DEDICATED FIXTURE DESIGN FOR POLISHING OF SILICON

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I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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To beloved Mom and Dad, the love of my life

“Vision without action is day dream and action without vision is a nightmare”

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ABSTRACT

Polishing of silicon is a major process seen in microelectronic and optical industries. As mirror-like surface finish is an essential factor that influences the performance of electronic and optical products, it has been believed that the fixture in finite element does play a role to produce such a quality surface on silicon. This paper centers on designing the fixture in finite element environment for polishing of silicon. Polishing process was virtually developed using general purpose FE codes. Process model consist of major components needed for polishing such as the base plate, the pad, the abrasive, silicon and of course of fixture. Currently only 2D model was considered because of the complexity of the process and limitation of the FE code. Fixed diamond abrasive proposed by VTT microelectronics was created in FE model to overcome the modeling difficulty of loose abrasives, to conveniently define polishing forces involved, and also investigated the effectiveness of the new abrasive design. Polishing forces were split into two-normal and tangential forces. The presence of micron-size diamond abrasive was modeled by defining friction coefficient at the interface between silicon and abrasive sheet. Typical values of polishing forces were defined as recommended by manufacturer. Finer mesh was designed at the top layer of the silicon in order to simulate the action of the diamond abrasive realistically. Polishing process was simulated by changing the various fixture designs. The goodness of the fixture design was justified by absence of high stress concentration in anywhere in the silicon.

ABSTRAK

Proses menggilap silikon adalah proses yang sangat penting didalam industri mikro-elektronik dan optik.Faktor penting yang mempengaruhi keberkesanan mikro-elekronik dan optik produk adalah ialah pemukaannya yang seperti cermin, maka dipercayai bahawa pemengang khas memainkan peranan penting dalam proses menggilap silikon.Tesis ini menfokuskan penciptaan pemengang silikon dalam kaedah “finite element”. didalam proses menggilap. Proses menggilap dilakukan secara tidak nyata melalui kod umum FE. Bahagian utama didalam proses adalah seperti plat dasar, pelapik kesat, silikon dan yang terutama sekali adalah pemengang khas. Kini hanya model dua dimensi yang di pertimbangkan memandangkan kod khas didalam “finite element” adalah terhad dan sangat rumit. Pelapik belian kasar jenis tetap yang di cadangkan oleh VTT mikro-elekronik telah dimodelkan untuk mengatasi kesukaran pelapik kesat jenis tidak tetap. Untuk memudahkan kerja, daya penggilap ditentukan dan keberkesanan penciptaan pelapik kesat yang baru turut dikaji. Daya penggilap terbahagi kepada dua jenis iaitu daya” normal and tangential”. Untuk menunjukan berlian kesat yang bersaiz mikro, ianya dimodelkan dengan pekali geseran pada permukaan diantara silikon dan pelapik kesat. Daya-daya penggilap sebenarnya ditentukan berdasarkan cadangan oleh industri. Untuk menunjukan kesan simulasi menggilap yang nyata “mesh” yang halus di lakukan pada bahagian atas silikon. Keberkesanan pemengang khas adalah ditentukan berdasarkan kehadiran tekanan daya yang kuat dan menumpu pada mana-mana bahagian silikon.

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σ_z	-	Stress of z-axis
τ_{xy}	-	Shear stress of x and y axis
τ_{xz}	-	Shear stress of x and z
E	-	Modulus of Elasticity
FE	-	Finite Element
FEM	-	Finite Element Method
FEA	-	Finite Element Analysis

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CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Silicon has been sought for 90% application in optical and electronic industries. It has played a major role in infrared application, integrated circuit technology and Microelectro-mechanical systems (MEMS) components. Performance of the component rely on the surface integrity, where polishing is an essential. However characteristic of silicon is very often make polishing process difficult. One of these is its brittleness. In order to obtain a surface with mirror finish and perfect form, fixture design is one of the influencing factors

Fixture can be classified as dedicated or reconfigurable. Dedicated fixture generally implies that they have been designed for specific workpiece geometry. Therefore dedicated fixtures are specially designed and fabricated for a given workpiece and are used in mass production due to the advantages of specially designed performance, such as convenient operation, stiff support in desired directions, and efficient structural space utilization.

Since fixture design contributes significantly to the manufacturing quality and lead time, it is desired to automatically design and verify dedicated fixture in the product design and manufacturing planning stage so that alternative designs can be compared for optimal solutions.

Fixture design research using computer aided design started early 1980s. Computer-aided fixture design (CAFD) techniques have been advanced rapidly so that fixture configurations can be generated automatically. Interactive fixture design techniques were built up on top of commercial computer aided design system and expert system tools.

However the approach were mainly concerned with fixture configuration and there are little analysis. Comprehensive fixture design should have analysis at different computational level. In this aspect, finite element modeling and analysis can be a good choice.

1.2 PROBLEM STATEMENT

In the optical and electronic industry surface integrity is a major quality- related problem. polishing of silicon is essential process, where dedicated fixture play important role to produce a component of high quality finish, however the important design concept seem to be overlooked and often design is based on try and error. Brittle nature of silicon is problematic in polishing.

1.3 OBJECTIVE OF THE PROJECT

I. To develop virtual process polishing using finite element method.
II. To design a fixture based on the analysis at different computational level.
III. To obtain database for feasible fixture design of polishing process.

1.4 SCOPES

I. The fixture used in typical polishing machine will be designed.
II. General purpose finite element code (ALGOR) will be used to design and analysis feasibility of fixture design based on stress theory.
III. Simulation of polishing process will be carried for various fixture geometries and material
IV. Design feasibility will be based on theories of plasticity and fracture mechanics

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Fixtures are important in both traditional manufacturing and modern flexible manufacturing system (FMS), which directly affect machining quality, productivity and cost of products. The time spent on designing and fabrication fixtures significally contributes to the production cycle in improving current product and developing new products.

Therefore, great attention has been paid to study of fixturing in manufacturing (Thomas and Ghadhi, 1986). A fixture design used in machining, assembly, welding and other manufacturing operation to locate and hold a work piece firmly in position so that the required manufacturing process can be carried out corresponding to design specifications (Nee and Senthil kumar,1991).

2.2 FIXTURE

Fixtures were develop for job, batch and mass productions, which are widely used in manufacturing operations locate and hold a part firmly in position so that the required manufacturing process can be carried out according to design specifications (Hoftman,1991)

In machining processes geometry accuracy of manufactured part mainly depend on the relative position of workpiece (silicon chip) to the machining tool (Rong, 1988).Fixture are needed to locate the workpiece relative to the machining tool in order to ensure the manufacturing quality. It is clear that the primarily requirement s for a fixture are located and secured the workpiece in a given position and orientation on a worktable of a machining tool.

To secure the workpiece on a fixture, clamps are often utilized to keep a stable location against the machining force. Clamping method can be classified into top and side clamping, which may provide normal and friction force, but in this case polishing due on top surfaces and top clamping is not encouraged. The fixture must be rigid enough to resist the harmful deformation and vibrating during machining. Clamping method and clamping position should be carefully selected to firmly hold the workpice .

In addition to the primary requirements in fixture design, many other demands also found, such as ensuring productivity like easy load and unload of the workpiece, utilization of automated or clamping semi automated devices. Special design for reducing formation of weak rigidly parts, simple and safe operation and effective cost reduction.

Hence the fixture design is complicated process. The application of these fundamental principles to individual fixture design depends on primarily designer's experience in manual fixture design.

2.3 DEDICATED FIXTURES

Since dedicated fixtures are commonly used in mass production, dedicated fixtures design are usually applied the fixture construction is perfectly designed for specific operation. As part of machining tooling, the application of dedicated fixture has greatly contributed to the development of automated manufacturing system. Therefore dedicated fixture designs are specially designed for each specific operation, with special consideration of fixture structure, auxiliary support, and other operational properties.

Moreover, the operations can be conducted quickly and the tolerance requirement can easily assured in the operation. The problem involving in dedicated fixture application includes the flexibility and long lead time required to designed and fabricate the fixture. When product design change like the shape and the size changes he dedicated fixture are usually not longer useful and scrapped. Today a flexible fixture is desired to a certain extent in order to design variations of the products.

2.4 FIXTURE DESIGN PRINCIPLE

Fixtures are one of operational equipment in manufacturing which are used to ensure the product quality and operational efficiency. Fixture design is desired to be rapid or on time, effective and economic.

2.5 POLISHING PROCESS

Polishing is the removal of material to produce a scratch-free, specular surface using fine (<3 μm) abrasive particles. Polishing is typically done at very low speeds using either polishing cloths, abrasive films, or specially designed lapping plates. Polishing with a cloth or lapping plate requires the use of free abrasive, and is a very low damage process when performed properly. Plate material and cloth material are critical when polishing a particular sample as the properties of these substrates are important in the final polish quality of the specimen.

2.5.1 Lapping

Lapping is the removal of material to produce a smooth, flat, unpolished surface. Lapping processes are used to produce dimensionally accurate specimens to high tolerances generally less than 2.5 μm uniformity. The lapping plate will rotate at a low speed (<80 rpm) and a mid-range abrasive particle (5-20μm) is typically used.
Lapping removes subsurface damage caused by sawing or grinding and produces the required thickness and flatness. Although the lapping process is less damaging than grinding, there are two regimes of lapping free abrasive lapping and fixed abrasive lapping.

Free Abrasive Lapping is when abrasive slurry is applied directly to a lapping plate e.g. cast iron. This is perhaps the most accurate method for producing specimens and causes the least amount of damage. Free abrasive lapping is accurate because of the rigid lapping surface which can be tailored to suit a particular material. Fixed Abrasive Lapping is when an abrasive particle in bonded to a substrate as with abrasive lapping films and SiC papers.

Abrasive lapping films have various particles bonded to a thin, uniform polyester substrate and are also capable of producing a very flat surface. SiC papers are much thicker than the film and create the potential for rounded edges on the sample.

2.6 POLISHING MACHINE

Lapping and polishing machines vary extensively depending upon the manufacturer. SBT (South Bay Technology) has designed a set of instruments that are specifically designed for universal lapping and polishing applications. Although variety of polishing machines is available nowadays polishing mechanism is basically the same

2.6.1 Model 920

The Model 920 Lapping and Polishing Machine (Figure 2.1) incorporates a precision spindle assembly housed in a solid cast aluminum casting to provide stable operation in any laboratory environment. Stability when lapping is critical in producing flat precisely controlled tolerances on a given specimen. The motor is a high torque, variable speed motor that allows a wide range of speeds to be employed.

Flexibility in speed control allows the instrument to be used as a grinding machine, high quality lapping machine, or polishing machine. During grinding high speeds are required, whereas lapping and polishing applications are generally completed at low speeds. The Model 920 also incorporates workstations, which allow for the use of precise Lapping and Polishing Fixtures.

Figure 2.1: Model 920 Lapping and Polishing Machine for precise lapping and polishing applications

2.6.2 Model CL50

The CL50 Lapping Machine (Figure 2.2) is a robust machine evolved specifically to meet the requirements of the low volume producer of thin sections. Its compactness makes the most of valuable laboratory space and the resilient plastic casing is easily cleaned. For convenience, the lapping plate is of a lift-off design which allows both quick and simple plate changing and easy access to the base of the machine for cleaning

A water flush nozzle is also provided to assist with this. The Abrasive Auto feed System does away with cumbersome manual techniques of applying abrasive and ensures a reliable volume and consistency of abrasive to lapping plates at all times. This means that processes can be repeated accurately

Figure 2.2: Model CL50 Lapping Machine is a robust machine

2.6.3 Model PM5 Auto Pol Precision

The PM5 Auto Pol Precision Polishing Machine (Figure2.3) provides a revolutionary new approach to flat polishing. It combines traditional techniques with microelectronics to give the highest, repeatable standards of polishing plate flatness

The automatic plate flatness control system allows discrete changes to the polishing plate at the touch of a button. This unique, microprocessor-driven feature greatly increases the efficiency of sample production by minimizing the time spent wear conditioning, and thus concentrating machine time on producing results. The PM5 Auto lap/pol offers the user the ultimate control over the preparation process.

Figure 2.3: Model PM5 Auto Pol Precision automatic plate flatness control

2.7 POLISHING MATERIAL

2.7.1 Diamond

Diamond powder has large application in polishing industry .Abrasive characteristic of diamond powder make it play important role for lapping, finishing and grinding different kind of material such as silicon wafer .

As it is visible on an illustration, diamond micro powders consist of regular intervals particles, the shape of which is provided by perfect control. Such diamond micro powders can provide high efficiency of processing and maximum cleanliness of a possible surface

Diamond slurry has been formulated for use on many different types of lapping plates and polishing pads .Diamond slurry actually diamond powder mix with special liquid make it slurry. The slurries can be hand sprayed onto the lapping or polishing plate

2.8 POLISHING PAD

Polishing pads are available in a range of sizes and materials to fit almost any application. The pads come with plain or adhesive backing for mounting to machine plates and can be used for polishing a wide variety of materials including metals, glass, semiconductor materials and more. Figure 2.5 shows the variety of polishing cloths.

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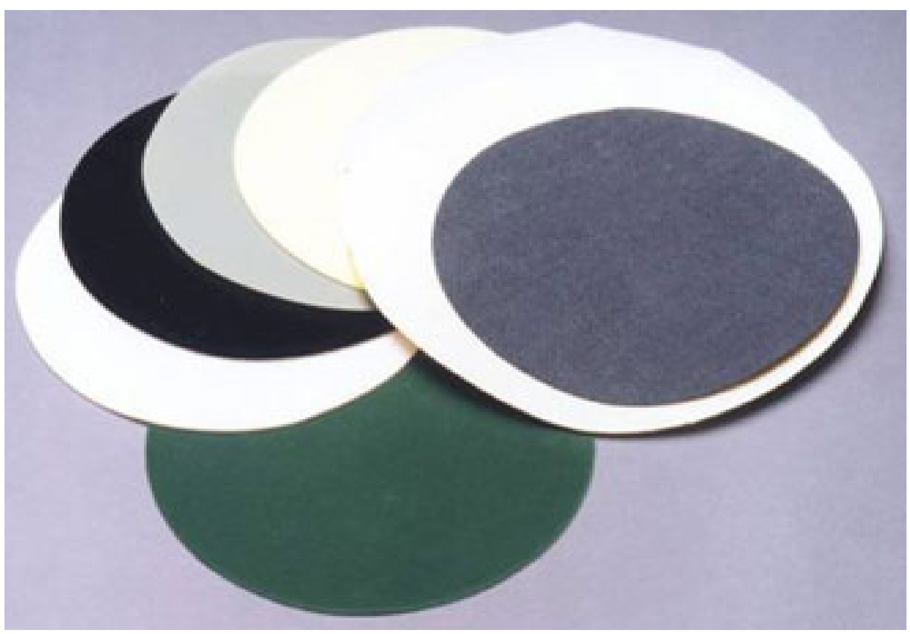


Figure 2.4: Polishing pad samples.

The samples of polishing cloth (Figure 2.5) are shown a various range of size and made from different material to accommodate almost of any polishing application.

Figure 2.5: Sample of various polishing cloth

The fixed abrasive shown in (Figure 2.6), is conditioned by the pattern of applied wafer,here the roughness of silicon.The abrasive dimension 200µm big and 50µm in height.The total contact area of these fix abrasive around 10% of the wafer surface.

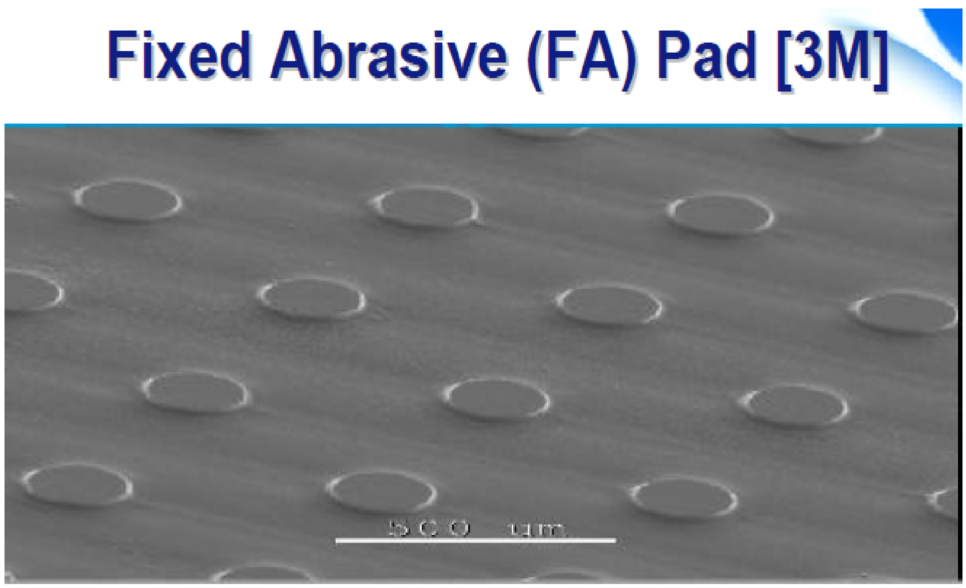


Figure 2.6: Fixed Polishing pad

2.9 LAPPING PLATE

Lapping processes are used to produce dimensionally accurate specimens to high tolerances and can be used to remove subsurface damage caused by sawing or grinding. Free abrasive Lapping is when abrasive slurry is applied directly to a lapping plate and used for material removal. This method is used with a variety of lapping plates of varying composition

2.9.1 Cast iron lapping plate

Cast iron lapping plates (Figure: 2.7) are used for rough lapping and stock removal of materials. Specimens around 8-10 on the Mohs Hardness Scale can be lapped using cast iron plates. Cast iron produces a gray surface finish and provides high removal rates.

Figure 2.7: Cast Iron (Fe)

2.9.2 Composite plate lapping plate

Composite plates (Figure: 2.8) are used for rough lapping and stock removal of materials. Specimens of 7-10 on Mohs Hardness Scale can be lapped on composite plates. These plates produce medium quality surface finishes with very high removal rates.

Figure 2.8: Composite

2.9.3 Aluminum lapping plate

Aluminum plates (Figure: 2.9) are generally used as a substrate plate for attaching glass plates for lapping, abrasive papers, or lapping films.

Figure 2.9: Aluminum

2.10 POLISHING MECHANISM

In the context of material removal mechanism, the lap imposes relative motion between the granules and the work and effect slurry and shaft transport through the contact.

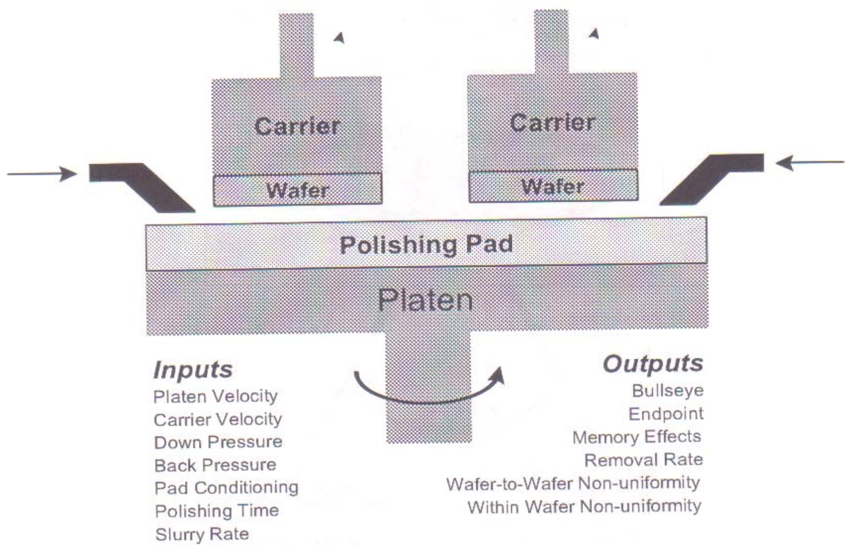


Figure 2.10: Schematic of conventional polishing mechanism

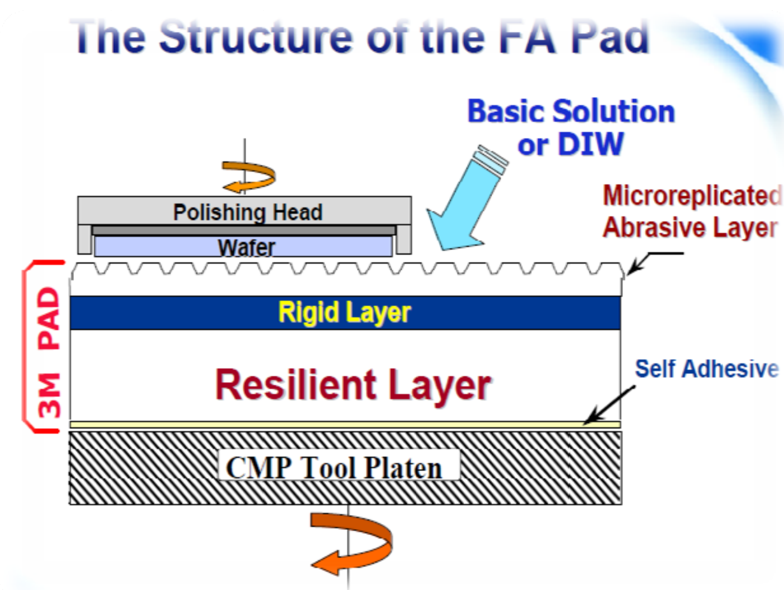


Figure 2.11: Polishing mechanism with fix abrasive

2.11 STRESS FRACTURE MECHANICS

The stress is concentrated around the crack tip or flaw developing the concept of stress concentration. The presence of high stress concentration indicates fracture of hard and brittle material and also indication of fracture surface. Two or more stress concentration at the same location in a structural member are said to be in a state of multiple stress concentration.

Stress concentration as a two dimensional problem can be discuss as when the stress components σ_z ,τ_{xy} and τ_{xz} can be assumed to be equal zero, this state called plane stress, and the stress component σ_z ,τ_{xy},τ_{xz} are functions of x and y only. The plane stress can be described as no normal stress to the cross sectional area, for example a plate under axial load.

2.12 FINITE ELEMENT METHOD

The finite element method (FEM) sometimes referred to as finite element analysis (FEA), is a computational technique used to obtain approximate solution of boundary value problems in engineering.

Boundary value is a mathematical problem and also called field problem. The boundary condition are specified values f the field variables on the boundaries of the field. The field variables may include physical displacement, temperature and heat flux depending on the type of physical problem being analyzed.

Finite Element Analysis can be used to analyze problems involving

- Irregular geometries
- General loading
- Different material properties
- Various Boundary Conditions
- Variable element types and size
- Easy modification
- Nonlinear and dynamics

The process of representing a physical domain with finite elements is referred to meshing. It is generally impossible to include the entire domain if the domain has curves. As the number of element increases, the finite element solutions approach the exact solution.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

To achieve the purpose of this project, a structure of overall methodology has been planned and illustrated as guideline. The main tasks included are:

1. Literature Review
2. Detailed Methodology
3. Design and analysis of Fixture using Finite Element method
4. Results and discussion

The following sections describe and explain these tasks.

3.2 FLOW CHART

Figure 3.1 shows overall view of the project methodology. It starts with literature followed by identifying related problems, defining objectives and project scope. Project flow continue with the modeling the fixture and will be analyze in finite element environment. The validation of fixture was interpreted through stress theory, if the result shows validity of fixture unsatisfied, the fixture will be re-design again.

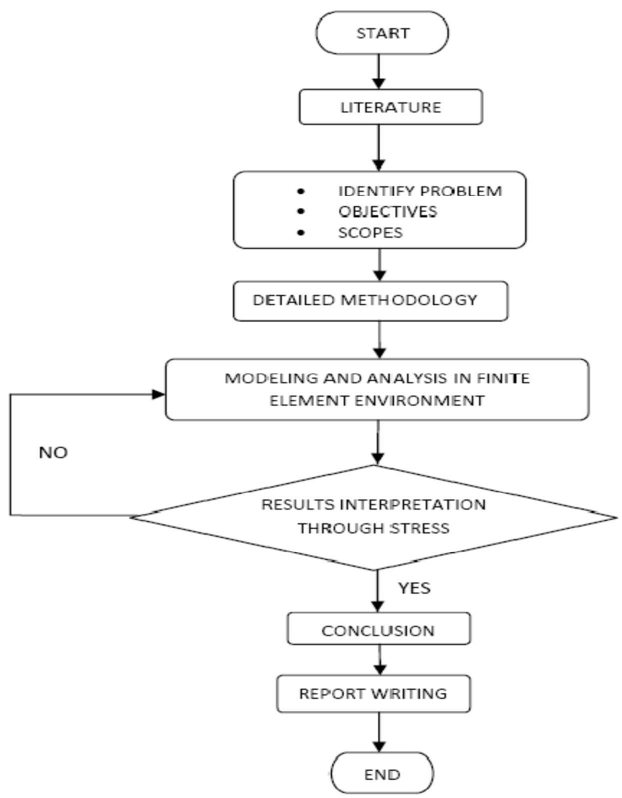


Figure 3.1: Methodology flowchart

3.3 FINITE ELEMENT MODELING

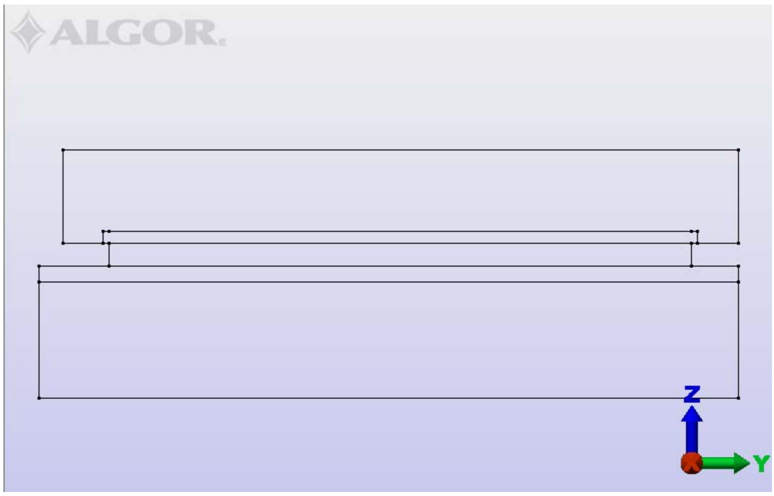
General-purpose FE code (ALGOR User's manual 2008) was employed to develop the computational model for fixture design. As many parameters are involved in polishing process and polishing mechanism is very complex, it would unfeasible to analyze the process in 3D finite element (FE) modeling with current FE code. In addition, modeling polishing agent in loose form is currently impossible because (1) it is made up of uncountable micro-size abrasive particles and (2) FE code has limited sketch features and meshing. Same problem came up even to model fixed abrasive as the size of each abrasive grain was as small as 100 µm.

Consequently, FE model was simplified into 2D model keeping the features in computational domain. Two FE models were developing as shown in figure 3.2, (a) pad with loose abrasive and fixture design 1 and (b) pad with fixed abrasive and fixture design 2. There are totally five parts in each model assigning part 1 to the bottom most and part 2 the second form the bottom and so forth. Then part 3 represents silicon and fixture includes part 4 and 5. Both FE model were intended for silicon wafer polishing assuming the wafer thickness is 1 mm thick. Figure 3.2 shows model geometry of the FE models. In model (a), very small elements were used at the interface between the silicon surface and pad surface to represent loose abrasive. In model (b), the fixed abrasive size of 500 um was modeled because of limitation in smallest element size that can be modeled in current FE code.

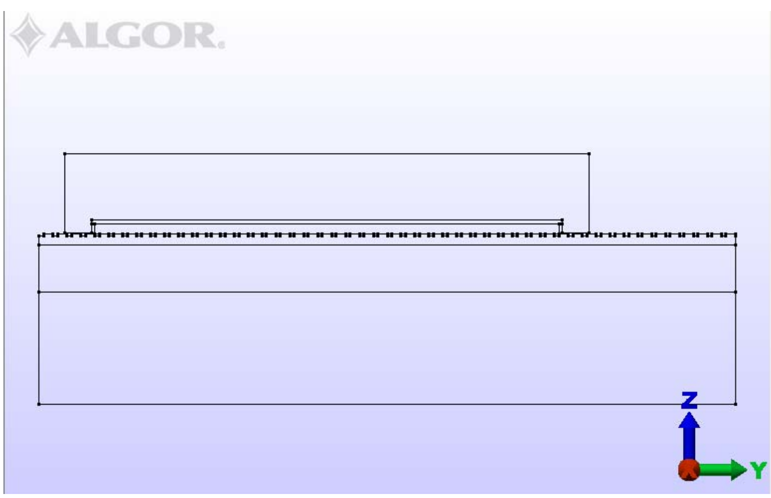
The model was discretized with 2D plane stress elements. All translations at the bottom nodes of part 1 were constrained in both models while translations on the right nodes on part 1 in the first model and on the left and right nodes of part 1 in the second model was constrained. Pressure load was defined by the normal force applied at the top nodes of part 5 (Figure 4.1) .The magnitude of pressure force was obtained from published report (Fynn et.al 2^{nd}). Force due to rotation of the pad and fixture was represented by tangential in opposites direction defined at the top of nodes of part 5. The force were estimated from power-torque relationship (Buyanas et.al 2008) since the motor power used in the actual polishing machine is known, the presence of abrasive was modeled by defining contacts and the friction coefficient at the interface between the pad and silicon surface.

Polishing process was simulated by changing fixture materials in both models. Table 3.1 shows the simulated parameter. Total nine simulations were carried out.

3.4 FIXTURE DESIGN



(a)



(b)

Figure 3.2: Finite element model of polishing process (a) loose-abrasive pad and fixture design 1 (b) fixed-abrasive pad and fixture design.

3.5 TABLE OF SIMULATED PARAMETER

Table 3.1: shows simulated parameters of fixtures design in various. In order to achieve good performance of fixture design the parameters of head and medium material will change during simulation.

Model	Number of Simulation	Fixture		Abrasive Types	
		Head Material	Medium Material	Fix	Loose
a	1	Aluminum 7075-0	DIAB divinycellr H45 semi rigid PVC foam		√
	2	Aluminum 7075-0	Dupont Teflonr PTFE Grade 7A Granular Molding Powder		√
	3	Aluminum 7075-0	Plastic- Acetal (copolymer)		√
	4	Aluminum 7075-0	Anocast silica-filled epoxy polymer composite		√
b	5	Aluminum 7075-0	Dupont Teflonr PTFE Grade 7A Granular Molding Powder	√	
	6	Aluminum 7075-0	DIAB klegecellr R 45 Rigid PVC –Closed Cell foam Core material	√	
	7	Aluminum 7075-0	Plastic- Acetal (copolymer)	√	
	8	Aluminum 7075-0	DIAB divinycellr H45 semi rigid PVC foam	√	
	9	Aluminum 7075-0	Anocast silica-filled epoxy polymer composite	√	

Table 3.1: Simulated parameters involve in fixture design

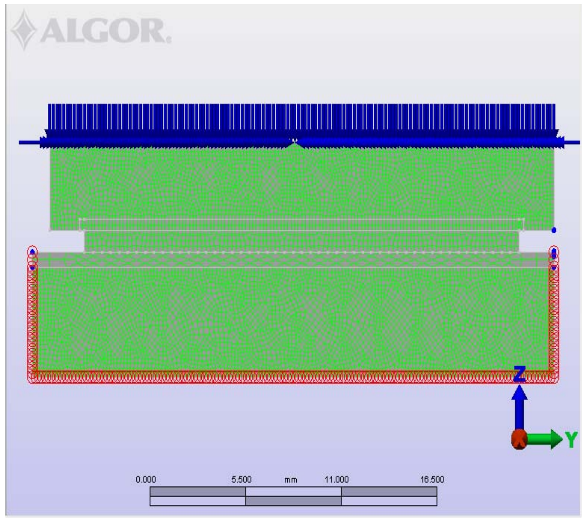
CHAPTER 4

RESULTS & DISCUSSION

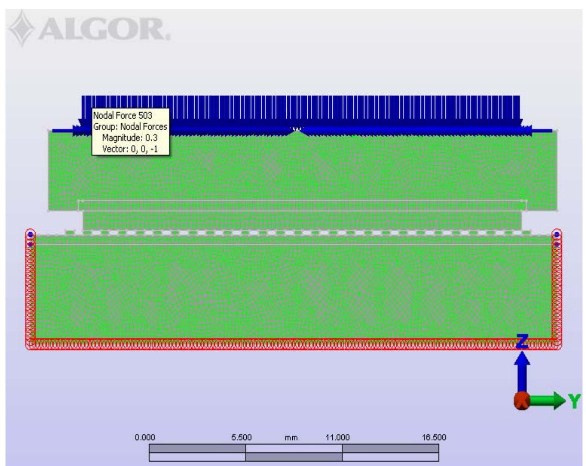
4.1 INTRODUCTION

In this chapter, stress contour plots in virtual polishing of silicon wafer are presented and discussed. Computed stress contours from 10 simulations are shown in order of improvement in fixture design. The results from each simulation are compared with one another interpreted according to stress distribution in silicon workpiece. The performance of fixture design was evaluated based on the stress theory in fracture mechanics and plasticity. The proper fixture design was justified by the low or absence of stress concentrations. The best fixture was selected finally.

4.2 FINITE ELEMENT MODEL



(b) Finite element model with Loose Abrasive



(b) Finite element model with Fix Abrasive

Figure 4.1: shows finite element (FE) model (a) with loose abrasive (b) fix abrasive developed for simulating polishing process and design analysis of the fixture used in polishing of silicon.

4.3 SIMULATED RESULTS

Referring to Table 3.1 in Chapter 3, there were (9) simulations in total. Two simulations were in fact preliminary simulations to identify proper computational domain where the FE code can be simulate polishing process and analyze for designing of the fixture. Based on the computed results from these simulations, the actual FE model was developed and used for simulation. Therefore, only the actual simulated results were presented and discussed in the following sections.

Figure 4.2 shows the computed stress contour in simulation 1. In this simulation, the head material was Aluminum 7570-0, (E=71700 N/mm^2) and the material for protective medium was DIAB divinycellr H45 semi rigid PVC foam, (E= 42 N/mm^2) . The result shows that silicon workpiece was completely damaged during polishing as no more silicon wokpiece was found after polishing. This is attributed to very high stiffness and hardness, meaning the fixture material is not suitable for polishing silicon. The stiffness of the fixture in this design was no compatible with that of silicon.

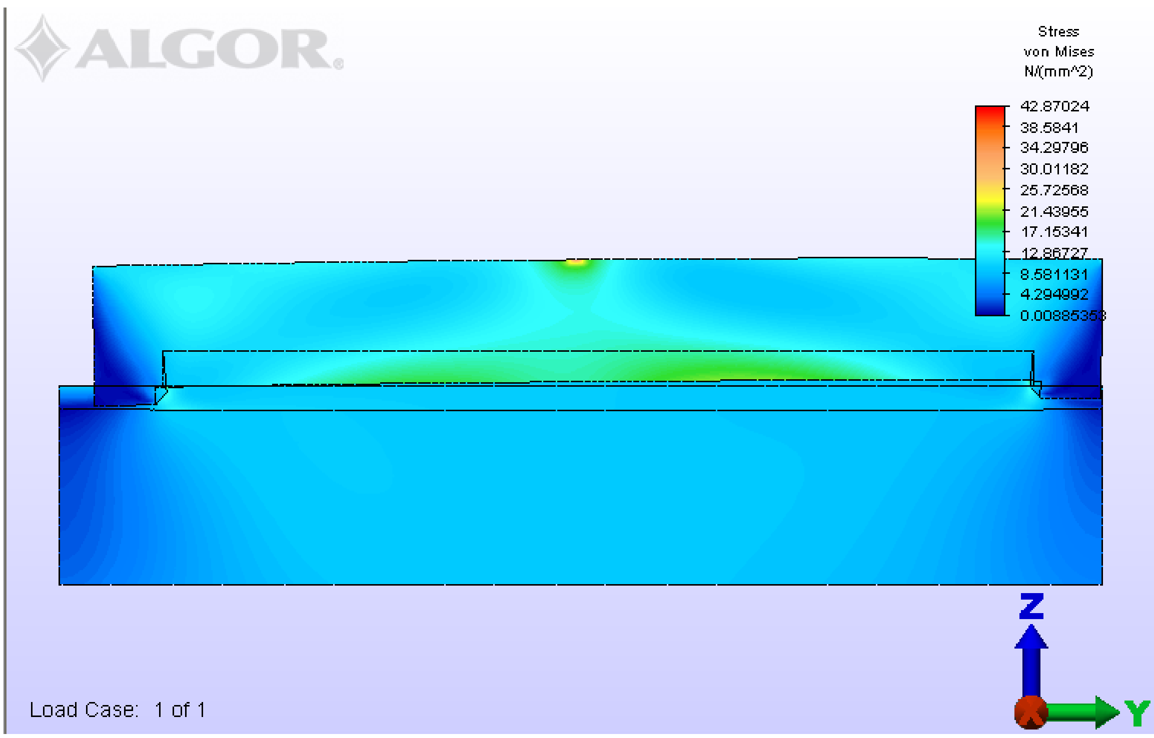


Figure 4.2: Computed effective stress in simulation 1

Figure 4.3 shows the computed stress contour in simulation 2. The result shows a slight improvement in fixture design. In this simulation, the head material was Aluminum 7570-0, (E = 71700 N/mm^2), and the material for protective medium was Dupont Teflonr PTFE Grade 7A Granular Molding Powder ,(E=460 N/mm^2) However, it is still having problem with the stiffness. As can be seen in the figure, silicon becomes thinner at the edge which indicates the fixture could not maintain uniform load during polishing. High stress concentration occurred in silicon surface layer. Although the maximum stress is still lower than yield stress of silicon, the probability of getting mirror surface finish is low due to the presence of stress concentration.

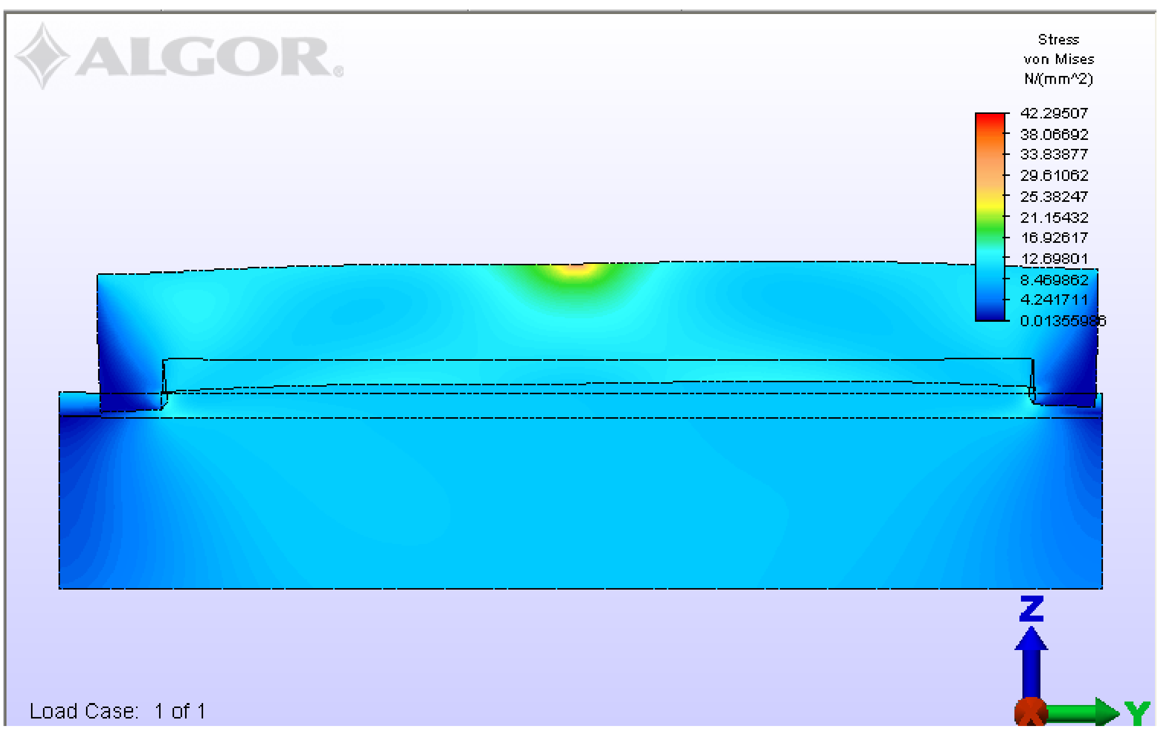


Figure 4.3: Computed effective stress in simulation 2

Figure 4.4 shows the computed stress contour in simulation 3. In this simulation, the head material was Aluminum 7075-0, (E = 71700 N/mm^2), and the material for protective medium was Plastic- Acetal (copolymer), (E=2757.9 N/mm^2) The results demonstrate that the fixture design is much improved from the view point of maintaining the geometry of the silicon. However, the medium material was too soft that it cannot match with the hardness of the head material and silicon as its shape is damaged. Moreover, stress concentration was high at the edges of silicon workpiece.

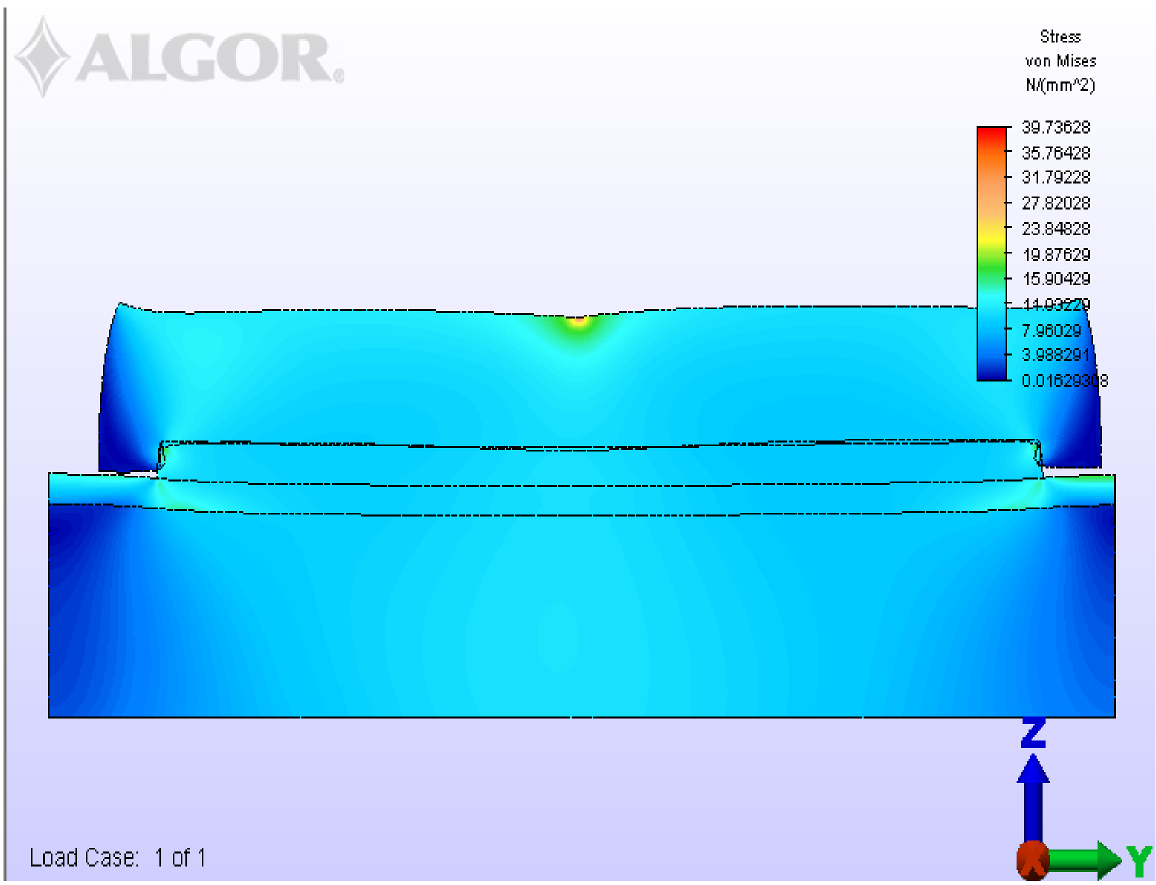


Figure 4.4: Computed effective stress in simulation 3

Figure 4.5 shows the computed stress contour in simulation 4. In this simulation, the head material was Aluminum 7075-0, (E = 71700 N/mm^2), and the material for protective medium was Anocast silica-filled epoxy polymer composite, (E= 32 N/mm^2). Among the four simulations with loose abrasive, the result from this simulation shows better than the others. No high stress concentration was found in the silicon surface except the edge. In addition, the geometry of the fixture was stable during polishing. As far as the surface finish is concerned, this design is acceptable.

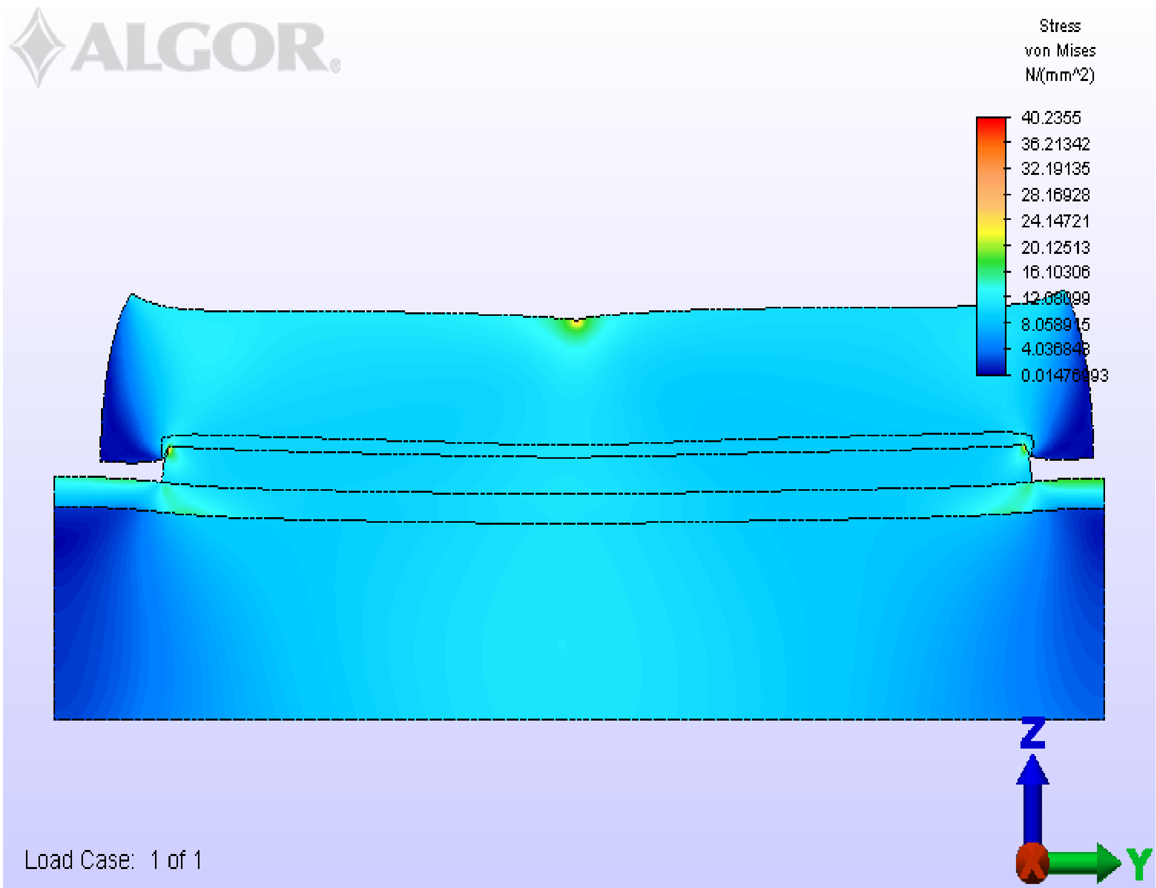


Figure 4.5: Computed effective stress in simulation 4

From simulation 6 to 10, the fixture geometry was the same but the abrasive type used was changed to fixed abrasive type. Figure 4.6 shows the computed stress contour in simulation 5. In this simulation, the head material was Aluminum 7075-0, (E = 71700 N/mm^2), and the material for protective medium was Dupont Teflonr PTFE Grade 7A Granular Molding Powder, (E=460 N/mm^2).Same phenomena with the very first simulation occurred here. As can be seen in the figure

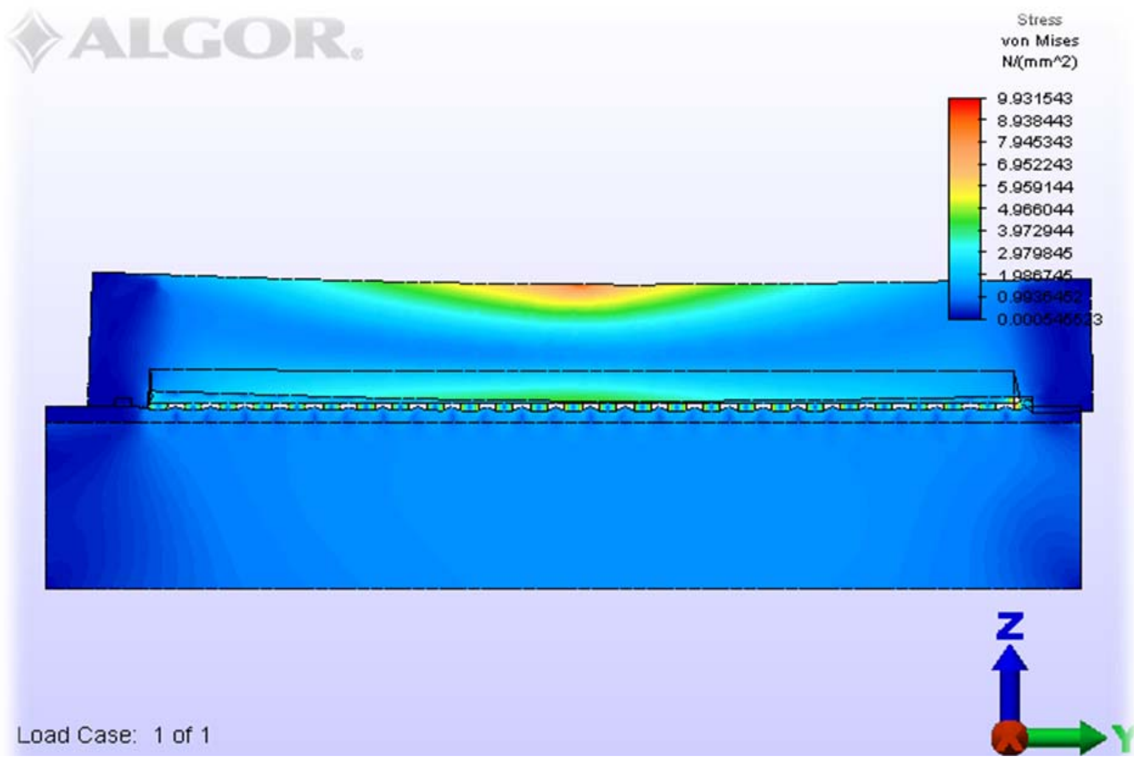


Figure 4.6: Computed effective stress in simulation 5

Figure 4.7 shows the computed stress contour in simulation 6. In this simulation, the head material was Aluminum 7075-0, (E =71700 N/mm^2), and the material for protective medium was DIAB klegecellr R 45 Rigid PVC –Closed Cell foam Core material, (E= 32 N/mm^2). The results demonstrate that the flatness of silicon was no longer there. It seems that silicon workpiece would likely to break at the middle. This could be due the insufficient stiffness of medium material that could not support the high load of polishing.

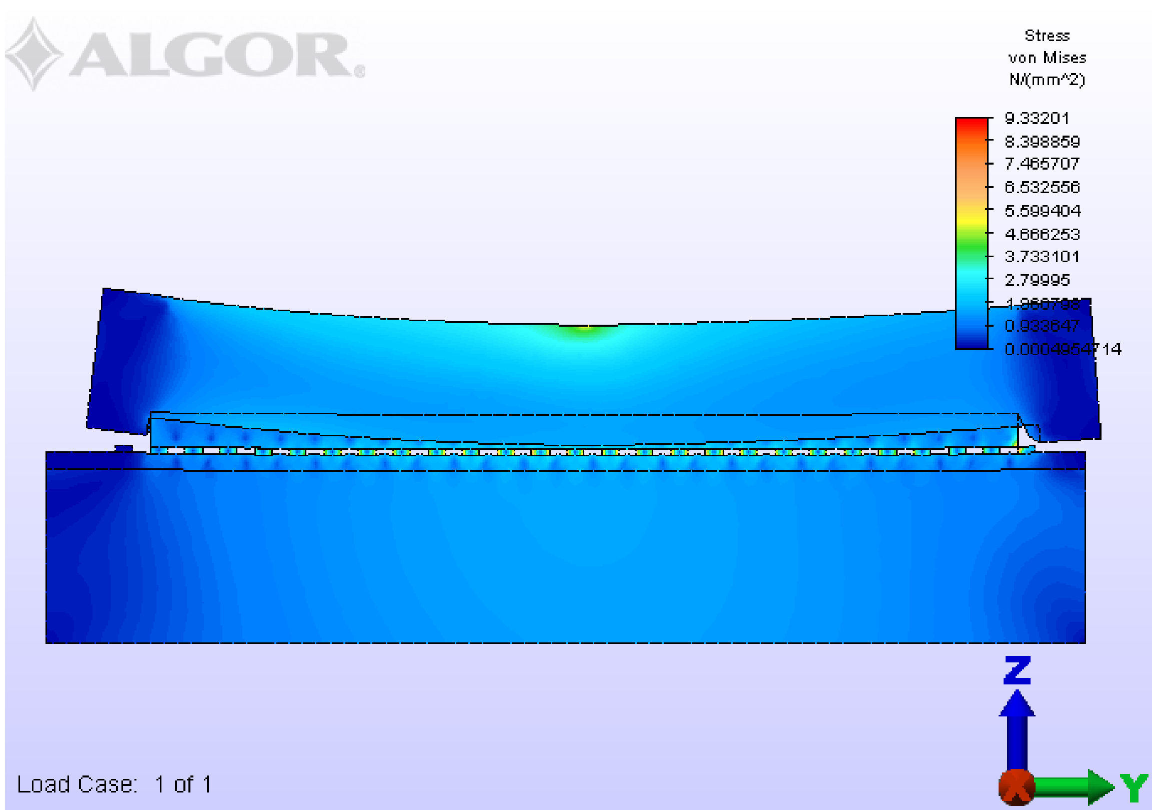


Figure 4.7: Computed effective stress in simulation 6

Figure 4.8 shows the computed stress contour in simulation 7 .In this simulation, the head material was Aluminum 7075-0 ,(E =71700 N/mm^2), and the material for protective medium was Plastic- Acetal (copolymer),(E= 2757.9 N/mm^2) .The result shows that polishing is improved compared to simulation 6 and 7. Stress contour at the silicon surface was acceptable as it appeared uniforms. However, silicon surface looked bent during polishing which is undesirable in producing perfect surface form. This indicates that the fixture could not maintain the flatness during polishing.

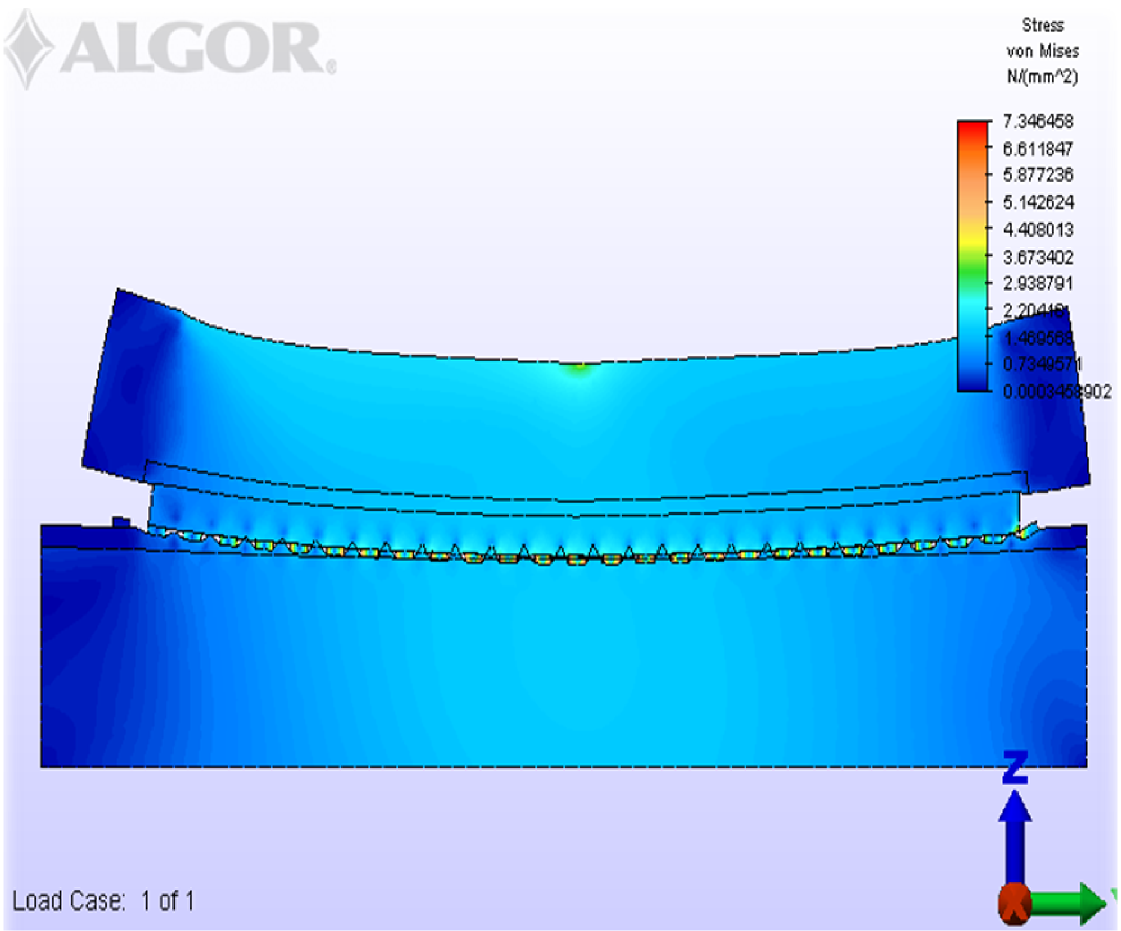


Figure 4.8: Computed effective stress in simulation 7

Figure 4.9 illustrates the computed stress contour in simulation 8. In this simulation, the head material was Aluminum 7075-0, (E =71700 N/mm^2), and the material for protective medium was DIAB divinycellr H45 semi rigid PVC foam, (E= 42 N/mm^2). Here, fixture design seems to be better for producing good surface finish. The only thing is that the medium material may not last long. Alternatively, it will wear out very fast during polishing and finally will affect the surface finish.

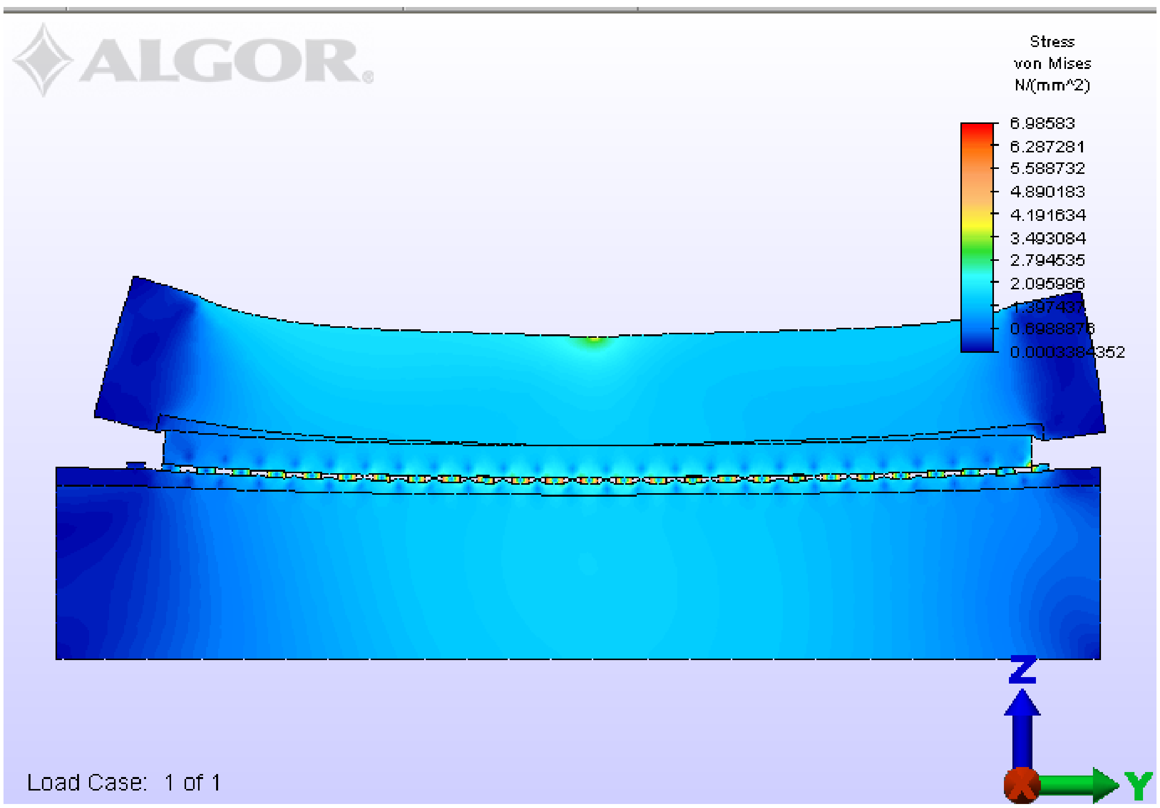


Figure 4.9: Computed effective stress in simulation 8

Figure 4.10 shows computed stress contour in simulation 9. In this simulation, the head material was Aluminum 7075-0, (E = 71700 N/mm^2), and the material for protective medium was Anocast silica-filled epoxy polymer composite, (E=32 N/mm^2). Computed stress contour appears uniformly at the silicon surface. In addition, the geometry of silicon workpiece, and the fixture were maintained. This implies that both form and surface finish of silicon would be perfect. Compared to the stress contour shown in simulation 4 where loose abrasive type was used for polishing, the stress contour here was more acceptable as no presence of stress concentration in any part of the silicon workpiece.

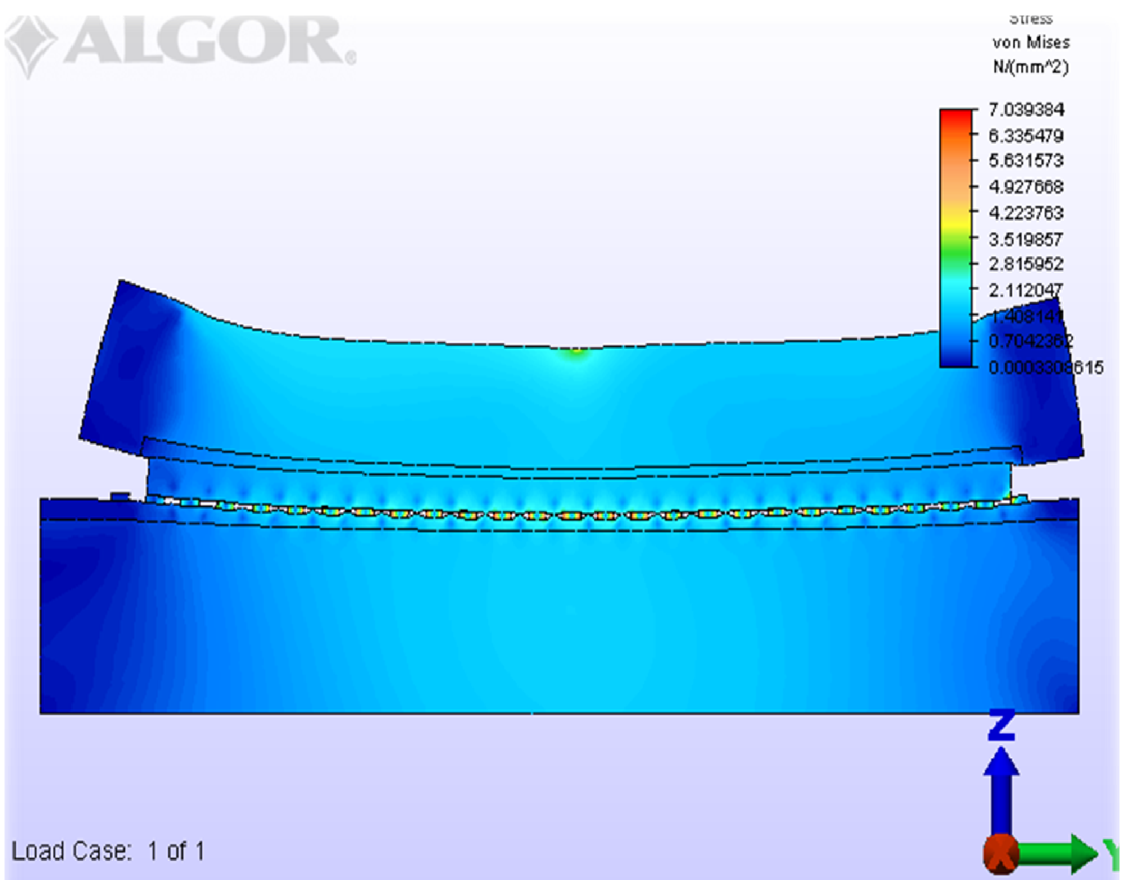


Figure 4.10: Computed effective stress in simulation

4.4 SELECTION OF FIXTURE DESIGN

In this analysis, the geometry of the fixture was very simple as that of the workpiece was just simple circular disc. Therefore the geometry would not affect the polishing mechanism significantly. However the aspect ratio of the workpiece is very high and at the same time the material characteristic was hard and brittle nature. Consequently, the material of the fixture is predominant to obtain good surface finish in polishing this type of workpiece. Overall results confirm this.

In total of (9) simulations investigated, simulation 4 where loose abrasive was used for polishing and 5 with the fixed abrasive indicates the best fixture design. However, compared to these two, the fixture design in the latter perform polishing better from the view point of surface finish as well as the structural stability of the fixture. Therefore the fixture design in which the head material made of Aluminum 7075-0 and the medium was Anocast silica-filled epoxy polymer composite was considered the best of all for polishing of silicon.

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 CONCLUSION

Through theoretical analysis and simulation studies, this dissertation presents the simulation foundation for predictable fixture design using finite element analysis (FEA). This thesis had shown the suitable method for analysis of performance of fixture in polishing delicate and sensitive material like silicon. As such, the computational model has been successfully developed for virtual polishing using FEA.

Basically, polishing simulations are carried out with two types of abrasives – fixed and loose abrasives. Simulation results for both type of abrasives show much differently. Generally, fixture design with fixed abrasive shows better result compared to that with loose abrasive.

Referring to the design analysis, the performance of fixture depends more on material rather than the geometry. The stiffness and hardness of the fixture material play essential role in polishing of silicon wafer.

The data base showing various fixture designs and their performance in polishing of silicon wafer has been presented. With reference to this data base, the best fixture design was found to be the one with the head material made of Aluminum 7075-0 and medium material made of Anocast silica-filled epoxy polymer composite.

5.2 CONTRIBUTION OF PROJECT

The result of this project will be presented and published in International Conference Science and Technology: Application and Industry & Education (2008) at Universiti Teknologi Mara Pulau Pinang 2008.

5.3 RECOMMENDATION

Based on the scope of the present research on dedicated fixture design for polishing of silicon, the following recommendations are made for future work:

The current FE package has limitation in element size. These results are unrealistic abrasive model that affect the accuracy of the analysis. In future it would better use advanced Finite Element Analysis software packages or the current FE code should be upgraded for modeling and analysis of polishing closer to reality. Hardware capacity also should be improved for efficient analysis.

In current analysis, model validation could not be done due to limited time frame. In future work, the FE model should be verified by actual fabrication of the proposed fixture and actual testing of the fixture.

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