The answer, when compared with the dispersion behavior of liquid solder the trend of changes should have in the same way, as the following

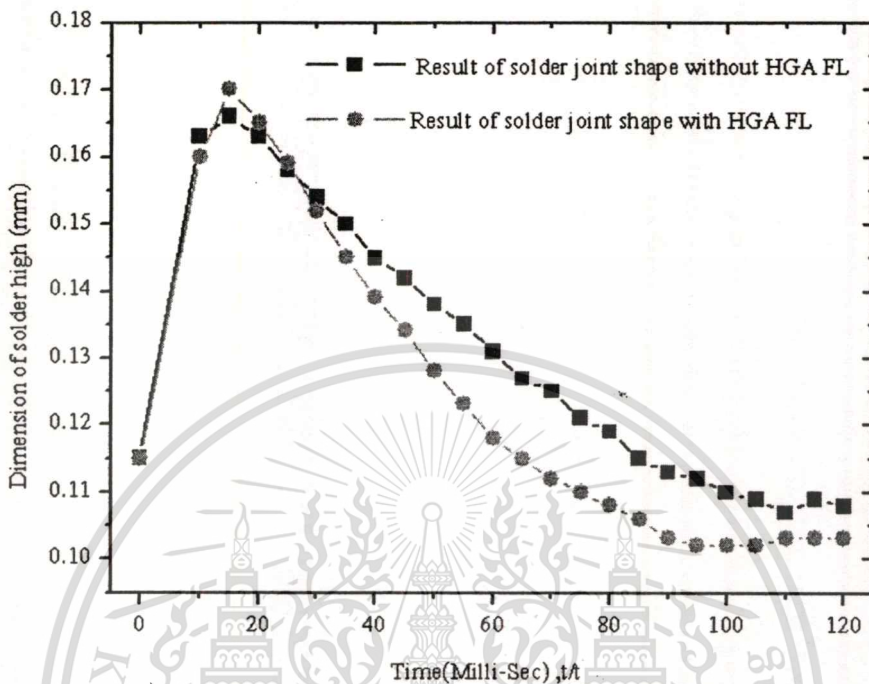


Figure 4.9 Comparing of solder high result between with and without HGA FL

Figure 4.9 shows of comparison of solder high results between both models are with and without HGA LT. In the axes of Y present of Y present the dimension of solder high result, for the axes of X present the time in formation of liquid solder, Square dot line to explain the behavior solder high result of solder joint shape with HGA LT model, The changing type of solder height, after examine and compared. Initially, graph of the axes of X $t/t_0 = 0$ to $t/t_0 = 10$, there're rapidly changes of height [7], within a short time, due to the surface tension retreats than the internal pressure of liquid solder. It's very hardly to see the different of changing for the both model, the next time was at $t/t_0 = 15$ seconds. Liquid solder were decreasing in term of high and reach at the peak. At this time, the height of graph in the axes of Y are differenced. Due to liquid solder of solder joint shape with HGA model was limited by the surface of HGA LT, and then the changing of solder high shall decrease. From line graph of the both models, the character of similarly changing, but different in height. With the only reason which similarly with the above season as said, Liquid solder of solder joint shape with HGA shall flow through the gap between FCB and HGA LT and then ramble into the upper surface of HGA LT. The direction of flowing

as seen in figure 4.11 and at specific period $t/t_0 = 30$ second. The height was decreasing by the same rate of changing. The change height of solder shall be constantly. There is a little change in these procedures. The change shall be occurring at $t/t_0 = 90$ seconds till the terminated of these experiments. How the height of liquid solder relative with the dispersion? This topic shall be present in the next topics.

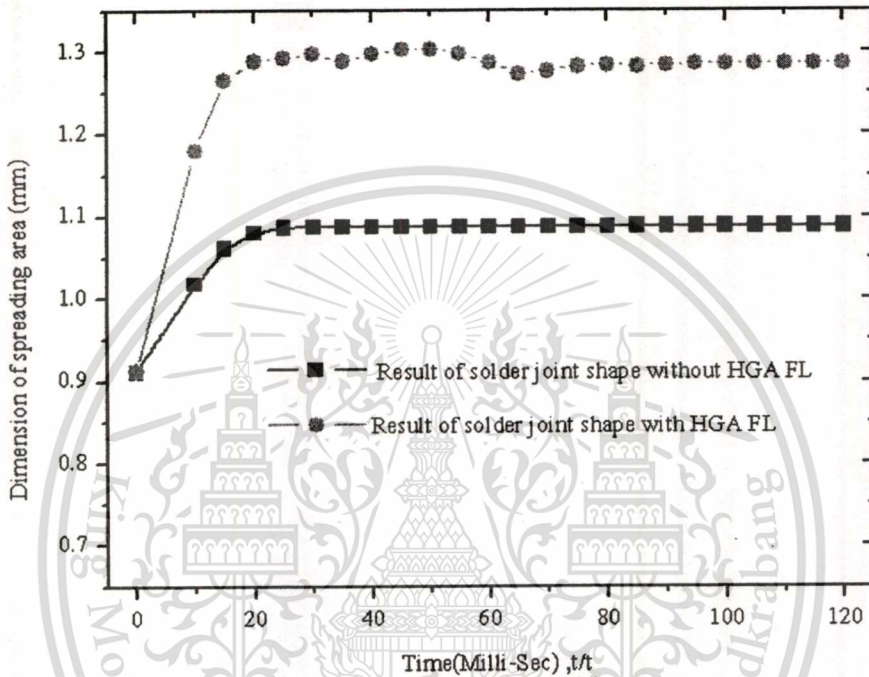


Figure 4.10 Comparison of solder spreading area result between with and without HGA FL

Figure 4.10 shows comparison of solder spreading area result between both models, are with and without HGA LT. In the axes of Y present the dimension of solder spreading area result while, the axes of X present the time of changing for liquid solder. Square dot line to explain the behavior solders spreading area result of solder joint shape without HGA LT model. Sphere dot line to explain the behavior solder spreading area result of solder joint shape with HGA LT. The character for the change of spreading area of liquid solder after examine and compared the both experimental differentiation. We said that forming of simulation models. We determined the same size of the both pre solder model. Then the originate size were not different, the changing behavior of dispersion at origin les at $t/t_0 = 0$ to $t/t_0 = 15$ than go degree. From both results, the changing trends are similar, but different in its values, because the dispersion of solder joint shape without HGA LT model shall be maintain its forms for free, thus disperse are not too much,

If compared with spreading area result of solder joint shape with HGA LT model. The main reason why the dispersion of solder joint shape with HGA LT model are far more disperse, as to the restriction of leads, then liquid solder shall move to the gap between FCB and HGA FL on surface of polyamine layer and copper layer. In order to make uncomplicated to understand the flowing direction, from 11 at the surface 1 and 2, liquid solder cannot maintain its sphere shape, due to the abstractions particles, That is layer of HGA LT, when the gaps between are small, then the liquid solder can disperse , more the result of dispersion of liquid solder in the without HGA LT model shall be constantly at about $t/t_0 = 25$ seconds, after that, It will not change anymore, as for the surface tension are greater than the atmosphere's pressure, than the liquid solder can be freely maintain its shape while the dispersion of the with HGA LT model shall be slower constant, at approximately $t/t_0 = 70$ seconds because the gravity force from the surface of HGA LT layer, it will take more time to disperse, as seen in the figure 4.11 formational behavior of wetting angle within the system shall be more explained in the next topics.

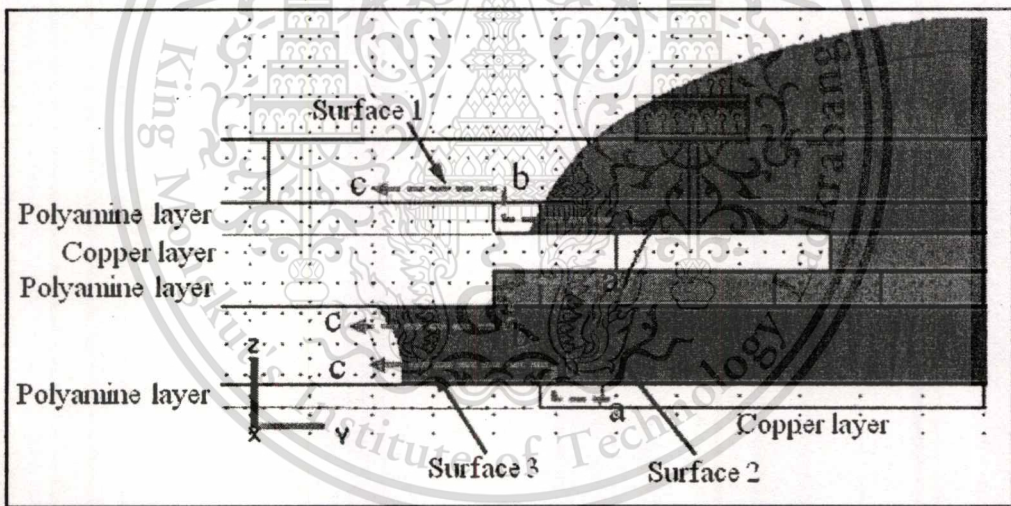


Figure 4.11 the Wetting angle flow direction result of with HGA LT model

Figure 4.11 shows the flowing direction of liquid solder on the surface of copper layer surface (Distant between A to B) and polyamine layer surface(distant between B to C) of both surfaces we studied, from the wetting angle which occurs on the both surface. Our data gathering derived from the measurement of its degree, by considerate Y-Axis as an origin and use the same measurement with the solder joint shape without HGA LT, By import the picture into the program of solid work by sketch mode along the angle of liquid solder shape and then measure its

size we expose our results of the test in term of graph. The changes of each period can see in figure 4.12.

Surface 1, 2 and 3, means the direction of motion for liquid solder on the surface of polyamine and layer of HGA LT. It was a continuous motion on the two different materials. By hypothesis, determine as a smooth surface, but it consideration as a mark of step on the soldering point of two materials. That is the original edge of Polyamine layer, and flowing character of liquid solder. It shall flow along the surface by gravity force, thus, liquid solder can't maintain its shape and it will change by the feature of materials. As same as, the changing of water, it shall alter along the shape its container, the forming of wetting angle, shall be depending on the character of surface at the contact surface and property of surface tension of liquid which shall be present the results of wetting angle form the experimental test, in the next graph.

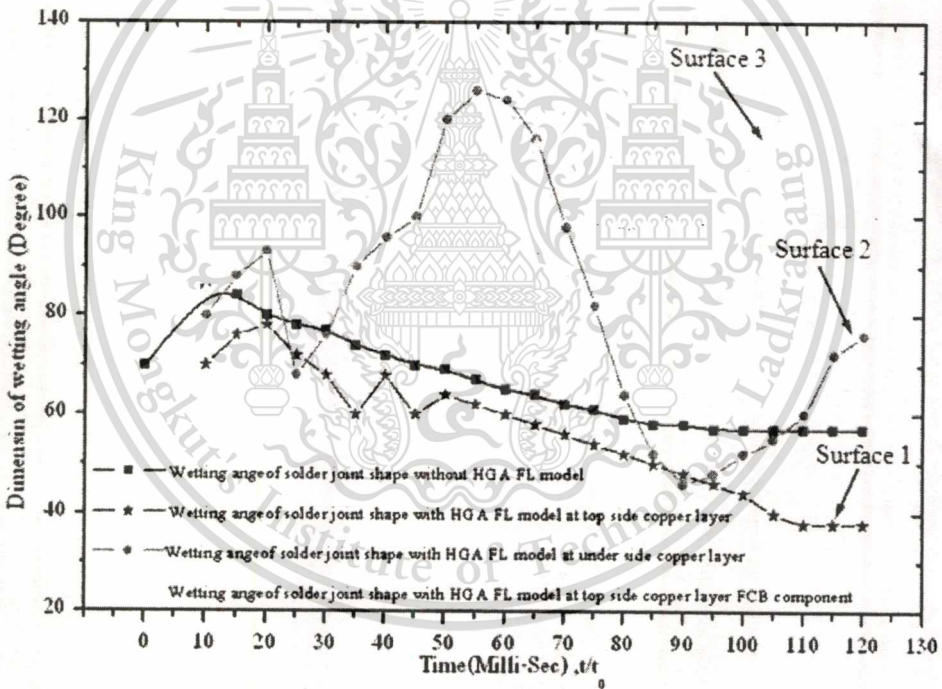


Figure 4.12 Comparison of solder wetting angle result between with and without HGA LT

Figure 4.12 shows comparison of solder wetting angle result between both models, are with and without HGA LT. In the axes of Y present the dimension of solder wetting angle result. For the axes of X present the changing time formation of liquid solder. Square dot line to explain the behavior solder wetting angle result of solder joint shape without HGA LT model, star dot line, sphere dot line and rectangle dot line to explain the behavior solder wetting result of solder

joint with HGA LT. The interesting point of changing form for wetting angle that is the wetting angle which occurs on the surface of polyamine layer of HGA LT and FBC component parts, from figure 4.12 we have a result of wetting angle form solder joint shape HGA LT, which classified for three experiments. They are surface 1,2 and 3 (Refer from figure 4.11) It's the forming of wetting angle at the upper and lower of Polyamine and copper layer of HGA LT and FCB, component parts, respectively., which can be seen the direction of motion from figure 4.11

Next, is the clarifying of relationship to surface and the changing of wetting angle and shell being affected to the dispose of liquid solder.

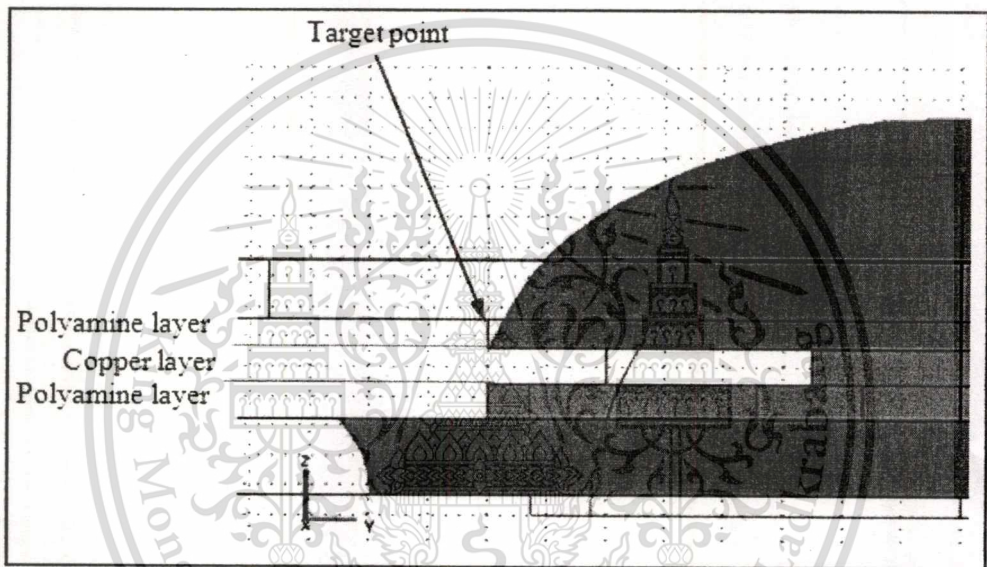


Figure 4.13 Show the perfect liquid t solder mass movement on HGA LT

Figure 4.13 shows the movements of liquid solder mass on HGA LT we need. It means the liquid solder mass reach the edges of Polyamine layer, from the picture, polyamine was placing on the copper layer. The main reason we used this point as to the real works situation within bonding process. We can examine it through the magnifier. But on the lower edges of copper layer we cannot examine through the magnifier. If have to use the cutting method in order to observe the inner part, then we're concentrated on the movement behavior of liquid solder mass which considerate on the consumption time for the movement on the upper surface of copper layer. It shall be gratifying with the time of melting solder. Then we have to control the time making more efficiencies in the bonding process, thus we collected the result of time that liquid slider mass reached the edges of polyamine. From the test of 32 models experimental which show in Figure 4.14, for the whole we designed and test it. Reaching in to the edges of

each model, apply the reaching time to the edges of target point (Figure 4.13) in different ways. The main topic we studied and concentrated on these studies was the consumption time of the movement on the upper surface of copper layer by the Z-Axis. With the data gathering, it originated from the pre-solder which arise to change, until it reaches the edges of polyamine layer. We used the results of each model to expose in term of graph, as in the next picture.

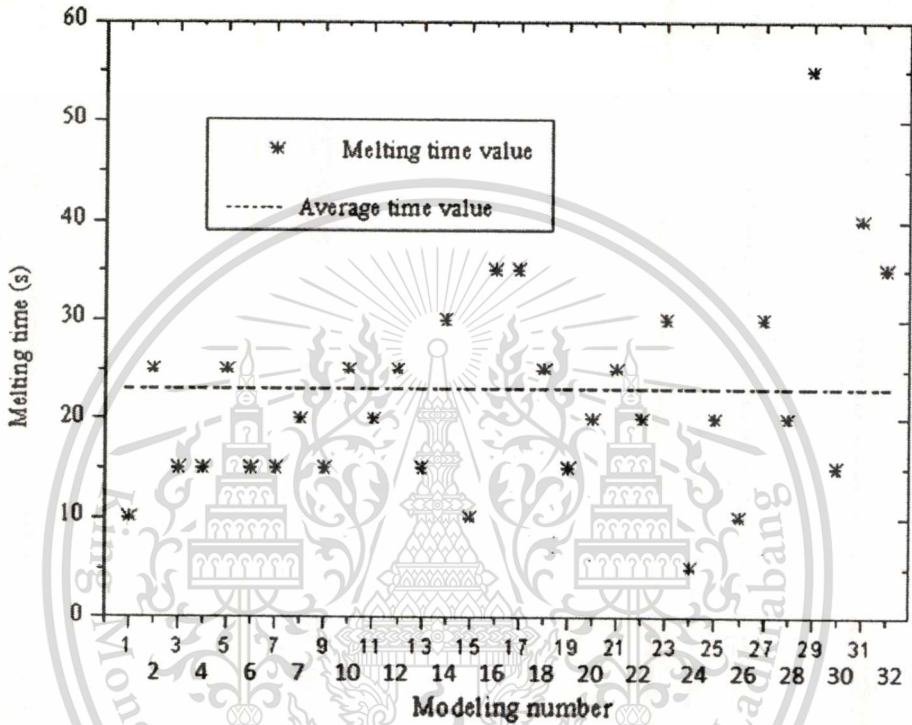


Figure 4.14 Dependence time liquid sliders mass movement until hit the edge of Polymer Layer

Figure 4.14 at X-Axis is a modeling number we have of 32 models from the left to the right Y-Axis is a melting time of pre-solder which determine the consumption time for melting from zero to 60 second. By expose the consumption time for melting of each model as the marking point (*), where the lowest is 5 second (at model 24) and the highest is 55 second (at model 29). From all and its results, most of them are about 80%, at 15-30 second. If present the acceptable time for the movement of liquid solder on the face of copper layer. More obviously, we used the results as a means (x). and it could illustrated to us that we should control the consumption time to melt solder in bonding process operation the reason of different time each models as for the thickness of each layer and solder height of each model, where different to each

others. The result which error from the causes of fabrication and assemble processed. The two main parts are FCB and HGA LT which more details to follow.

FCB can be divided into two parts which affect the movement time of liquid solder mass. They are polyamine thickness and Pre-solder high.

HGA LT can be divided for three parts. They are thickness of copper, Polyamine on the top side of copper and polyamine under the side of copper.

If was conclude that they are 5 variables which affected the movement time of liquid solder mass for the viscosity of liquid solder, we hypothesis that liquid viscosity of them are not different.

However, solder joint shape after pasted bonding process is an unexpected thing in the real works, thus controlling the factor which affected to solder joint shape are necessary. By all means, we cannot control all factors at one time, then we have to choose one which controllable and also relate to the result we need to select the factors which we should have to control. The result from DOE by searching of the main effect plot for final height of solder after pasted bonding process, It's relation values of the components which affected to the height of solder that is the factor which affected to the changing behavior of slider height (Figure 4.9) the highest is pre-solder height (block a), which shall be explain its results from the following table

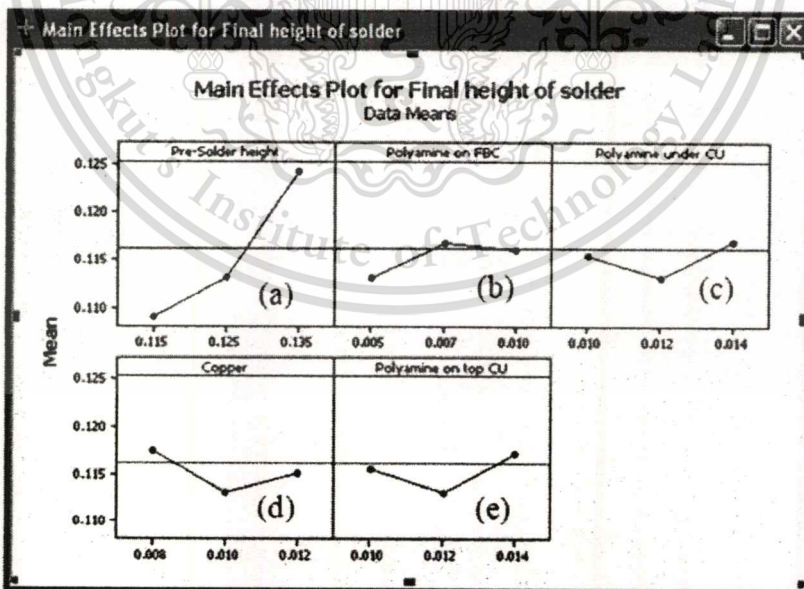


Figure 4.1.5 Main effect plots for final height of solder

Figure 4.15 shows main effects plots for final solder joint shape after passed solder bonding process. A comparison of relative thickness which is changeable in each parameter at 0.110 until 0.125 of X-Axis are final height result (a) block, it obviously perceived that. It affected to solder joint after past bonding process. Look at the end of the both side of the line, it's widened to each other nearly to be the straight line and produce 45 degree. When compared with the axes of Y and X. It's very greatest when compare with another parameters. The main effect of final height after passed soldering process is pre-solder height that important to control incoming material.

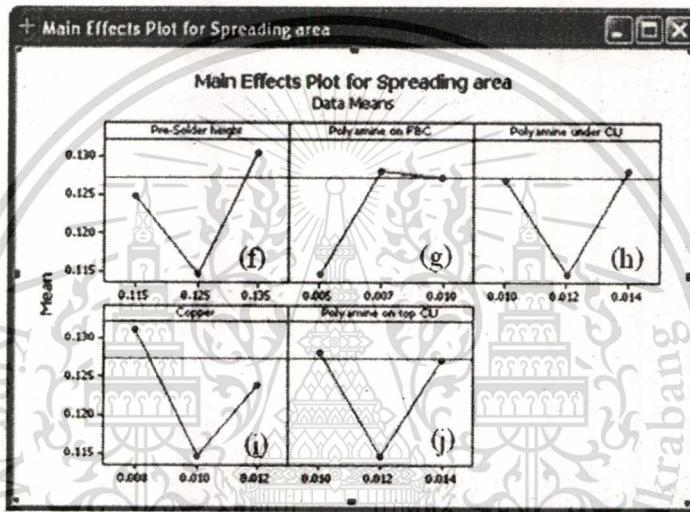


Figure 4.16 Main effect plots for spreading area

Figure 4.16 shows main affects plots for spreading area of solder joint shape after passed solder bonding process. A comparison of relative thickness enables change able in each parameter. Look at the end of the both side within the blocks (e) to (i). It's obviously perceived that there is not any line which nearly to be the straight line. That means. Thickness is not affected to the solder joint after past bonding process.

4.4 Validation of simulation result with HGA LT

Comparison of predictable to the shape of solder which derived from simulation model and the result from the real works, to cut and take a photo through the microscope as to make more reliability of simulation models.

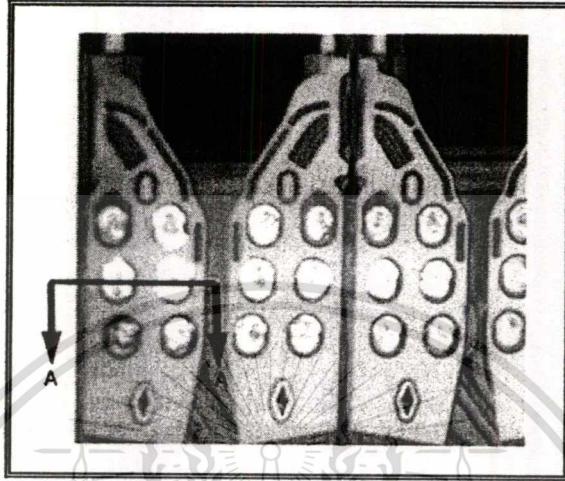


Figure 4.17 HGA LT and FCB before cross section

Figure 4.17 shows HGA LT and FCB after pasted bonding process. We can see the section line A-A for determine the direction of cross section (x-section) on the sample. The crosses section for inspection the rule result of final shape of solder joint

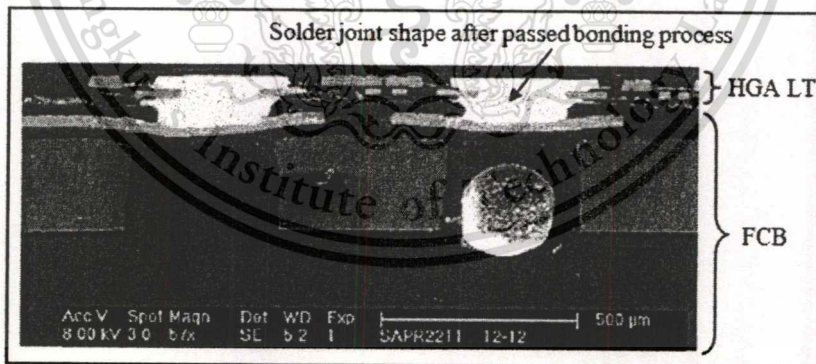


Figure 4.18 Cross section of specimen

Figure 4.18 shows the result of cross section which takes a photo by 57 x of microscope compared with the life size at 500 micron (0.5 mm), before section with the roller cutter, molding by liquid resin and harden in order to not affect the shape of solder. After that, Shining its surface to make smoothly plain and results to the photo with height efficiencies, as to created move

coincidence to what we interesting and examine the dispersion behavior of the solder as in the next picture.

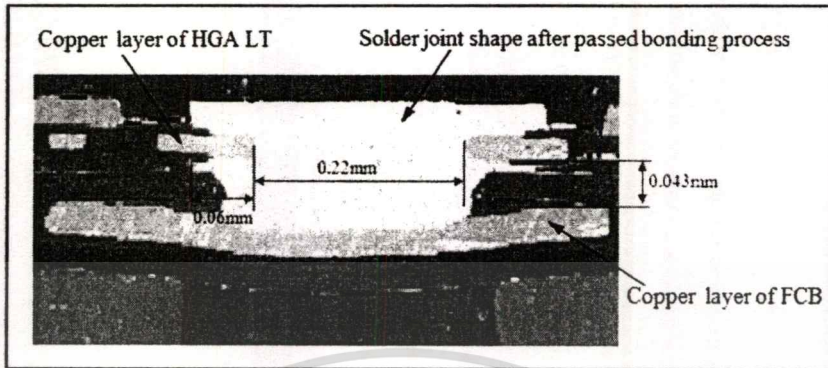


Figure 4.19 Zoom in cross section of specimen

Figure 4.19 shows the enlargement of dash line square frame on the picture 2, In order to facile to measure the size of solder after passed bonding process and as to understand the movement of liquid solders which affected to solder joint at final shape. We compared the size of cross section result and stimulation result, with comparator measurement of solder after passed bonding process.

Figure 4.19 dimension of sizes 0.043 is the gap between HGA LT and FCB. We used this size to compare with the model with the same size of gap, thus use it to form the validated of an experimental result. The reason that we have selected same model, because its vary by thickness of each layer, refer by the tolerance of drawing, when we establish the model and causes the gap which different size for 0.22 mm, a size of key at HGA LT and 0.66, a solder mass which movement on the surface of copper layer at HGA LT

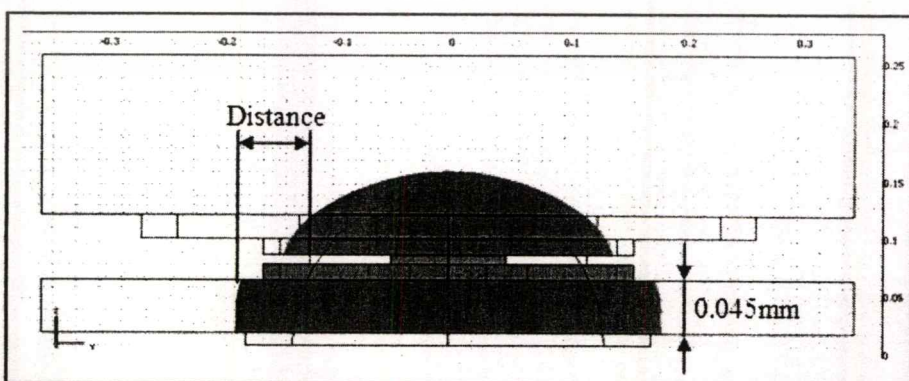


Figure 4.20 Simulation result at the gap between HGA LT and FPC equal 0.045 mm.

Figure 4.20 shows the position of movement of solder mass on simulation result and expose the gap between HGA LT and FCB, that's 0.045 mm. The distance that shows in fixture is movement length of solder mass from original point. We validate the movement length same as actual sample part figure 4.19 at distance 0.06mm

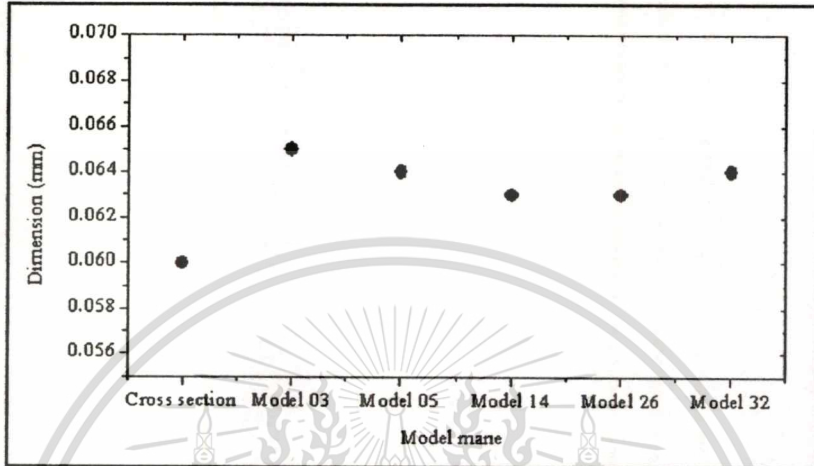


Figure 4.21 Comparison of cross section result and the result of solder mass movement dimension

Figure 4.21 shows comparing graph of solder mass after bonding process by measurement the originate values form the edge of circular key hole. The result from the 5 models of mean are 0.0638 mm, It greater than the cross section result. If was $0.0638 - 0.06 = 0.0038$ mm or 6%. We prove the model capable to predict solder joint shape after passed bonding process.

4.5 Simulation result of Heat Transfer model

In designation of experimental test, we're appreciated the principle of laser. The density of light is in the middle part and it shall be continuously decrease by the distant of the centre, as seen in figure 4.24. It's an origin of grid construct in simulation model as in figure 4.23

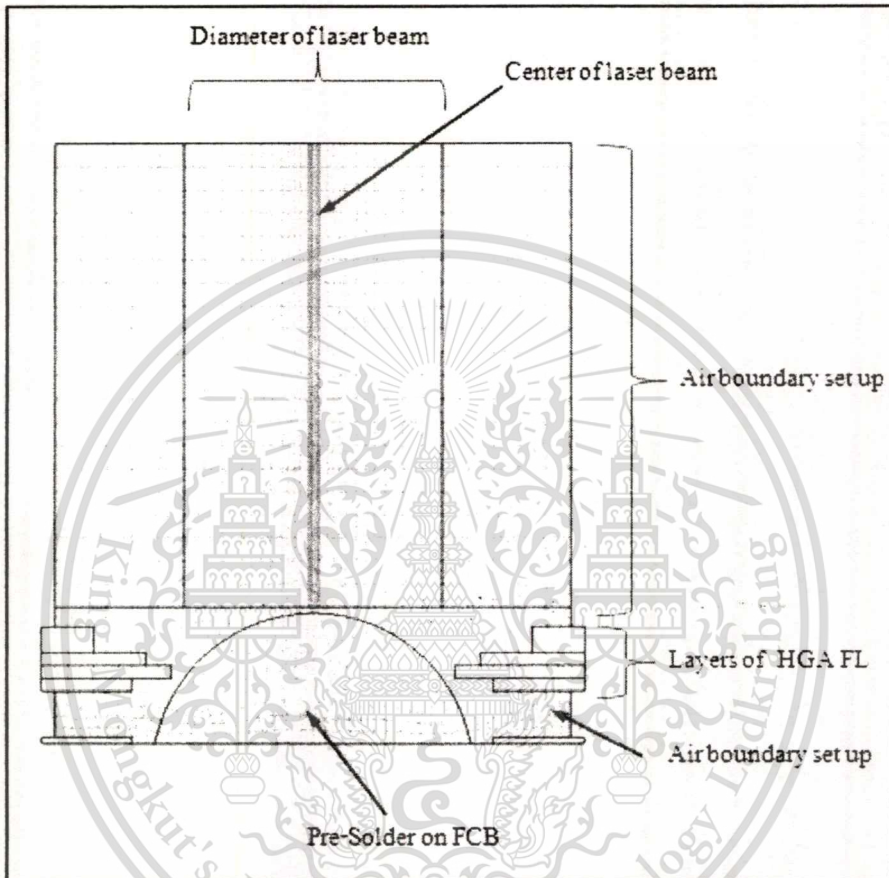


Figure 4.22 Mesh result of hest transfer model mesh consist of 1858 elements

Figure 4.22 shows the meshing result of heat transfer model. Diameter of laser beam means. We identify the area that applied for the power of laser beam by the way, the density of laser at the middle point of the highest density point, then the establish of middle, must be concentrate at the dispersion of light at the middle point, where the highest light density. From the picture at the center of beam must be construct the mesh which highest frequency and continuously decrease when the radius were far away from the center of laser beam. Air boundary set up is an external definite for the diameter of laser beam in room temperature. Air boundary set up from bottom-up of the picture. It's also creating the square meshing, too. Layer of HGA LT and pre-solder on FCB are also creating of square meshing. It was concluded that the arising of

mesh for air boundary, layer of HGA LT and Pre-Solder on FCB. It attained 1858 elements, which the patterning of thermal energy occurring shall be exposé in the next topic.

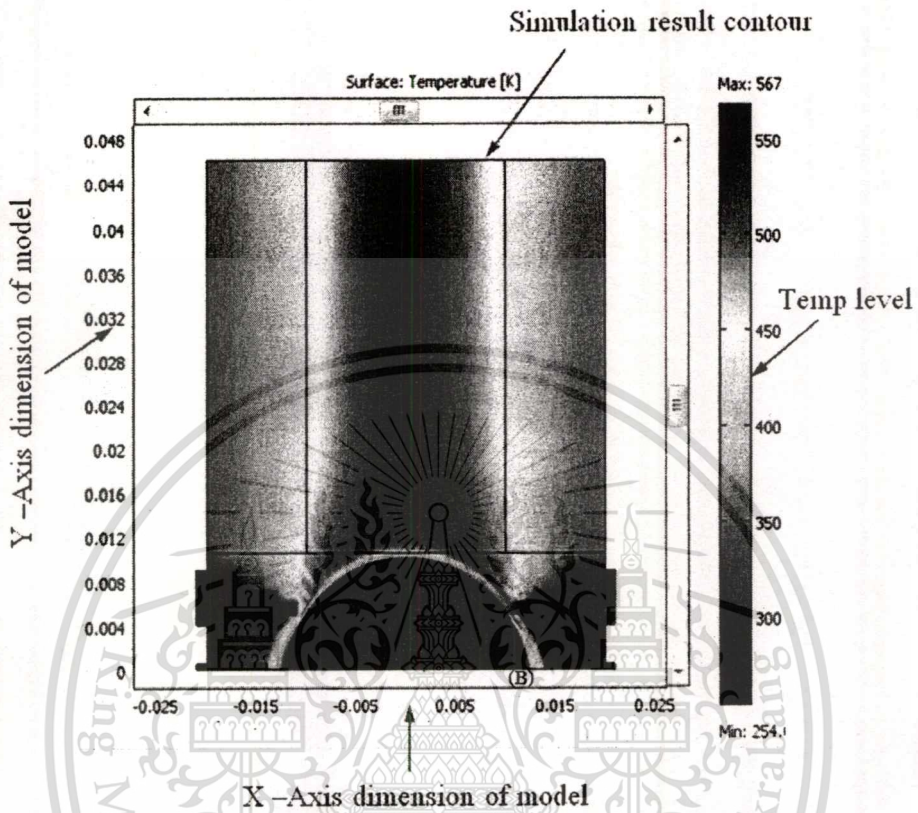


Figure 4.23 Temperature distributions contour of laser beam

Figure 4.23 show the temperature distribution of laser beam, from the volume of laser capillary trip at 0.2 mm at 60 second simulation time by hypothesis and from the theory the heating point is in the middle part of laser diameter, from the result. It accords with the theory. The warm side is on the right side of the peak. Locally the temperature reaches around 550 K, but this values completely meshing dependent. Nevertheless, the temperature distribution was just a few mesh elements away. It is represents the real temperature quite well.

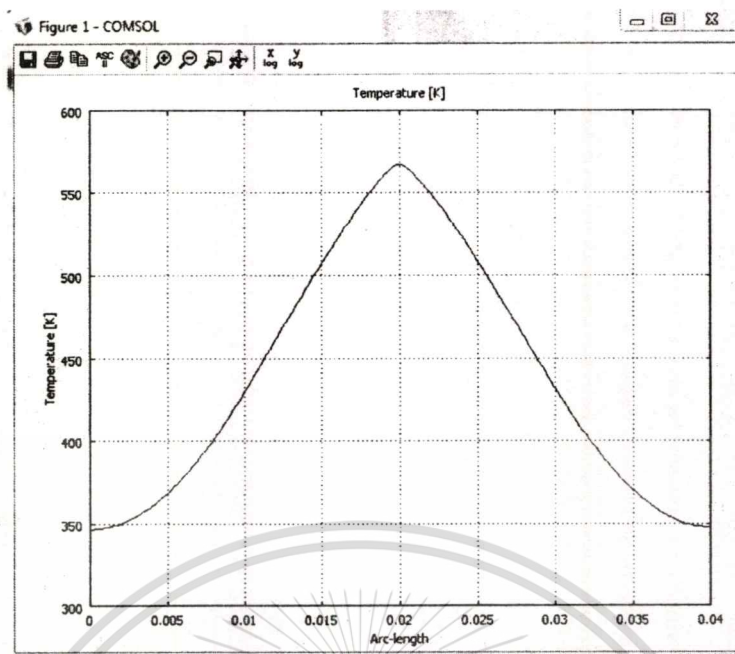


Figure 4.24 Temperature power profile of laser beam

Figure 4.24 shows the temperature plot at difference power applied. Y axis is the temperature of simulation result. It starts from room temperature at 300K until result, this is beam was described by a Gaussian distribution [19]. X axis is a simulation time which originates from zero to 60 second seeking for acceptable temperature and melting time, then utilize to reference with the real achievement. The first thing we anxiety is the temperature at 550 K (See figure 4.24 at Y axis). It's an agreeable zone for melt solder.

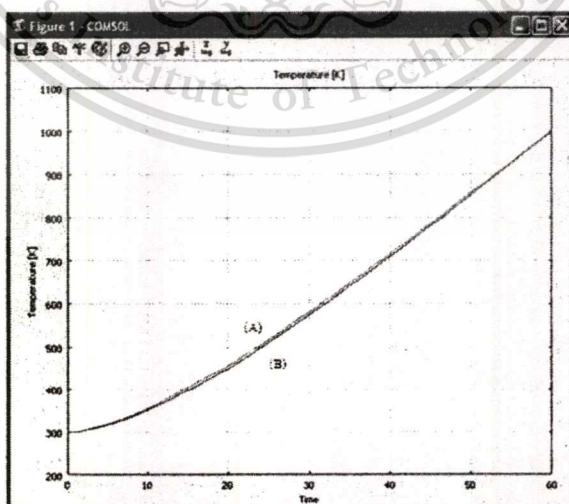


Figure 4.25 Temperature power incident trajectories at pre-solder surface

Figure 4.25 shows the time plot at difference applied. Y axis is the temperature of simulation result. (A) and (B) graft are temperature result at difference time (0-60Sec) start from around 300 K up to 1000 K. (A) and (B) that refer the point of temperature result on Fig2.3.

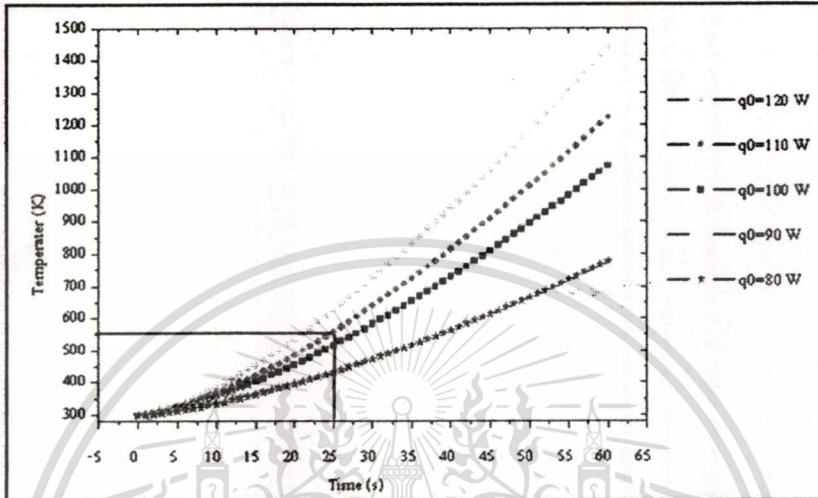


Figure 4.26 Dependence of power level HGA LT

Figure 4.26 shows the temperature plot at difference power applied Y axis is temperature of simulation result start from room temp 300K until maximum of simulation result able to cover is 1500 K. X axis is simulation time from zero to 60 second. The appropriate of temperature is 550 K and melting time is 25 second bases on simulation result.

Chapter 5

Conclusion

This thesis presented the studies of solder joint shape after passed solder bonding process. First of all, we reviewed all literature related to solder joint shape knowledge and Laser beam for solder melting. And we found that the solder joint shape is depending on behavior of physical wetting angle and spreading [2], the mainly factor are surface roughness [5], surface tensions and gravity field. In case of laser beam, we reviewed YAG Laser wave length 355 nm [6] for melt solder, the main factors which have to pay more attention is the temperature from laser beam. Then we proposed a Level set method for predicting solder joint shape after passed solder bonding process and developed the model for Heat transfer distribution.

First of all we have done the experimentation on water droplet by using high speed camera to capture water drop on flat stainless steel surface at room temperature. The objective for this study to understand behavior of water's shape then take these results to compare with second experiment.

Then we have done the stimulation of solder joint shape after passed bonding process without HGA long tail by using COMSOL Program. The simulation technique by used of a level set method. The objective of this model is to validate model at initial state. The result indicated similar behavior for all physical changed (height, spreading and wetting angle) when compare to water droplet. We also compared behavior amount physical changed, the result showed as following;

More height → less spreading → more wetting angle

Low height → more spreading → less wetting angle

Based on above data, we can proved that a level set method is capable to apply for predict solder joint shape after passed bonding process.

Next, we added HGA long tail to the model and simulated by used a level set method. We recorded three physical changed of solder joint shape after passed bonding process. The result when compared to 2nd experiment (simulation without HGA long tail) indicated height and spreading area are similar with 2nd experiment while wetting angle is difference since 2nd simulation used flat surface but this model used surface of FCB and HGA long tail. We can

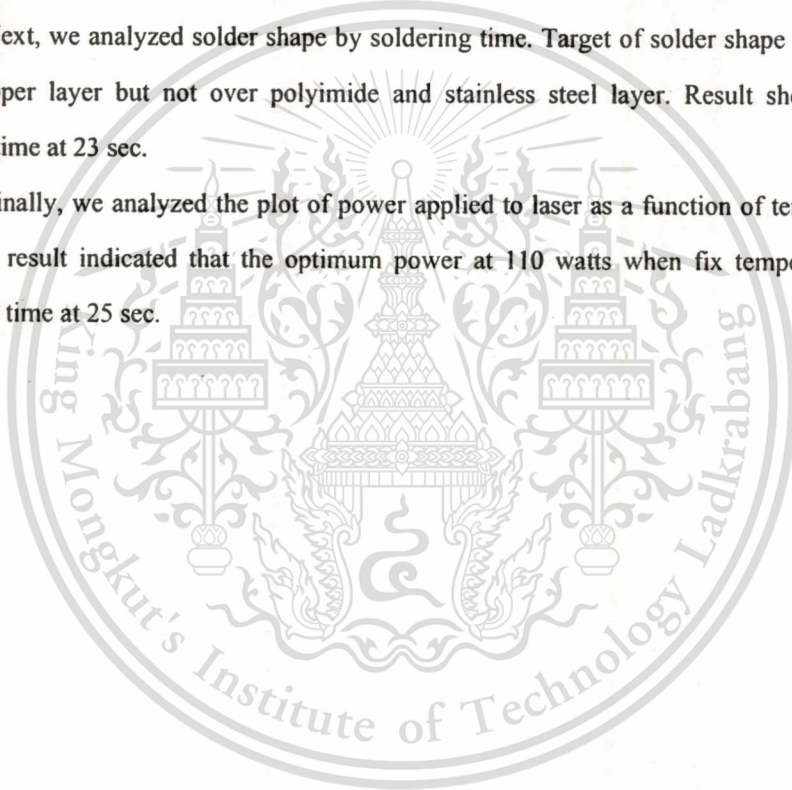
conclude that surface roughness is related to behavior of wetting angle after solder bonding process.

Next, we studied main effect of solder joint shape changed after solder bonding process. The study follow DOE full factory by varying 5 parameters, 3 level each parameter, totally 32 models. And analysis data by main effect plot. The result indicated pre-solder height is main factor of solder joint shape after passed bonding process. Base on the result we recommend controlling height of pre-solder.

Next, we compared distance of solder mass after solder bonding process with actual solder bonding sample. The comparison result showed that the difference distance at 6%.

Next, we analyzed solder shape by soldering time. Target of solder shape is solder mass cover copper layer but not over polyimide and stainless steel layer. Result showed that the optimum time at 23 sec.

Finally, we analyzed the plot of power applied to laser as a function of temperature and time. The result indicated that the optimum power at 110 watts when fix temperature at 550 Kevins and time at 25 sec.

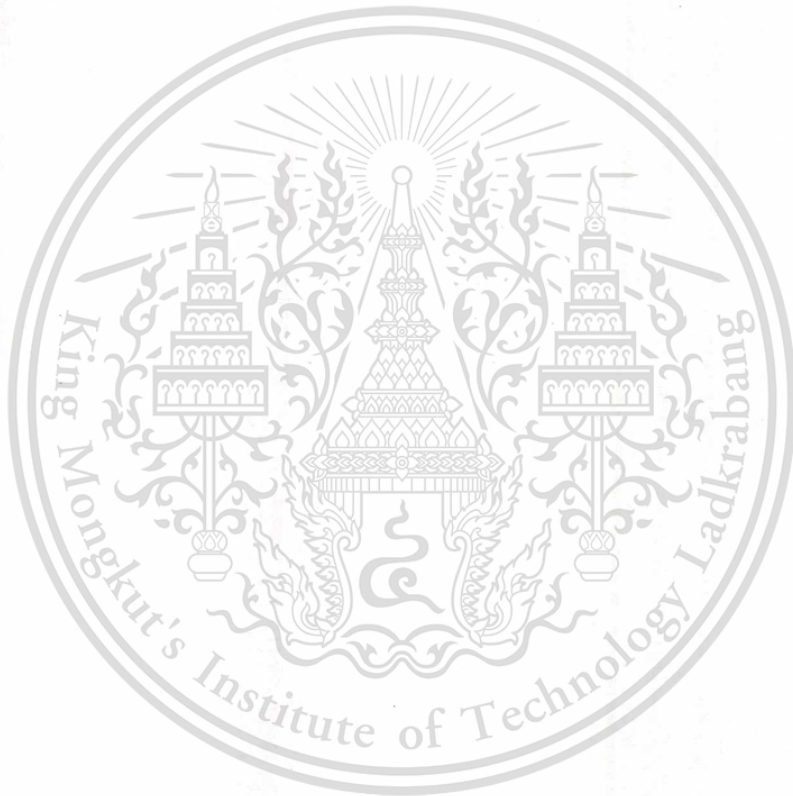


References

- [1] S.W.Or, H.L.W.Chan a, V.C.Lo a, C.W.Yuen. **“Ultrasonic wire-bond quality monitoring using piezoelectric sensor.”** Department of Applied Physics and uterials Research Center, The Hong Kong Polytechnic University, Hughom, Kowloon, Hong Kong A S M Assembly Automational Ltd. 4/F, Watson Center, 16 Kmg Y i p Street, Kwai Chung, Hong Kong, Hong Kong
- [2] Y. X. Gao, H. Fan, Z. Xiao **“A Thermodinaics Model for Solder Profile Evolution.”** School of Mechanical and Production Engineering, Nanyang Technological University Singapore 639798, Republic of Singapore
- [3] Tanai L. Marin **“Solidification of a Liquid Metal Droplet Impinging on a Cold Surface.”** University of Chile, Faculty of Physics and Mathematics Sciences Department of Mining Engineering Av. Tupper 2069, Santiago, Chile
- [4] Kwang-Lung Lin and Steven Yao **“Solder Thickness Variation with Respect to Soldering Parameters”** **IEEE Trasation on components and packing technologies.**, vol.23, no. 4, December 2000.
- [5] Tamás Hurtony, Bálint Balogh, Péter Gordon. **“Optimization of Flip-chip Laser Soldering forLow Temperature Stability Substrate.”** Budapest University of Technology and Economics Department of Electronics Technology Goldmann tér 3, 1111 Budapest, Hungary
- [6] E. Bovet, L. Preziosi, B. Chiaia. F. Barpi. **“The Level Set Method Applied to Avalanches.”** Politecnico di Torino C.rso Duca degli Abruzzi 24, 10129 Turin Italy
- [7] Sara Z, Katarina G, Gunilla K. **“A conservative level set method for contact line dynamics.”** School of Computer Science and Communication, Royal Institute of Technology, 100 44 Stockholm, Sweden.
- [8] TIAN De-wen, WANG Chun-qing, TIAN Yan-hong. **“Effect of solidification on solder bump formation in solder jet process:Simulation and experiment.”** School of Materials Science and Engineering, Harbin Institute of Technology, Harbin 150001, China.

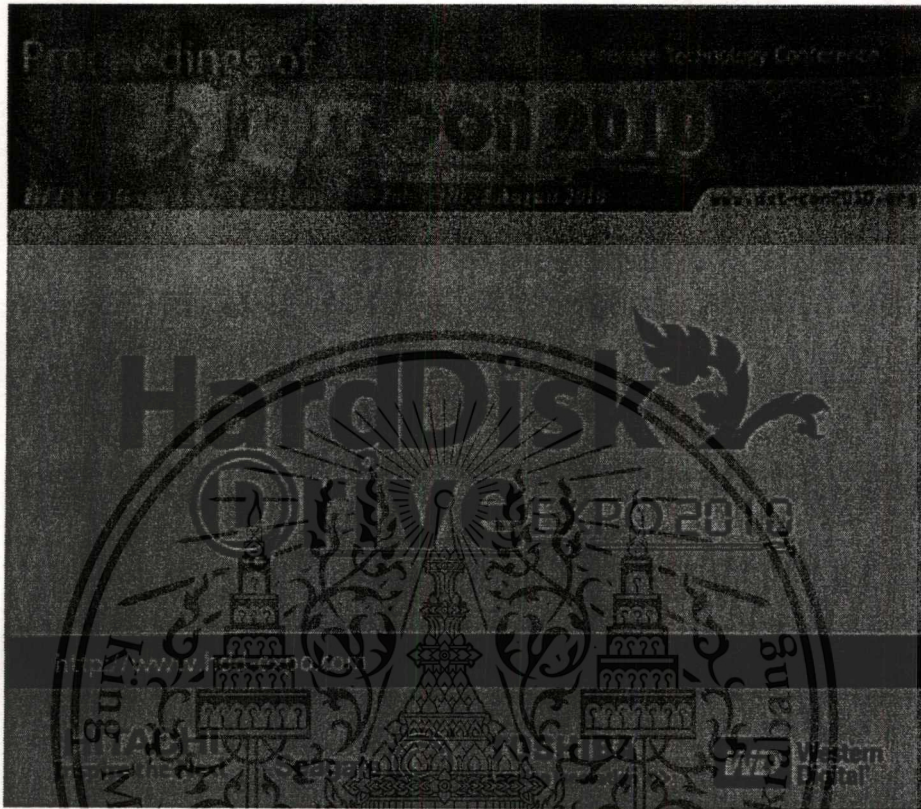
- [9] Y. Takeuchia, K. Yamanoia, Y. Endo, S. Murakamia, K. Izum . **“Velocities for the dry and wet snow avalanches at Makunosawa valley in Myoko.”**, Japan
- [10] Y.-S. Yang, H.-Y. Kim, J.-H. Chun **“Spreading and Solidification of a Melten Microdrop in the Solder Jet Bumping Process.”** Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, MA 02139 USA
- [11] W.M. Healy, J.G. Hartley, S.I. Abdel-Khalik **“On the Validity of the Adiabatic Spreading Assumption in Droplet Impact Cooling.”** Building and Fire Research Laboratory National Institute of Standards and Technology Gaithersburg, MD 20899-8632 USA
- [12] Wolfgang Hornv **“Welding and Soldering with High Power Diode Lasers.”** DILAS Diodenlaser GmbH, Galileo-Galileo-Str.10, 55129 Mainz, Germany
- [13] T. Teutsch, L. Titerle, T. Oppert, G. Azdasht, E. Zakel **“Laser Assisted Soldering and Flip-Chip Attach for MEMS Packaging.”** Pac Tech-Packaging Technologies USA, Inc 328 Martin Avenue Santa Clara CA 95050 USA
- [14] H.-Y. Kima and J.-H. Chun **“The recoiling of liquid droplets upon collision with solid surfaces”** Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139
- [15] Tadmor, Rafael (2004). **“Line Energy and the Relation between Advancing, Receding, and Young Contact Angles.”** Langmuir 20 (18): 7659. doi:10.1021/la049410h. PMID 15323516.
- [16] Javier Alda **“Laser and Gaussian Beam Propagation and Transformation.”** University Complutense of Madrid, Madrid, Spain
- [17] S. G. KANDLIKAR and M. E. STEINKE **“CONTACT ANGLES OF DROPLETS DURING SPREAD AND RECOIL AFTER IMPINGING ON A HEATED SURFACE.”** Mechanical Engineering Department, Rochester Institute of Technology, New York, USA
- [18] F. P. Renken, G. Subbarayan **“A Two-Body Formulation for Solder Joint Shape Prediction.”** CAMPmode: Center for Advanced Manufacturing and Packaging of Microwave, Optical, and Digital Electronics, Department of Mechanical Engineering, University of Colorado at Boulder, Boulder, CO 80309-0427

- [19] Alexander F. H. Kaplan “**Modelling the Primary Impact of an Yb Fibre Laser Beam Profile on the Keyhole Front.**” Lulea University of Technology, Dept. Engineering Sciences and Mathematics, SE-971 87 Lulea,Sweden



Appendix

Hard Disk Drive Expo2010



This material is reserved for educational use only, not allowed for commercial use.

Forbidden to modify the content, and cite the document when use.

A Level Set Method for the Simulation of the Soldering Process at HGA Long Tail

A Thongsuksar^{*)}, S Boonsang^{**)}

^{*)} College of Data Storage Technology and Applications, King Mongkut's Institute of Technology, Ladkrabang, Bangkok 10520, Thailand

^{**)} Electronics Department, Faculty of Engineering, King Mongkut's Institute of Technology, Ladkrabang, Bangkok 10520, Thailand

Abstract— in this paper, the level set method is applied to a fluid flow problem of a molten solder at Head Gimbals Assemblies (HGA) Long Tail (LT) and Flex Circuit board (FCB). The system constituted by air and molten solder is considered as a domain composed by two fluids which have different densities. In particular, a fluid-like constitutive behavior is assumed for solder as well as a Newtonian one. The 2D model simulation is used to predict the solder mass towards HGA LT layer. The simulation results indicate that the optimum time setting of a molten solder is 0.25 seconds.

Keywords— Level set method, Newtonian, Soldering deformation.

I. INTRODUCTION

One of the key processes in Head Stack Assembly process is to make electrical connection between Head Gimbals Assemblies (HGA) Long Tail (LT) and the input of preamplifier part. However, faulty solder joints remain one of the major causes in the assembly process. The simulation of the soldering process may be helpful to predict the soldering behavior. This could help the process engineers to reduce their time and cost to optimize the soldering process.

Many techniques are used for developing solder joint shapes such as a level set method. The simulation presented by Tanai L. Mann, using a level set method to simulate of a liquid mass droplet impinging on a cold surface, shows that the liquid droplet spreading onto the substrate surface is spreading without phase change [1]. The other simulation presented by Sara Zahedi, et. al. was studied on the distance between two contact points plotted as a function of time [3]. And comparison the velocity of snow two situation are dry and wet by Y. Takeuchi, et. al. They studied natural avalanches of dry and wet snow started in the same zone and ran the same path. They calculate results by Voellmy's model. Velocity for the dry was 43 m/s and for the wet was 30 m/s [4].

II. GOVERNING EQUATION

A. Fluid Flow

The flow of the liquid solder and gas surrounding the fluid were modeled by using the Navier-Stokes equations

for incompressible laminar flow [1-2]

$$\rho \frac{\partial u}{\partial t} - \nabla \cdot (\nu \nabla u + (\nabla u)^2) + \rho(u \cdot \nabla)u + \nabla p = F \quad (1)$$

$$\nabla \cdot u = 0 \quad (2)$$

In above equations, ρ [kg/m³] denotes the density, u is the velocity (m/s), t equals time (s), p is the pressure (Pa), and surface tension force is denoted by F .

B. Level Set Method

In the model proposed in this study, the liquid-gas interface is tracked by the Level Set method. A brief description of this method is given below. A volume function ϕ is defined such that it takes strictly negative values for the liquid phase, zero at the interface and strict positive values for the gas phase. The function ϕ is advected by the fluid flow according to the following equation [1-2]

$$\rho \frac{C\phi}{\Gamma} + \mu \nabla \cdot \phi = 0 \quad (3)$$

III. EXPERIMENT SETUP

In our study, we used COMSOL program to create the HGA long tail soldering module and used the level set method [1] to simulate and find out the optimum dimensionless time of soldering process.

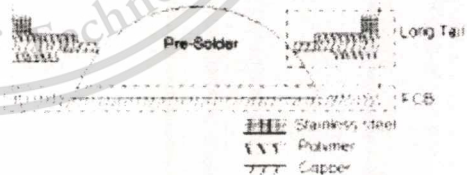


Figure 1. Model of the assembly parts of HGA long tail and Flex circuit board (FCB).

Figure 1 shows the model of assembly parts of HGA long tail and flex circuit board which is pre-soldering process. The solder is used for bonding the HGA long tail to flex circuit board. FCB is including tow layer from bottom of flex circuit board, the first layer is copper and the second is polymer. The long tail is consisting of 4 layers, polymer, copper, polymer and stainless steel.

Figure 2 shows the domain setup of the soldering simulation. We separated the model into 4 sub-domains, sub-domain 1, 3 and 4 is air and sub-domain 2 is solder (Lead free 96.5Sn-3.5Ag).

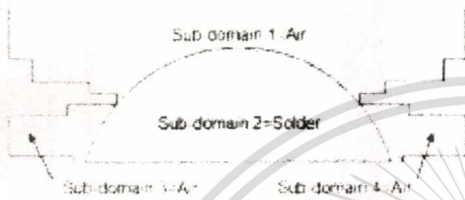


Figure 2. 2D model using for solder simulation

IV. RESULT AND DISCUSSION

Figure 3 shows the simulation result of a solder spreading diameter changed as function of dimensionless time. Y axis is spreading diameter and X axis is time. The result shows that the spreading diameter is increasing during the time from starting until 0.7 seconds, the maximum value at 79.6 micrometers.

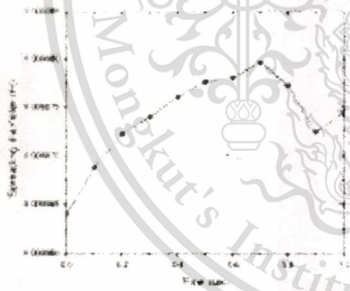


Figure 3. Spreading diameter of liquid solder

Figure 4 shows spreading dimension of each time. From the result, at time 0.25 seconds, the liquid solder expand and rise to the edge of copper long tail which is the optimum point of soldering process. Based on the result we suggested that in actual soldering work the optimum time for closing the air gap between long tail and base should be considered.

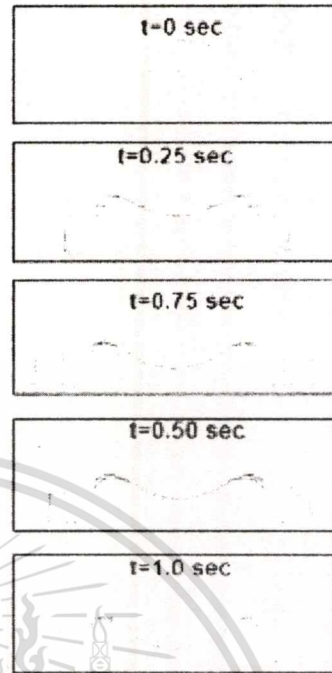


Figure 4. The deformation shape of a liquid solder per each time (t = 0, 0.25, 0.5, 0.75 and 1 second)

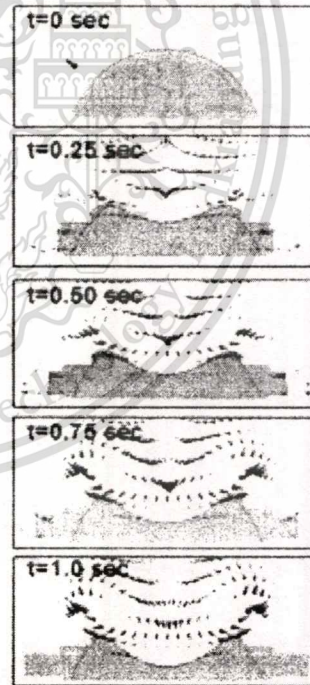


Figure 5. The Velocity field of liquid solder flow per each time (t = 0, 0.25, 0.5, 0.75 and 1 second)

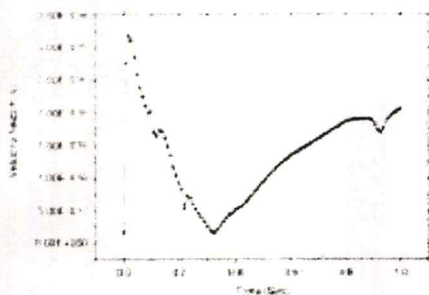


Figure 6. The Velocity field value of liquid solder flow

Figure 5 shows the interface and the velocity field at five different times following the initial stage.

Figure 6 shows simulation result of a velocity field diameter changed as function of dimensionless time. Y-axis is velocity value and X-axis is time. The result shows that the velocity field value is increasing during the time from starting until

V. CONCLUSION

We have developed and presented a level set method for two phase flow. In our model, we concluded that for the soldering process, the soldering time has optimum point at 0.25 seconds based on 2 dimensions simulation.

By the way, the further study on 3 dimensions model should have more accurate result.

ACKNOWLEDGMENT (HIMADUS)

This paper is supported from Industry/University Cooperative Research Center in Data storage Technology and Applications, King Mongkut's Institute of Technology Ladkrabang and Western Digital (Thailand) Co. Ltd.

REFERENCES

- [1] Tania J. Martin "Solidification of a Liquid Metal Droplet Impinging on a Cold Surface" University of Chile Faculty of Physics and Mathematics Sciences Department of Mining Engineering, Av. Tupper 2069, Santiago, Chile
- [2] E. Bosvi, L. Preziosi, B. Chua, J. Blum "The Level Set Method Applied to Avalanches" Politecnico di Torino Corso Duca degli Abruzzi 24, 10129 Torino, Italy
- [3] Sara Z. Katarina, G. Ganilla K. A conservative level set method for contact line dynamics. School of Computer Science and Communication, Royal Institute of Technology, 100 44 Stockholm, Sweden.
- [4] Y. Takeuchi, K. Yamazoe, Y. Endo, S. Murakami, K. Iwami "Velocities for the dry and wet snow avalanches at Makumozawa valley in Miyoko, Japan"

Author Biography

- Author** Mr ANGKHAN THONGSUKSAI
- Date of Birth** January 30, 1979
- Address** 97/354 Moo. 1 Bungyitho Thumyaburi Phatumthani 12130
Email. Bgfcklong3@gmail.com, Angkhan.thongsuksai@wdc.com
- Education** 2000, Graduated in Bachelor of Industrial Engineering of Srinakharinwirot University.
2011(Present), Master degree of Engineering in college of Data Storage Technology and Application of King Mongkut's Institute of Technology Ladkrabang.
- Published research** "A Level Set Method for the Simulation of the Soldering Process at HGA Long", the 3rd International Data Storage Technology Conference 2010 (DST-CON2010) on 30 Jul - 1Aug 2010, Bangkok, Thailand.

