DESIGN DIP COATER FOR WET COATING TECHNOLOGY

By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
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CERTIFICATION OF APPROVAL

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Approved:

Assoc. Prof. Dr. Norani Muti Mohamed
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

June 2005

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Khairuldin Mohd Isha

ABSTRACT

Wet Coating Technology is widely used in industries nowadays. Dip coating is one of the techniques used in Wet Coating Technology. The device required to implement the technique is called dip coater. The conventional dip coating technique used to deposit sol-gel thin films on flat substrates is well established and accepted because of its simplicity and the high coating quality that can be obtained. Advanced Material Research Centre (AMREC) SIRIM Berhad as a collaborator provided the dip coater for the project. With the current dip coater, the thin-film produced has several problems including wavy surfaces and non-uniformity of the thickness. The dip coater control box is only limited to two speed controls which are 0.5 mm/s and 1.5 mm/s. The purpose of this project is to improve the performance of AMREC dip coater by designing a new improved dip coater. Preliminary work of the project involved evaluating the performance of current dip coater by analyzing the coatings produced using several characterization tools. Examination of how dip coating process works lead to the identification of what causes the poor quality of the coating. Factors that contributed to the problems are vibration produced by the sample movement and type of the motor choosen for the dip coater. It was found that the vibration of the system can be reduced when the nut follower pitch was reduced. Circuit of the system has been redesigned to allow the change of the motor movement, control the speed and providing various speed for dipping process.

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On a personal note, the author wishes many thanks to his parents, Mr. Mohd Isha Dan and Mdm. Latifah Ahmad. Their support and show of confidence in the author have helped motivate the author to complete his tasks with peace of mind.

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LIST OF ABBREVIATIONS

AC	Alternating current
AMREC	Advanced Materials Research Centre
DC	Direct current
IC	Integrated Circuit
PETRONAS	Petroliam Nasional Berhad
SIRIM	Standards and Industrial Research Institute of Malaysia
SR	Spectroscopic reflectometer
TTL	Transistor transistor logic
UTP	Universiti Teknologi Petronas

CHAPTER 1
INTRODUCTION

1.1 Background of Study

Wet coating technology is widely used in industries nowadays. The simple use of wet coating for a non transparent material is for the purpose of decoration such as in printing techniques. Another significant application of wet coating technology is to coat transparent material using organic paint. This technology can be implemented in all industrial areas, which require improvement in the advantages of the quality and performance of the product.

One of the wet coating techniques advantages is the ability to develop coating with new properties either preserving using newly-formed molecular structure or by modifying the surface using heat-treatment method. For example, cooking utensils such as frying-pan is coated with a conductive thin film with the purpose of increasing the heat distribution to the entire surface of the pan.

There are various techniques that can be used to apply the wet coating technology depending on the requirement of the product and application. They are dip coating, spray coating, flow coating process, spin coating process, capillary coating, roll coating, printing techniques, chemical coating techniques.

Dip coating technique or sometime known as sol-gel dip coating has gained popularity for coating film because of its cheap equipment setup, easy operation, lower process temperature and homogeneity that can produce uniformly distributed structures. Dip coater is the device required to coat the layer using dip coating technique. The device is made up of two parts, a dipper and a control box.

1.2 Problem Statement

The thickness of the coating produced by the dip coating technique is mainly defined by the withdrawal speed, the content and viscosity of the substances. It was found that the current dip coater used in AMREC produced low quality coating which are wavy surface and non-uniformity of the thickness.

The dip coater control box which control dip coater mechanism was found not in working order. Fuse at control box always break when operation of dip coater was switched to manual mode. The dip coater control box does not provide various speed controls. It is believed that the operation of the dip coater would be more effective if other functions are added to the control box.

To get good quality of coating product, dip coater must operate on suitable speed. This will be determined by choosing the suitable motor and gear set.

1.3 Significance of the Project

This project will involve the student to the real project and acquire a hands-on experience in operating the dip coater. This coating technology is widely used in photonic and electronic fields. Coating Technology was developed to support the research area of electronic component and other related to electrochemical study.

This Project of Dip Coater is a collaborative work with AMREC under Photonic and Electronic Material Unit. At the end of this project, the student will come out with the solution to increase the quality of coating product and this will contribute to the development of coating research in AMREC.

1.4 Objective and Scope of Study

The scope for the whole project (two semesters) can be divided into four parts. Scopes of the project are:

1. Testing of the performance of the current dip coater
2. Designing of the new improved dip coater
3. Testing of the performance of the new dip coater
4. Adjustment and adaptation of the new improved dip coater with the process parameters

This project only concern with the development of dip coater in term of dip coater mechanism and has no involvement in the study of the coating material. A student needs to acquire a basic knowledge to handle coating material and the dip coating operation. The specific objectives of this project are:

1. To conduct experiments / surface test to examine the coating product.
2. To research on suitable speed and motor for dip coating
3. To improve the quality of coating product in term of coating surface.
4. To design suitable dip coater for wet coating process - control dip coater mechanism.
5. To design other techniques or options to replace previous technique if necessary.

To define dip coater circuit and components that will be used in control box. This circuit will control the mechanism of dip coater.

CHAPTER 2

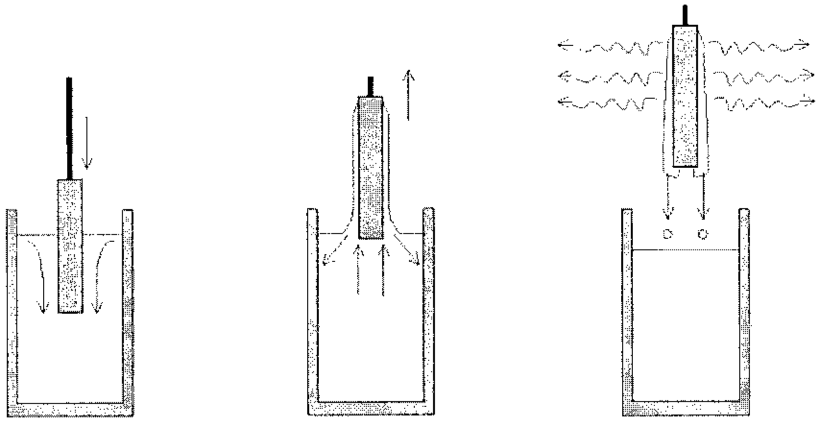
LITERATURE REVIEW AND THEORY

2.1 Sol-Gel Coating Process and Dip Coating Equipment

Dip coating is a process where the substrate to be coated is immersed in a liquid and then withdrawn with a well-defined withdrawal speed under controlled temperature and atmospheric conditions. Vibration-free mountings and very smooth movement of the substrate is essential for dip systems. An accurate and uniform coating thickness depends on precise speed control and minimal vibration of the substrate and fluid surface. The coating thickness is mainly defined by the withdrawal speed, the solid content and the viscosity of the liquid.

$$h = 0.94\frac{(\eta.v)^{2/3}}{\gamma_{LV}^{1/6}(\rho.g)^{1/2}} \tag{2.1}$$

If the withdrawal speed is chosen such that the sheer rates keep the system in the Newtonian regime, the coating thickness can be calculated by the Landau-Levich equation, shown by Equation (2.1), where h = coating thickness, η = viscosity, v = velocity, γ_{LV} = liquid-vapor surface tension, ρ = density, g = gravity. The schematics of a dip coating process are shown in Figure 2.1.



Dipping Wet layer formation Solvent evaporation

Figure 2.1: Stages of dip coating process from dipping of the substrate into the coating solution, wet layer formation by withdrawing the substrate and gelation of the layer by solvent evaporation.

For an acid catalyzed silicate sol, thickness obtained experimentally fit very well to calculate ones. The interesting part of dip coating processes is that by choosing an appropriate viscosity the coating thickness can be varied with high precision from 20 nm up to 50 µm while maintaining high optical quality.

If reactive systems are chosen for coatings, as it is the case in sol-gel type of coatings using alkoxides or pre-hydrolyzed systems, the so-called sols - the control of the atmosphere is indispensable. The atmosphere controls the evaporation of the solvent and the subsequent destabilization of the sols by solvent evaporation, leads to a gelation process and the formation of a transparent film due to the small particle size in the sols (nm range). This is schematically shown in Figure 2.2.

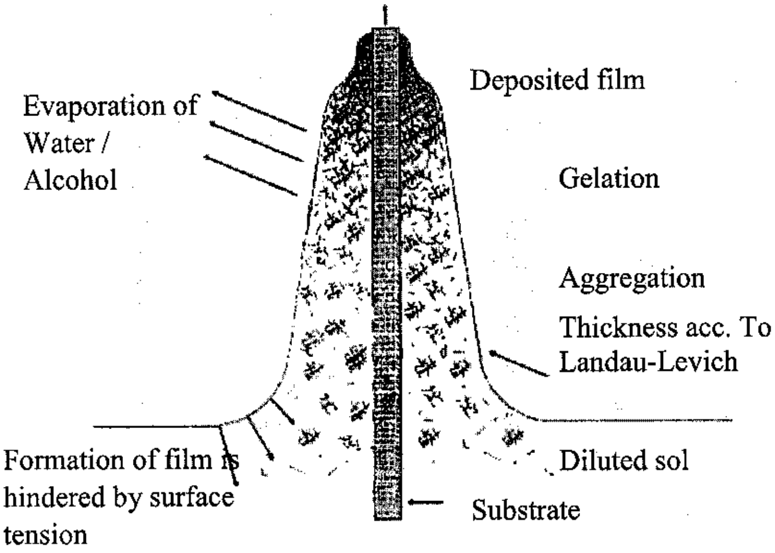


Figure 2.2: Gelation process during dip coating process, obtained by evaporation of the solvent and subsequent destabilization of the sol.

In general, sol particles are stabilized by surface charges, and the stabilization condition follows the Stern's potential consideration. According to Stern's theory the gelation process can be explained by the approaching of the charged particle to distances below the repulsion potential. Then the repulsion is changed to an attraction leading to a very fast gelation. This takes place at the gelation point as indicated in Figure 2.2.

The resulting gel then has to be densified by thermal treatment, and the densification temperature is depending on the composition. But due to the fact that gel particles are extremely small, the system shows a large excess energy and in most cases a remarkably reduced densification temperature compared to bulk-systems is observed.

However, it has to be taken into consideration that alkaline diffusion in conventional glasses like soda lime glasses starts at several hundred degrees centigrade and, as shown by Bange, alkaline ions diffuse into the coated layer during densification. In most cases, this is of no disadvantage, since the adhesion of theses layers becomes perfect, but influences on the refractive index have to be taken into consideration for the calculations for optical systems.

2.2 Thin Film Measurement

2.2.1 Ellipsometer

Ellipsometer which will be used to test the surface of thin film is shown in Figure 2.3. An ellipsometer enables the researcher to measure the refractive index and the thickness of semi-transparent thin films. The instrument relies on the fact that the reflection at a dielectric interface depends on the polarization of the light while the transmission of light through a transparent layer changes the phase of the incoming wave depending on the refractive index of the material.

An ellipsometer can be used to measure layers as thin as 1 nm up to layers which are several microns thick. Applications include the accurate thickness measurement of thin films, the identification of materials and thin layers and the characterization of surfaces.

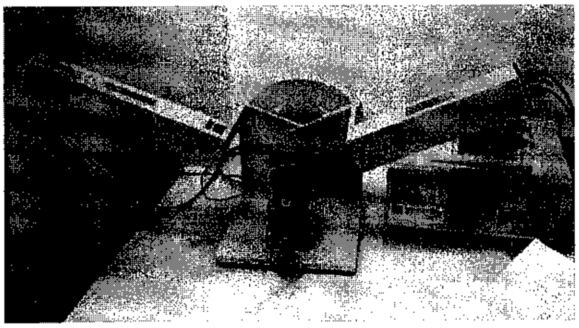
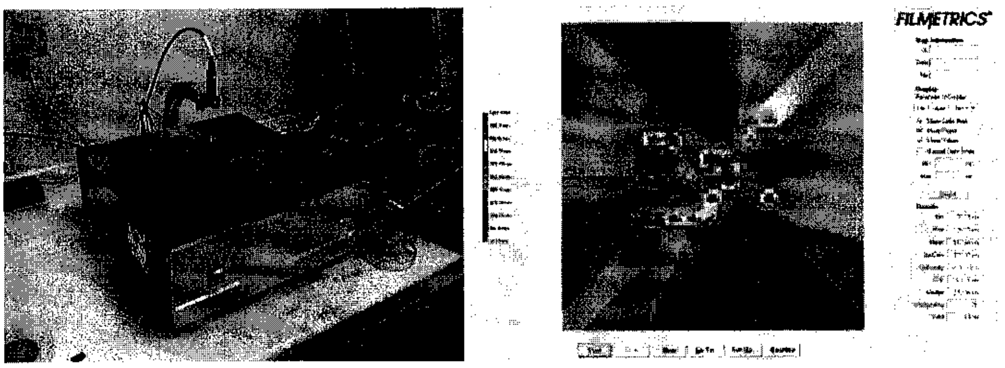


Figure 2.3: Ellipsometer, AMREC SIRIM Berhad

2.2.2 Spectroscopic Reflectometer

Spectroscopic reflectometer or SR (Figure 2.4 (a)) was provided by AMREC. Spectral reflectance illustrated in Figure 2.4 (b) can be used to measure a large percentage of technologically important films. However, when films are too thin, too numerous, or too complicated to be measured with spectral reflectance, oftentimes they can be measured with the generally more powerful technique of spectroscopic ellipsometry.

By measuring reflectance at non-normal incidence (typically around 75° from normal) ellipsometry is more sensitive to very thin layers, and the two different polarization measurements provide twice as much information for analysis. To carry the idea even further, variable-angle ellipsometry can be used to take reflectance measurements at many different incidence angles, thereby increasing the amount of information available for analysis.



(a) (b)

Figure 2.4

Figure 2.4 (a): Spectroscopic reflectometer and
Figure 2.4 (b): Sample result

2.3 Dip Coater Circuitry

For this project, dip coater circuitry use Integrated Circuit (IC) of H-bridge from ST Microelectronics which is dual full h-bridge driver (L298N), refer Figure 2.5. H-bridge circuit function is to control the direction of the motor either clockwise or counter clockwise. For the clockwise rotation, transistor A and D is ON by supply voltage to the base junction of the transistor. While for anticlockwise rotation, B and C are ON by the same configuration. The basic H-bridge configuration was shown in Figure 2.6.

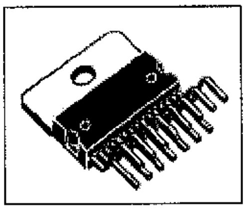


Figure 2.5: L298N IC

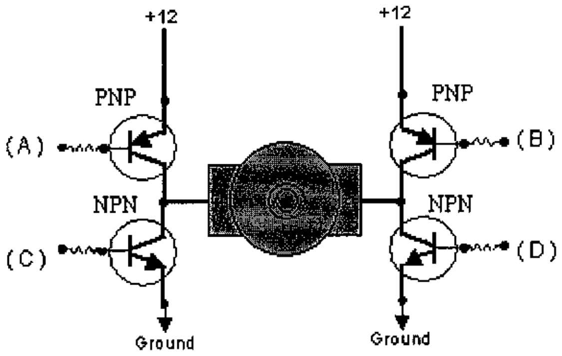


Figure 2.6: Basic H-bridge using four transistors

The L298 is an integrated monolithic circuit in a 15-lead Multiwatt and PowerSO20 packages. It is a high voltage, high current dual full-bridge driver designed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the input signals. The emitters of the lower transistors of each bridge are connected together and the corresponding external terminal can be used for the connection of an external sensing resistor. An additional supply input is provided so that the logic works at a lower voltage.

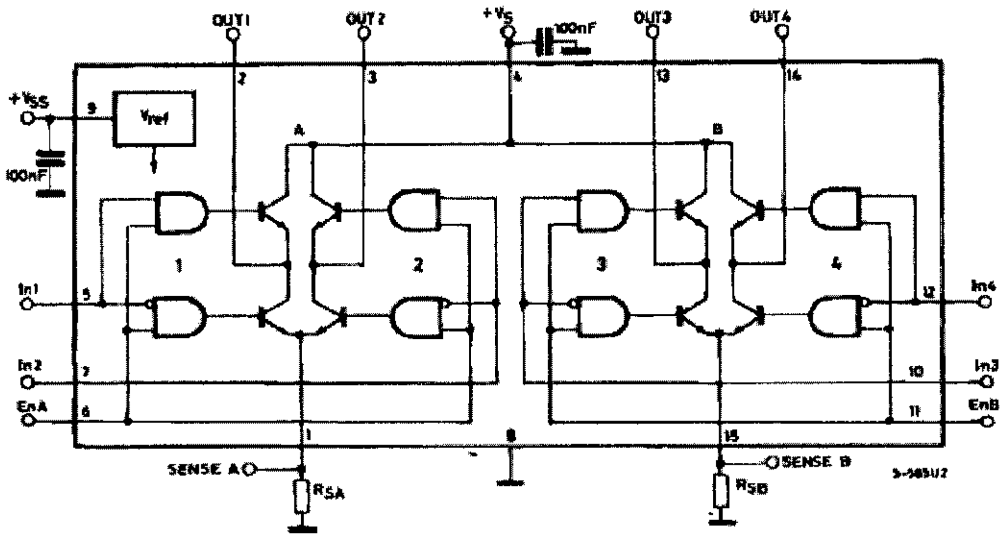


Figure 2.7: Basic diagram L298N IC

CHAPTER 3

METHODOLOGY / PROJECT WORK

3.1 Procedure Identification

3.1.1 Analysis of Present Dip Coater

In order to improve the present dip coater as shown in Figure 3.1, the performance of the device must be examined by conducting the coating process and producing few samples. Result from the device was used to determine the quality of coating product. The dip coating process was handled in proper method and this was guided by experienced researcher in AMREC. Thin film measurement devices will be used to examine the coating product quality.

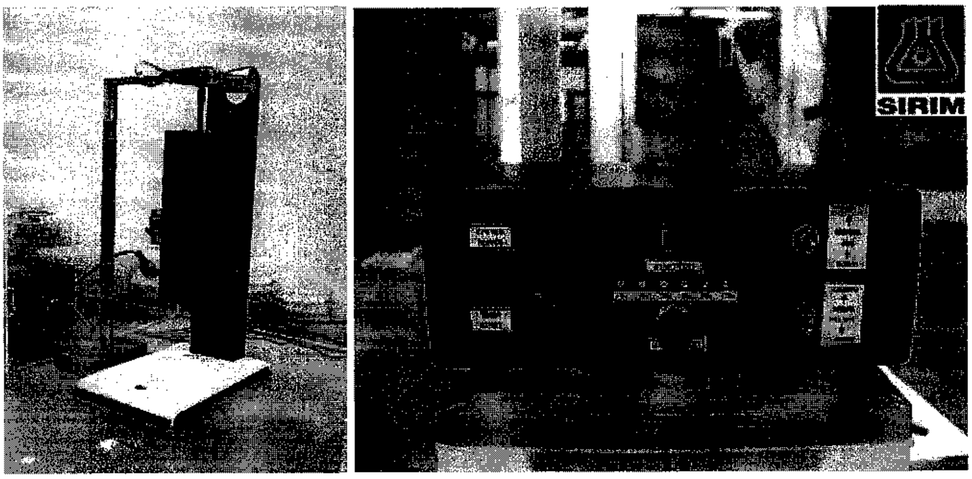


Figure 3.1: Dip coater and control box from AMREC SIRIM Berhad

Dip coating was done completely in the AMREC SIRIM Berhad, Kulim Hi-Tech Park, Kulim Kedah. The coating process involves preparing of coating material, dipping, withdrawing and firing sample in the furnace. The setup is shown in Figure 3.2. The sample data produced is shown below:

Table 3.1: Dip coating data samples

Sample substrate	Glass slide and silicon wafer (Glass slide was clean before it was used with acetone, ethanol and distill water)
Coating material	SiO_2
Dipping time	0, 1, 30, 60 (seconds)
Withdrawal speed	0.5, 1.5 (mm/sec)
Firing temperature	1000 (°C)

Samples were produced under cleanroom environment and without cleanroom environment. Dip coater control box used three fuses in order to prevent the control box circuitry from damages. The fuses used have limit to 0.5 A. The fuses were used to protect AC, DC and motor in the circuit.

Figure 3.2: Coating silicon dioxide to silicon wafer

Preparation of substrate:

Substrates used in this work are glass slide and silicon wafer. Dimension for glass slide used is 7.0 x 2.5 x 1.0 cm and for silicon wafer is 4 x 3 x 0.1 cm. They were cleaned with alkaline free detergents and then were immersed in an aqueous solution of 30 % H_2O_2, HCl, and deionized H_2O for 15 minutes, then washed with abundant distilled water, and dried in air at 100 °C.

Preparation of the SiO_2 solution:

SiO_2 was stirred vigorously for 10 minutes and the solution was kept at room temperature for 2 hours. The SiO_2 thin films were prepared by the sol-gel method using dip-coating technique. The coatings were made by withdrawing the glass substrate from the coating solutions at rate 0.5 mm/s and 1.5 mm/s. After drying, the substrates were treated at 100 °C for 30 minutes, and at 1000 °C for three minutes (only for silicon wafer).

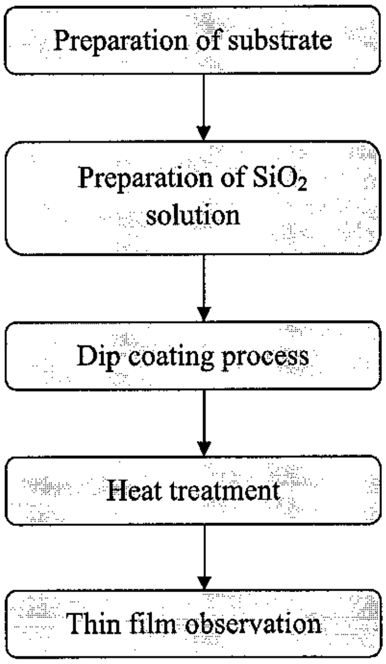


Figure 3.3: Coating process flow chart

Figure 3.4 described the whole process starting from preparation of coating material to the final observation of the film produced.

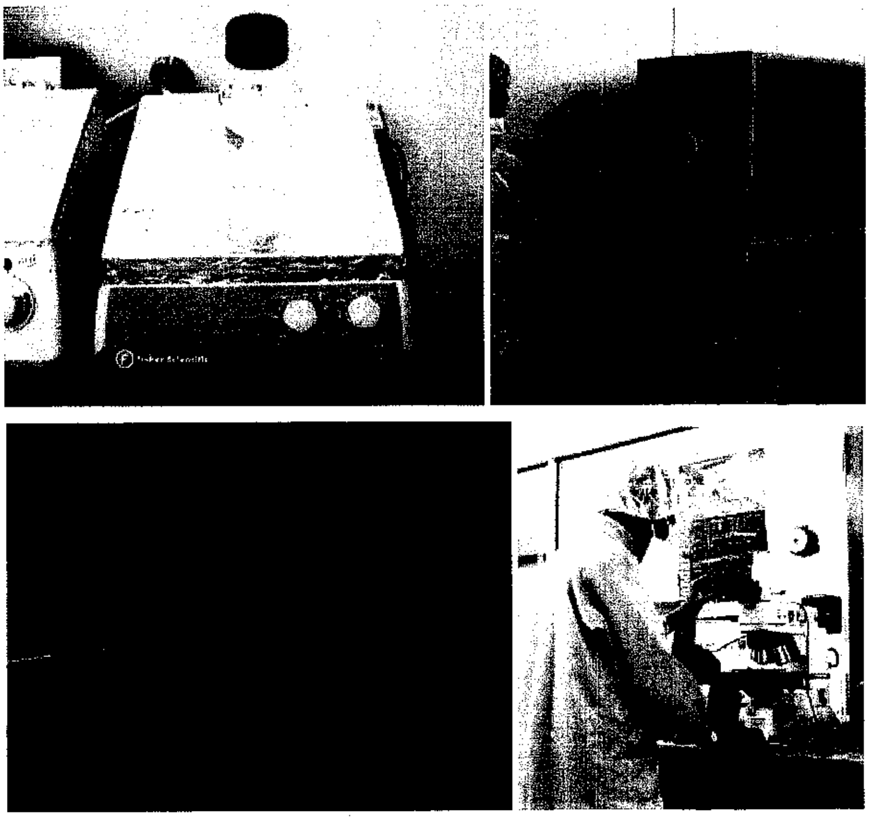


Figure 3.4: Dip coating process: coating material preparation, firing process and thin film observation

3.1.2 Analysis of the Dip Coater Mechanical Movement

Choosing the right gear is important for the dipper system. For this project, the gear as shown in Figure 3.5 was chosen to move the nut follower up and down by rotating the gear clockwise and anticlockwise. By applying suitable gear, vibration to the system will be reduced. Gear was attached to gear board that consist a few types of gears.

Gear was moved by a DC motor. Choosing the suitable motor is the key factor in reducing the vibration to the system. Motor was attached at the same gear board.

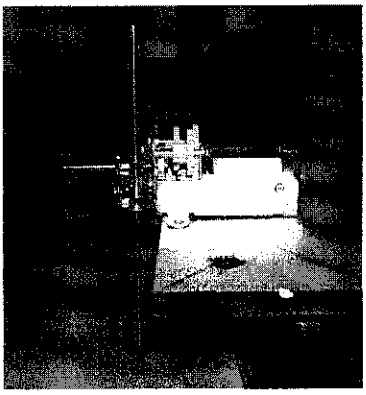


Figure 3.5: Gear set used to move the nut follower

Dip coater circuitry use Integrated Circuit (IC) of H-bridge from ST Microelectronics which is dual full h-bridge driver (L298N). H-bridge circuit function is to control the direction of the motor clockwise and counter clockwise. Control circuit was designed similar to circuit below. Complete circuit for the dip coater is shown in Appendix D: Dip Coater Control Circuitry.

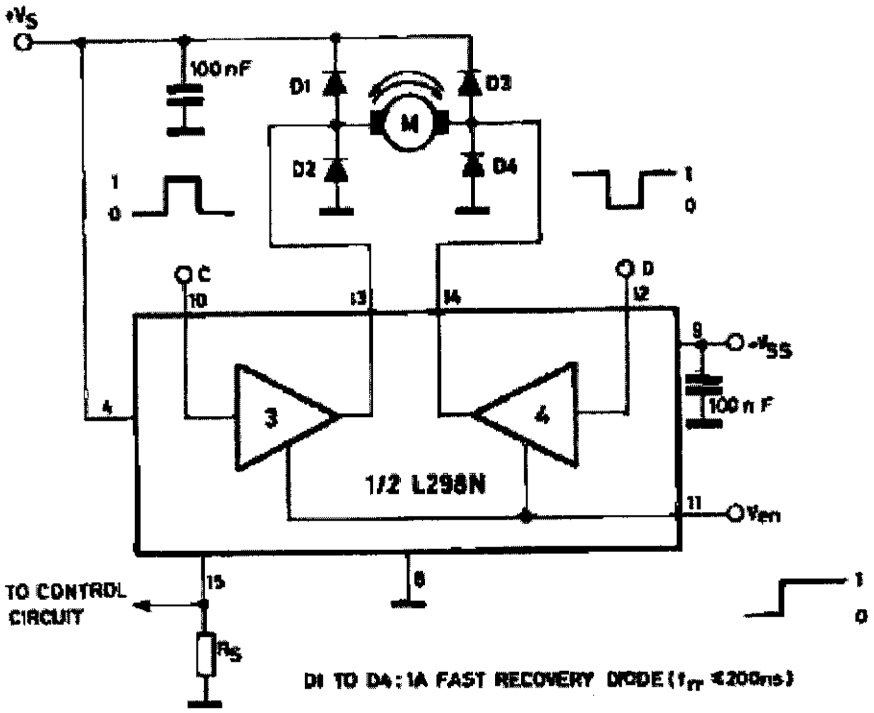


Figure 3.6: Bidirectional DC motor control

3.2 Tools and Equipment Required

The most important tool for the project is AMREC dip coater because the main objective of the project is to improve performances that contribute to coating quality. The thin film measurement devices were used to test the surface quality of the product. The devices are ellipsometer and spectroscopic reflectometer. The functionality of the device was elaborated in section *2.2 Thin Film Measurement.*

Other requirements would be the coating material used to produce coating and the furnace used to give heat treatment to the finished product. Heat-treating of the coatings influences their protective properties. Substrates used for coating are glass slide and silicon wafer.

In order to reduce nut follower pitch, lathe machine was used. Turning process can be done by using this lathe machine. Dimensions of thread produced are 12 mm diameter and 1.75 mm pitch.

Electronic components will be used in designing the control box circuit. Main component of the control circuitry is H-bridge IC (L298N). This component controls the direction of the motor clockwise and counter clockwise. Softwares required to design circuit are PSpice version 9.2.3 and Multisim 2001 Power Pro.

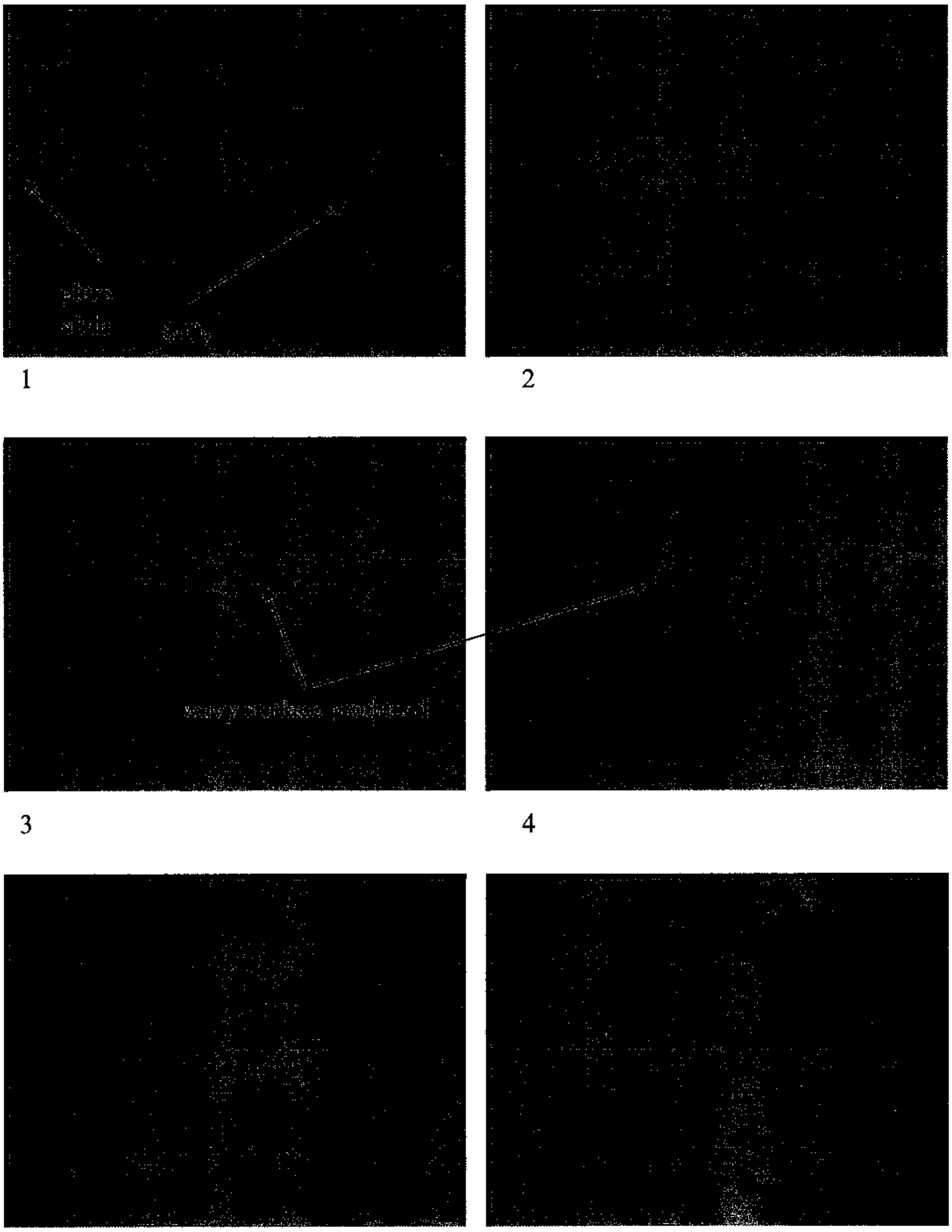
CHAPTER 4
RESULTS AND DISCUSSION

4.1 Thin-film Observation and Measurement

4.1.1 Optical Microscopy

Dip coating process was done on the glass slide. The glass slide cannot be exposed to high temperature of 1000 °C. Normally for every coating product produced, it must go through the firing process. Glass slides cannot withstand high temperature, so it will not go through the firing process. The coating on silicon was fired in the furnace for 3 minutes at 1000 °C.

It is obvious from the optical microscopy result shown in Figure 4.1, the coating produced has a wavy surface. These wavy surfaces were produced due to problem in dip coater mechanism. When the nut follower is moved up the sample holder, the sample will be withdrawn from the coating material (SiO_2). The smoothness of the movement will contribute to the smoothness of the coating.



1

2

3

4

5

6

Figure 4.1: Optical microscopy results

4.1.2 *Spectroscopy Reflectometer*

Table 4.1: Sample 1 to Sample 5 characteristics

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Withdrawal Speed (mm/s)	0.5	1.5	0.5	0.5	0.5
Dip time (s)	0	0	1	30	60

Table 4.2: Result from spectroscopy reflectometer

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Min. (nm)	32.57	32.5	38.19	37.07	87.5
Max. (nm)	1267.5	1267.5	1267.5	1229.2	1267.5
Mean (nm)	485.08	438.64	543.84	558.8	570.61
Std.Dev. (nm)	293.63	304.25	372.37	317.22	326.98
Uniformity (%)	±127.3	±140.8	±113.0	±106.7	±103.4
CTE (nm)	-934.48	-99.78	-1073.5	-208.37	-486.56
Wedge (nm)	327.99	691.46	270.04	638.69	446.36
Wedge Ang.	237°	153°	79°	30°	-84°
Valid	49/49	49/49	49/49	49/49	49/49

Table 4.3: Data analysis from dip coating

Withdrawal Speed (mm/sec)	0.5	1.5
Thickness (nm)	485.08	438.64

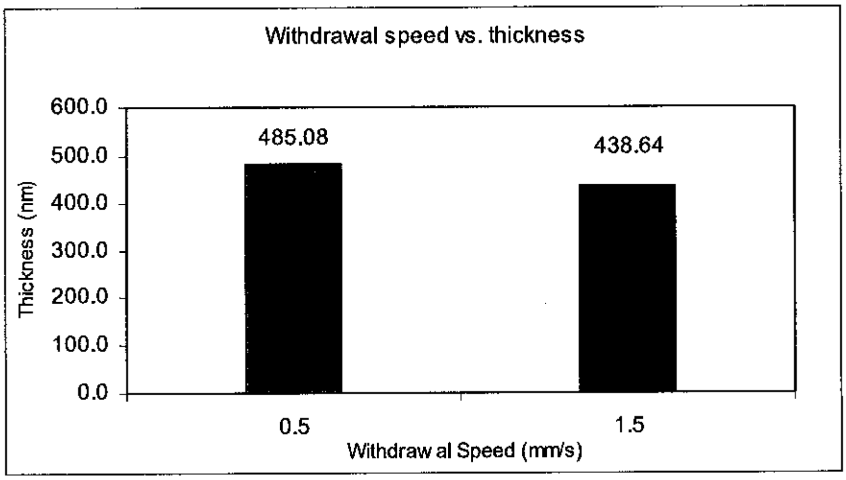


Figure 4.2: Graph withdrawal speed vs. thickness

Table 4.4: Data analysis from dip coating

Dip Time (s)	0	1	30	60
Thickness (nm)	485.08	543.84	558.80	570.61

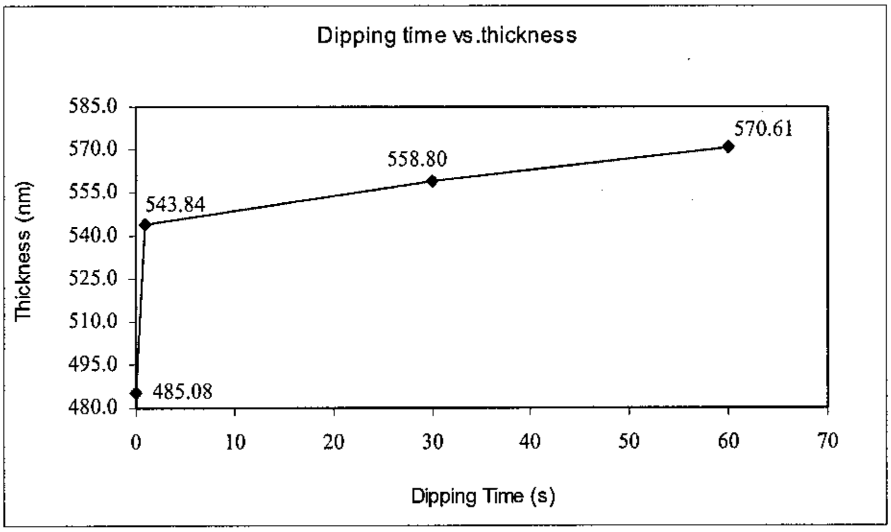


Figure 4.3: Graph dip time vs. thickness

From the five samples produced (with different in withdrawal speed and dipping time), we can easily see the different in mean thickness. Based on the Landau-Levich equation, we can know for every increasing in withdrawal speed, it will reduce the thickness of the coating layer. From the result which is tabulated in Table 4.3, mean thickness was reduced from 485.08 nm to 438.64 nm for withdrawal speed of 0.5 mm/sec to 1.5 mm/sec. AMREC dip coater only provide two speed controls which are 0.5 mm/sec and 1.5 mm/sec.

Dipping time also contribute to the change in coating thickness. From the result as shown in Figure 4.3, it is clearly seen that increasing the dipping time would increase the thickness of coating. Mean thickness of dipping time for 1 second, 30 seconds and 60 seconds are 543.84 nm, 558.80 nm and 570.61 nm, respectively.

Result for the SR test was shown in appendix. Refer to the *Appendix A: Spectroscopy Reflectometer Result*, we can see the different in color of coating surface. This show the coating product surface is not uniform. Without any coating to glass slide (set as reference), we can see that the glass slide is already uniform.

4.1.3 Mechanical Part for Dip Coater

Dipper is the part that moves the sample up and down. It consists of a few components that control the movement. The most important component of the dipper is nut follower. To perform under low vibration, the dipper does not operate by applying motor and gears direct to the sample holder. It is difficult to reduce the vibration by applying motor and gears as a dipper mechanism. Movement of the motor is already producing vibration to the sample.

Nut follower was operated by using external motor. Part that holds the sample was attached to the nut follower. The movement of the nut follower will push the part up and down.

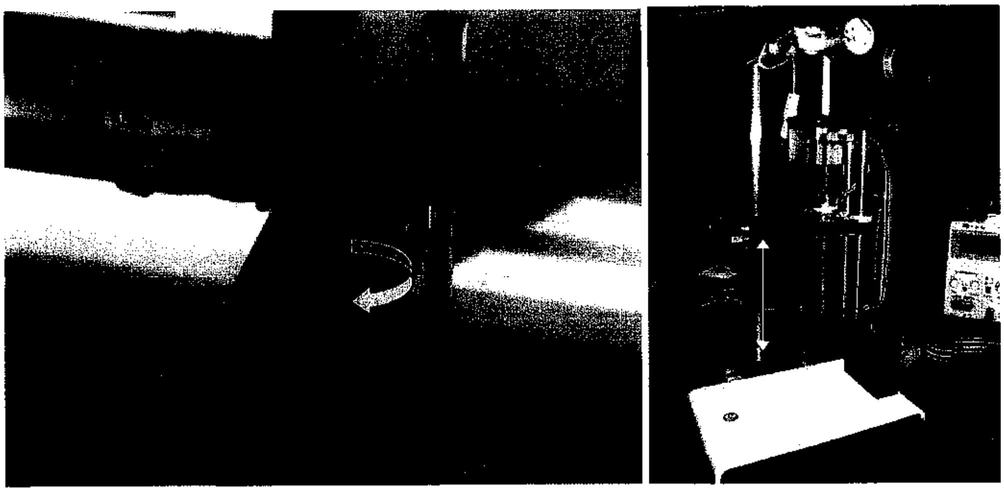


Figure 4.4: Motor moves the connection part and the nut follower will automatically pushed up and down.

The nut follower isolates the motor vibration from interrupting the sample holder. The setup of the nut follower show the dipper is free from motor control. From Figure 4.4, it is obviously shown that the person fabricate AMREC dip coater try to reduce vibration by separating the motor and the movement part.

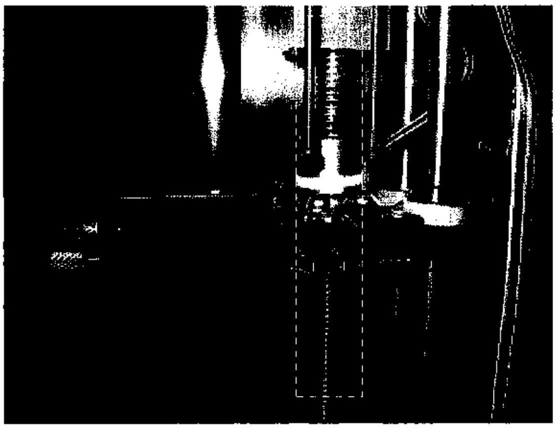


Figure 4.5: Nut follower

To reduce vibration in dip coater, the pitch of the nut follower was reduced. Pitch is the distance between adjacent thread forms measured parallel to the thread axis. When pitch of the screw is reduced, gap between nut and the screw is smaller and reduce shaking during the sample movement.

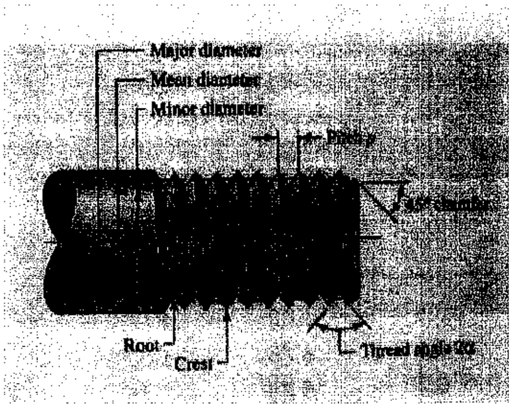


Figure 4.6: Basic thread

Screw pitch used for previous dip coater is 2.0 mm and diameter 12 mm. The pitch then reduced to 1.75 mm. Material used for the screw is aluminum because it is easy to shape.

Figure 4.7 shows nut follower that was produced by using lathe machine. Dimensions of the nut follower are 12 mm diameter and 1.75 mm pitch.

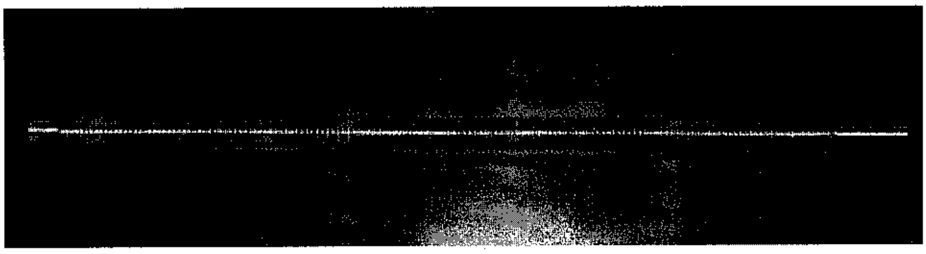


Figure 4.7: Screw produced: pitch 1.75 mm, diameter 12 mm

The nut follower then was attached to the dip coater body shown in Figure 4.8. L-bar was used to form this base. From rough observation, it is physically shown that new dip coater produce less vibration than previous dip coater.

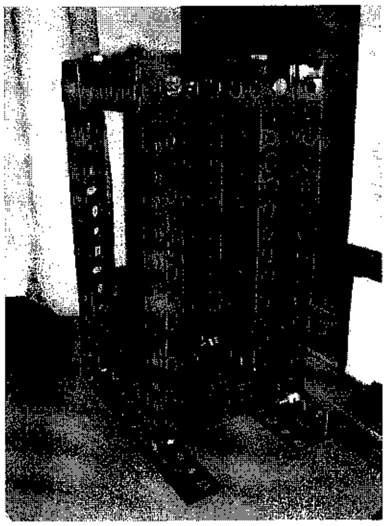


Figure 4.8: Dip coater body

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In the first part of the project, experiment to coat coating material (sol-gel) to the substrate: glass slide and silicon wafer have been successfully carried out. Surface tests namely SR and Optical Microscopy, were used to examine the surface of coating product. Data obtained shows that the current dip coater produces low quality coating in the form of non-uniformity and wavy surfaces.

The surface test result contributes to the research in finding the suitable mechanism and speed of the dip coater. Sample data was collected for various speeds to find the effect of the speed to the film thickness. From the coating process, data shows that increasing the withdrawal speed would reduce the thickness of the film. New dip coater offer various speed controls for dip coating process by providing variable resistor. This resistor controls the speed of the dip coater motor.

Vibration has been identified as the source of problem providing low quality films. The vibration can be reduced by reducing the nut follower pitch. Nut follower dimensions now are 12 mm diameter and 1.75 mm pitch. Previous dip coater pitch is 2.0 mm. Physically this improvement has shown to have less vibration when it is operating. From physical observation, the vibration has been reduced up to 30 percent.

5.2 Recommendation

Standard small DC motor was chosen. The DC motor is obtained from the gear set kit. The motor was chosen because it is small and produce less vibration. The application of the motor is still in the trial condition. It is suggested that a linear motion system motor by Oriental Motor Co. Ltd. to be used as a main motor in the dip coater system. The motor was proven by others to work efficiently in high precision operation. The motor mechanism converts rotational motion into linear motion.

Integrated motion control systems contain matched components such as controllers, motor drives, motors, encoders, user interfaces and software. The manufacturer optimally matches components in these systems. They are frequently customized for specific applications. Number of axes, motor power and torque, controller interface and networking options are developed with the applications area of a manufacturer. Systems specifications, network options, direct back plane interface, and environment are all important to consider when searching for motion control systems.

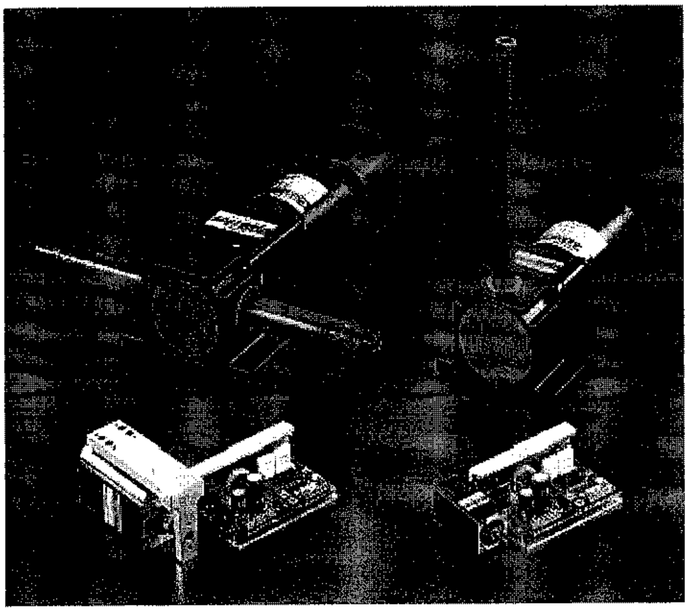


Figure 5.1: Precision Linear Actuator and Linear Heads, Oriental Motor Co. Ltd.

Compact Actuators DRL Series by Oriental Motor is a compact motor and has lightweight body houses. The DRL Series model helps to achieve a significant reduction in the size of the dip coater system. This model minimizes the number of the number parts involved in linear conversion results in higher reliability. DRL Series also eliminates the need to design, acquire and assemble the parts necessary to convert rotary to linear motion.

Oriental Motor also offered Linear Heads LH Series. Linear heads are linear motion rack and pinion units for use with standard AC motors. This model offered various types of movements. Precision Linear Actuator and Linear Heads motor was shown in Figure 5.1. Detail on Oriental Motor product was shown in Appendix E: Linear Motion System. It is believed that the operation of the dip coater would be more effective if the linear motion motor is used.

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8. C. Velásquez, A. Campero, Aortiz, Cadmium Stannate Thin Films Prepared by Sol-Gel Process, Departamento de Quimica, Universidad Autónoma Metropolitana-Iztapalapa, Instituto de Investigación en Materiales, Universidad Nacional Autónoma de México
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10. http://www.solgel.com
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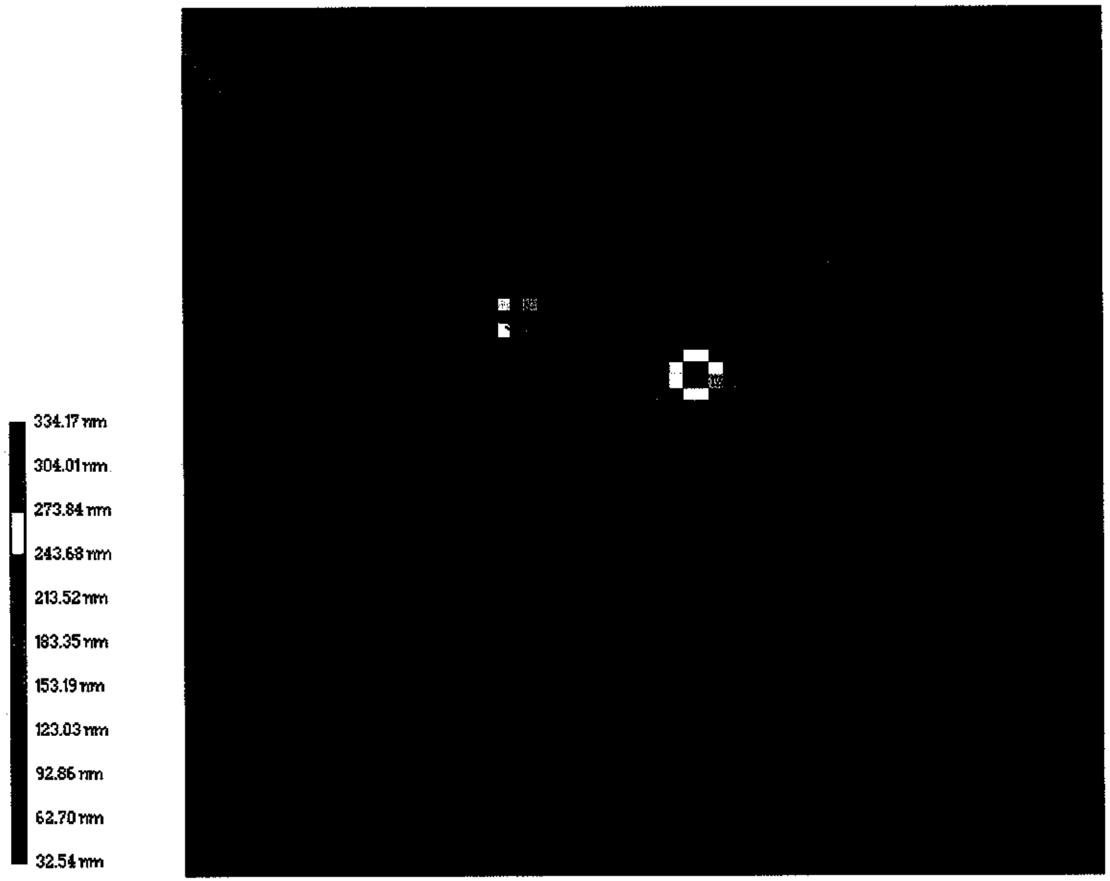
APPENDICES

APPENDIX A

SPECTROSCOPY REFLECTOMETER RESULT

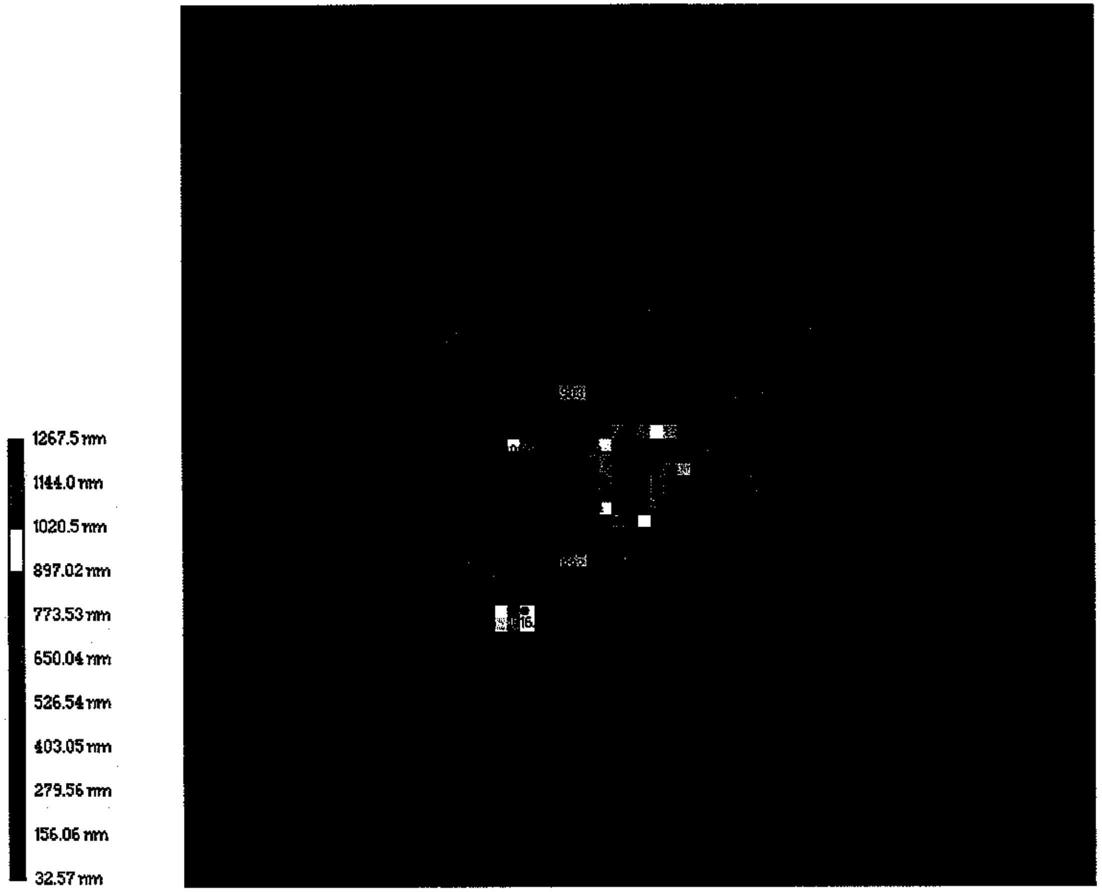
1. REFERENCE: Glass slide, without coating

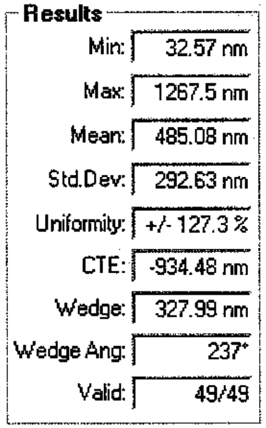


Results

Min:	32.54 nm
Max:	334.17 nm
Mean:	92.95 nm
Std.Dev:	60.29 nm
Uniformity:	+/- 162.2 %
CTE:	-59.78 nm
Wedge:	47.82 nm
Wedge Ang:	56°
Valid:	49/49

2. Glass slide, 0.5mm/sec, dip 0sec.




Results

Min: 32.57 nm

Max: 1267.5 nm

Mean: 485.08 nm

Std.Dev: 292.63 nm

Uniformity: +/- 127.3 %

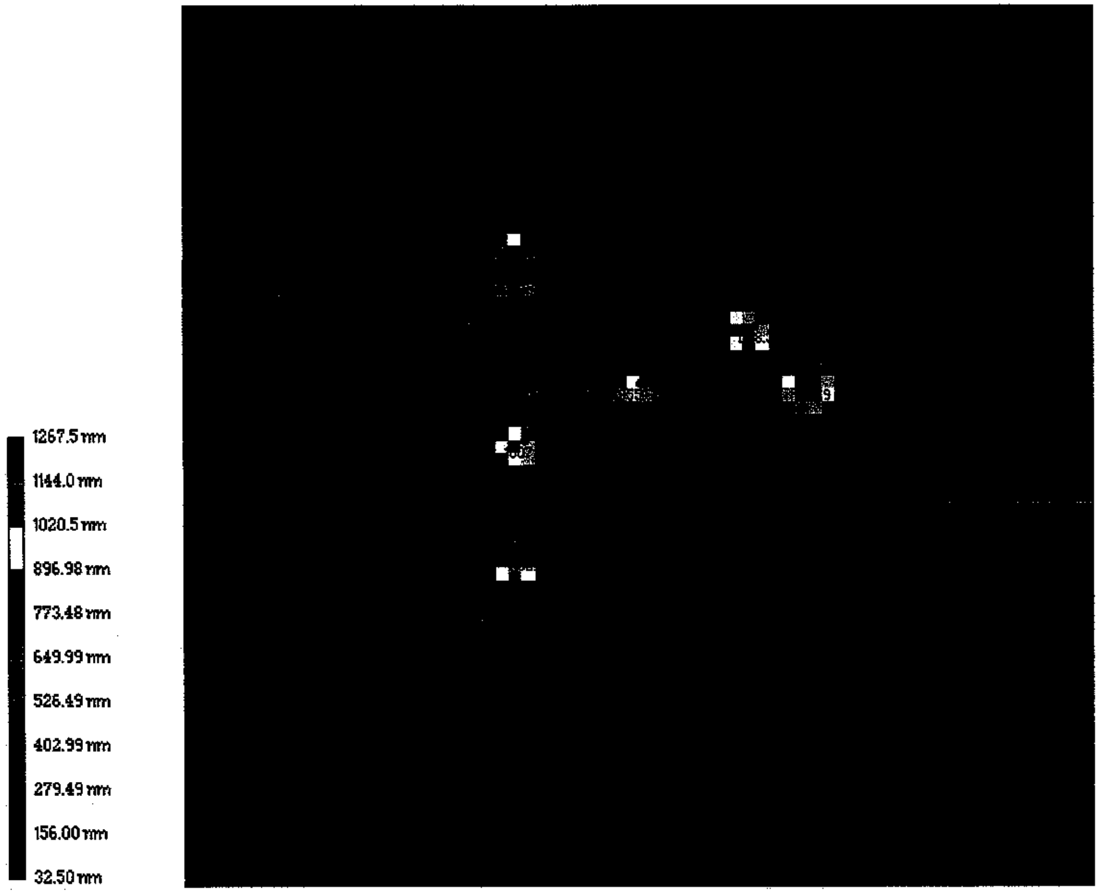
CTE: -934.48 nm

Wedge: 327.99 nm

Wedge Ang: 237°

Valid: 49/49

3. Glass slide, 1.5mm/sec, dip 0sec.



SIRIM

Results

Min: 32.50 nm

Max: 1267.5 nm

Mean: 438.64 nm

Std.Dev: 304.25 nm

Uniformity: +/- 140.8 %

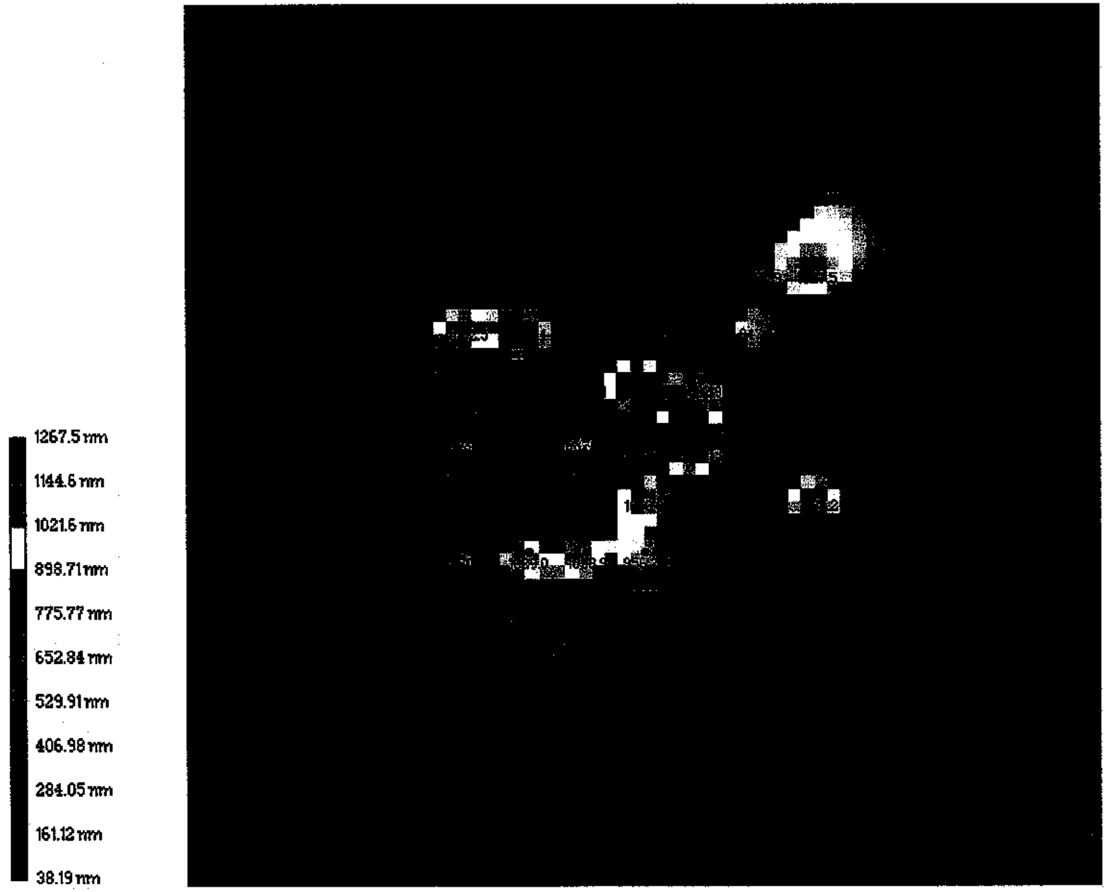
CTE: -99.78 nm

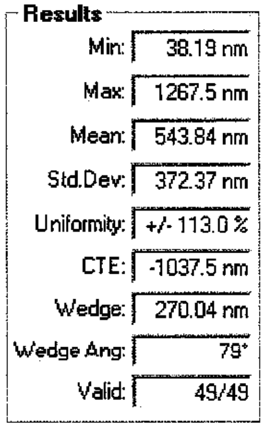
Wedge: 691.46 nm

Wedge Ang: 153°

Valid: 49/49

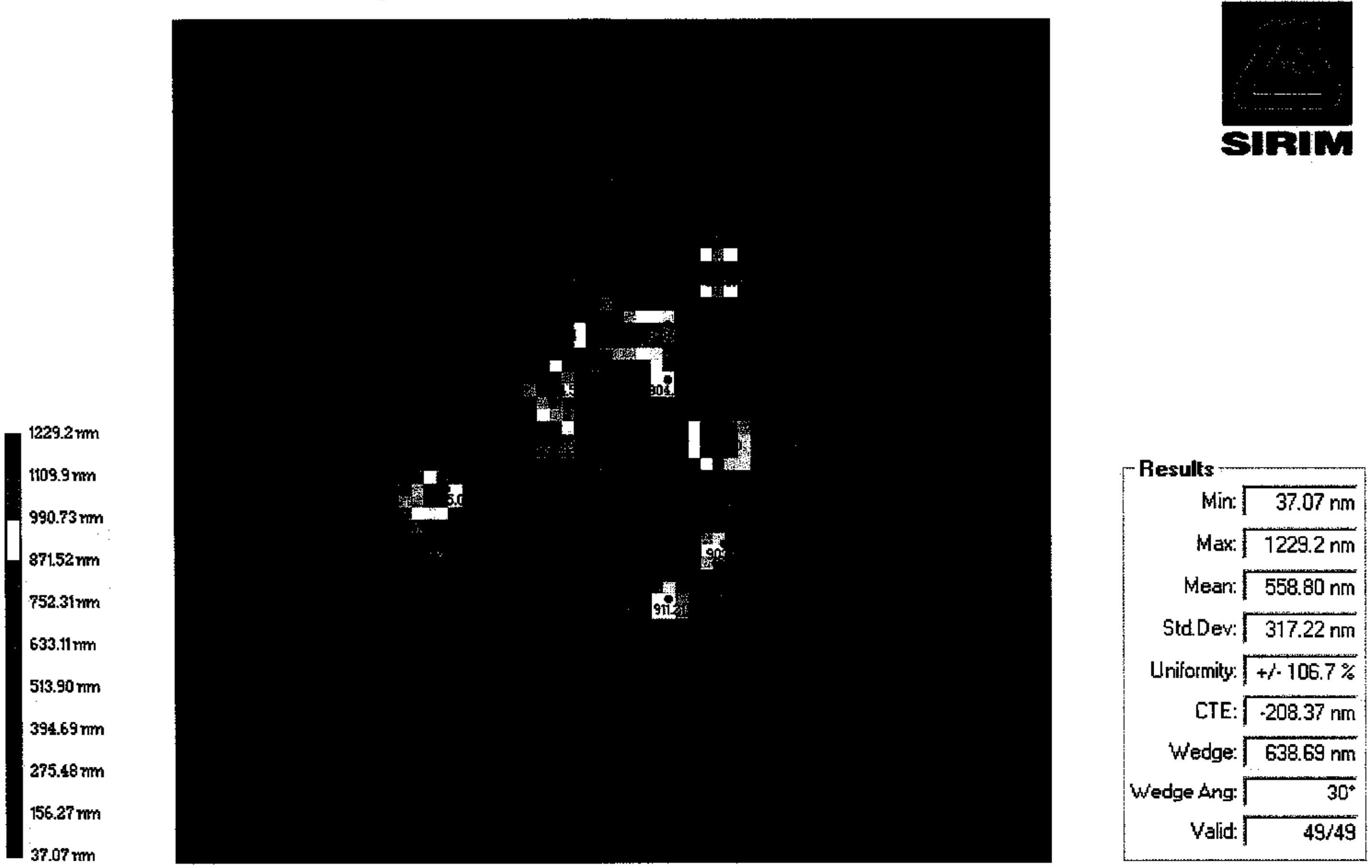
4. Glass slide, 0.5mm/sec, dip 1sec.




Results

Min: 38.19 nm
Max: 1267.5 nm
Mean: 543.84 nm
Std.Dev: 372.37 nm
Uniformity: +/- 113.0 %
CTE: -1037.5 nm
Wedge: 270.04 nm
Wedge Ang: 79°
Valid: 49/49

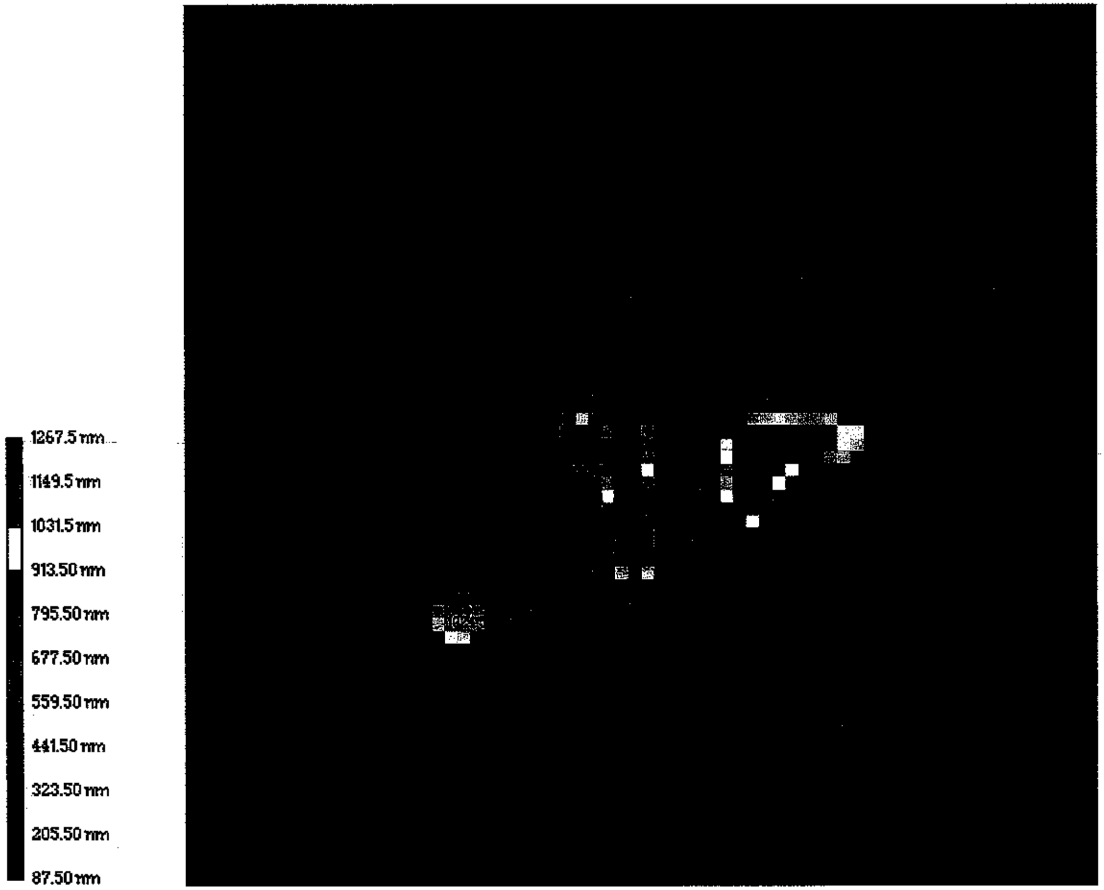
5. Glass slide, 0.5mm/sec, dip 30sec.

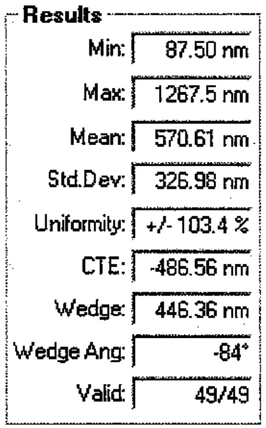


Results

Min:	37.07 nm
Max:	1229.2 nm
Mean:	558.80 nm
Std.Dev:	317.22 nm
Uniformity:	+/- 106.7 %
CTE:	-208.37 nm
Wedge:	638.69 nm
Wedge Ang:	30°
Valid:	49/49

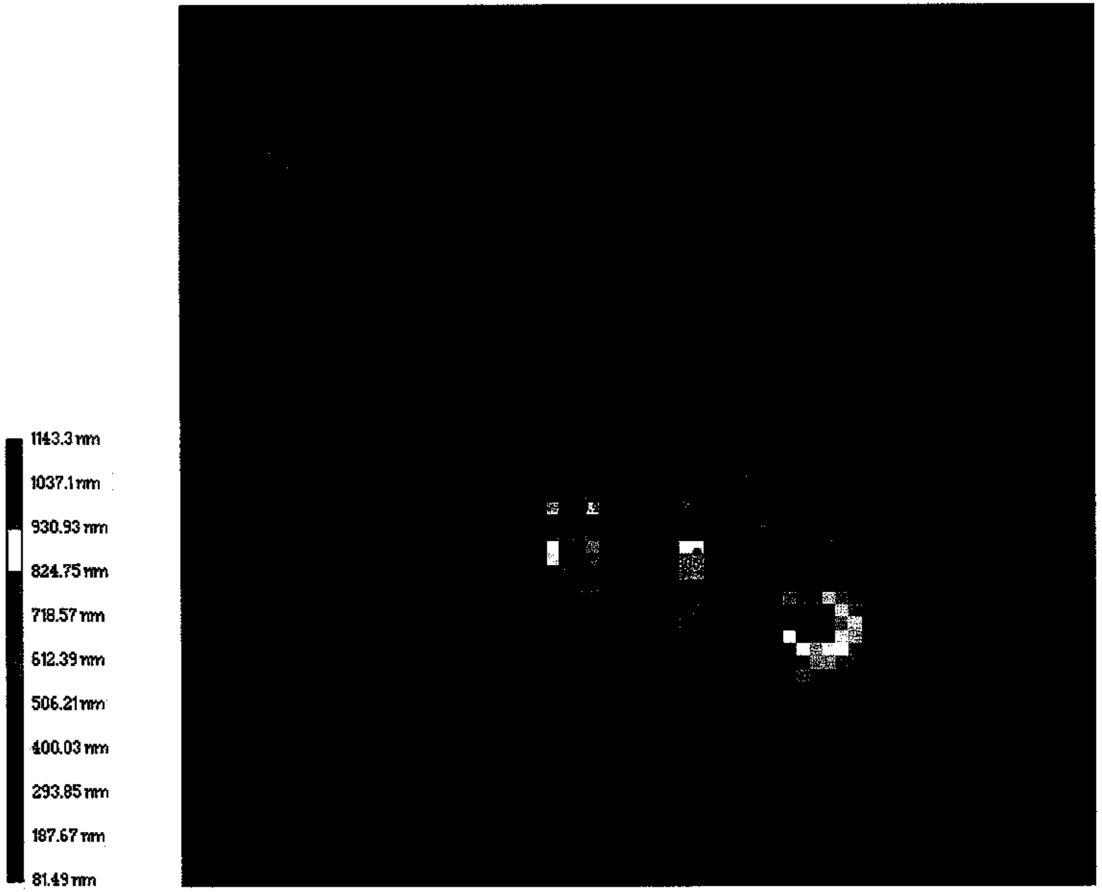
6. Glass slide, 0.5mm/sec, dip 60sec.

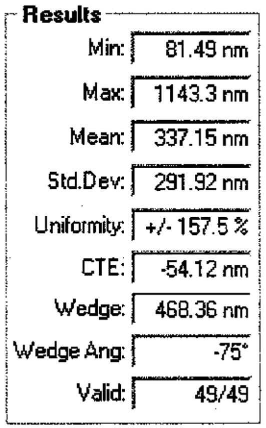



Results

Min:	87.50 nm
Max:	1267.5 nm
Mean:	570.61 nm
Std.Dev:	326.98 nm
Uniformity:	+/- 103.4 %
CTE:	-486.56 nm
Wedge:	446.36 nm
Wedge Ang:	-84°
Valid:	49/49

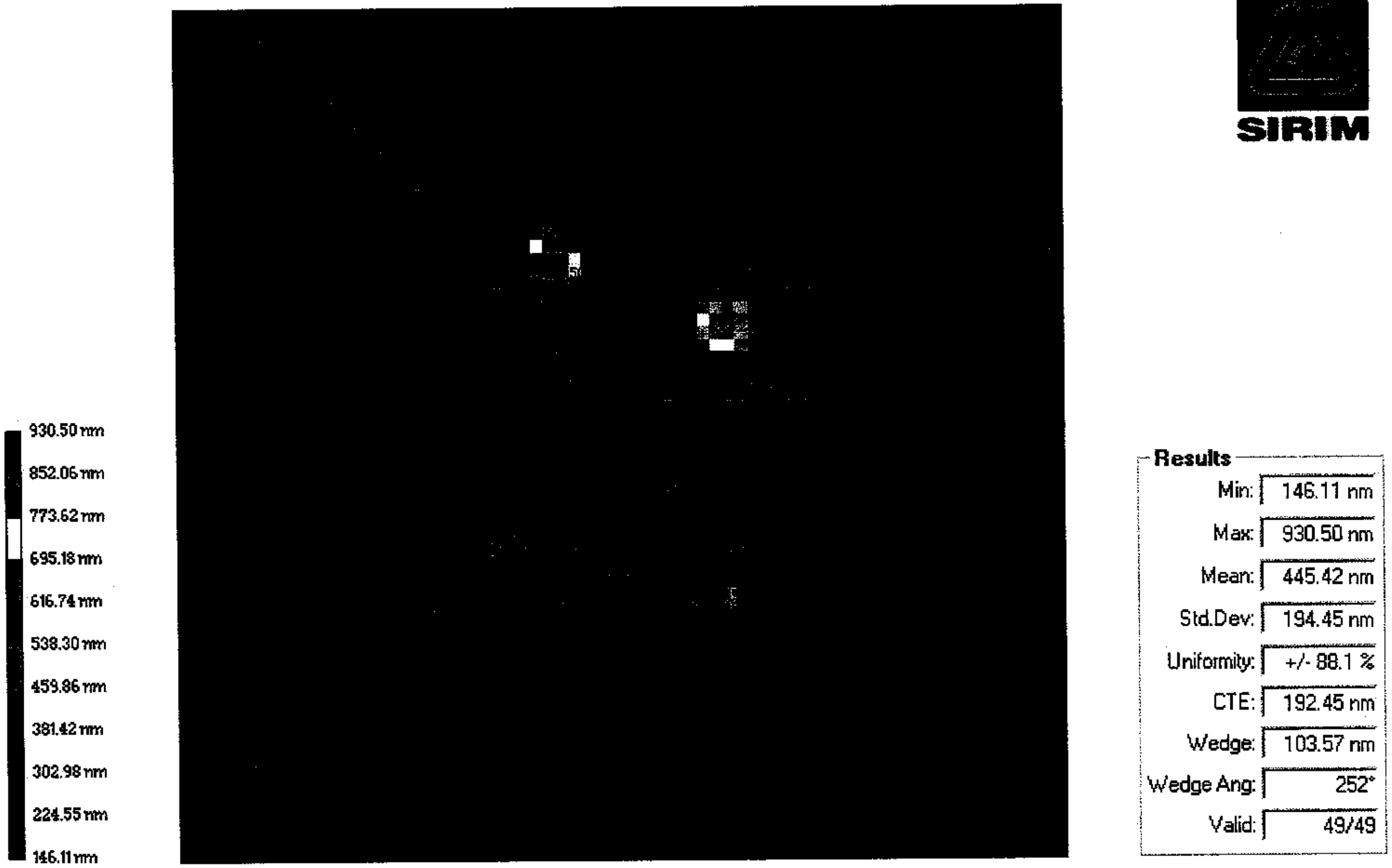
7. Glass slide, 0.5mm/sec, dip 0sec., 1 layer




Results

Min: 81.49 nm
Max: 1143.3 nm
Mean: 337.15 nm
Std.Dev: 291.92 nm
Uniformity: +/- 157.5 %
CTE: -54.12 nm
Wedge: 468.36 nm
Wedge Ang: -75°
Valid: 49/49

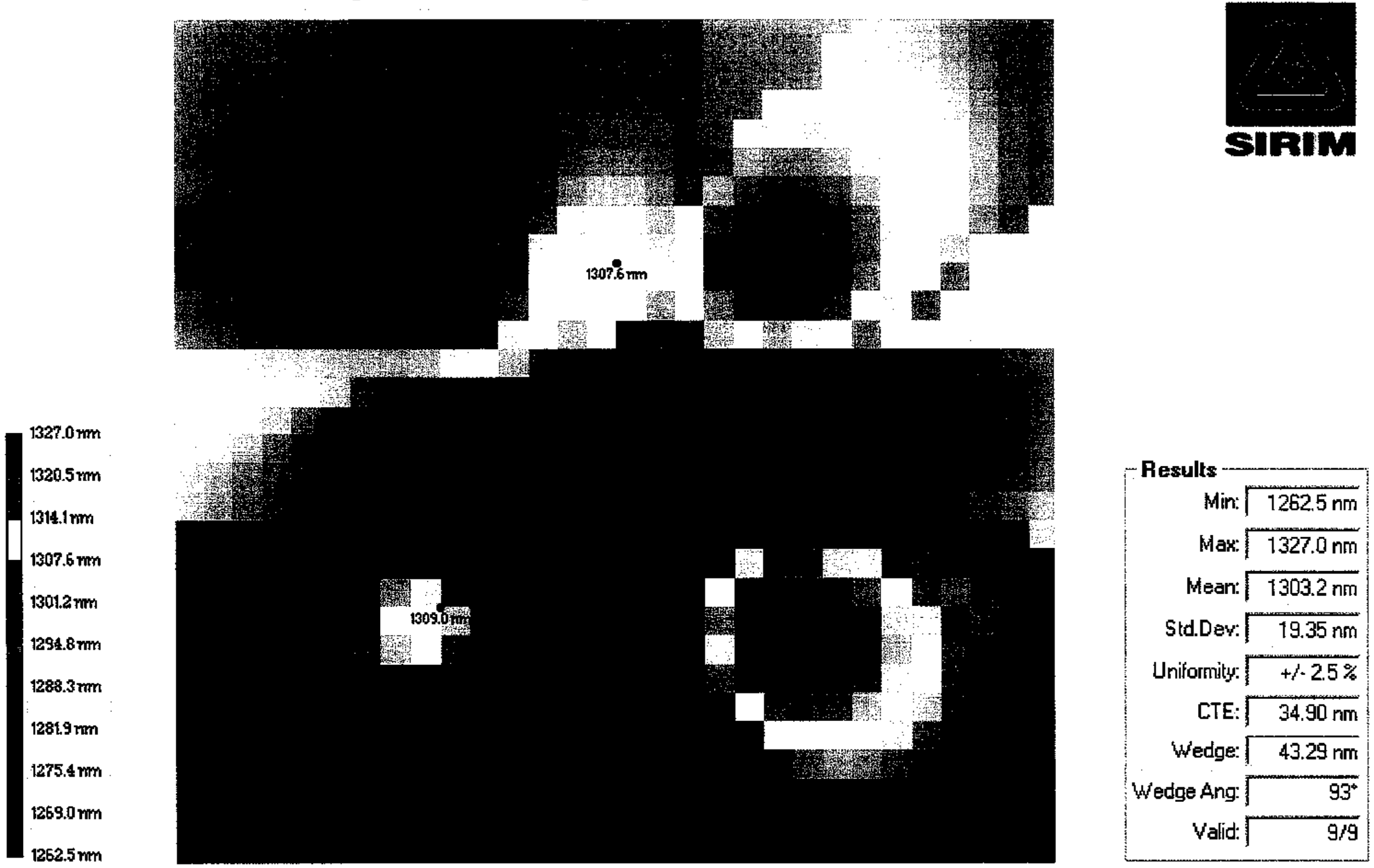
8. Glass slide, 0.5mm/sec, dip 0sec., 2 layers



Results

Min: 146.11 nm
Max: 930.50 nm
Mean: 445.42 nm
Std.Dev: 194.45 nm
Uniformity: +/- 88.1 %
CTE: 192.45 nm
Wedge: 103.57 nm
Wedge Ang: 252°
Valid: 49/49

9. Si-wafer, 0.5mm/sec, dip 0sec., before firing



Results

Min: 1262.5 nm

Max: 1327.0 nm

Mean: 1303.2 nm

Std.Dev: 19.35 nm

Uniformity: +/- 2.5 %

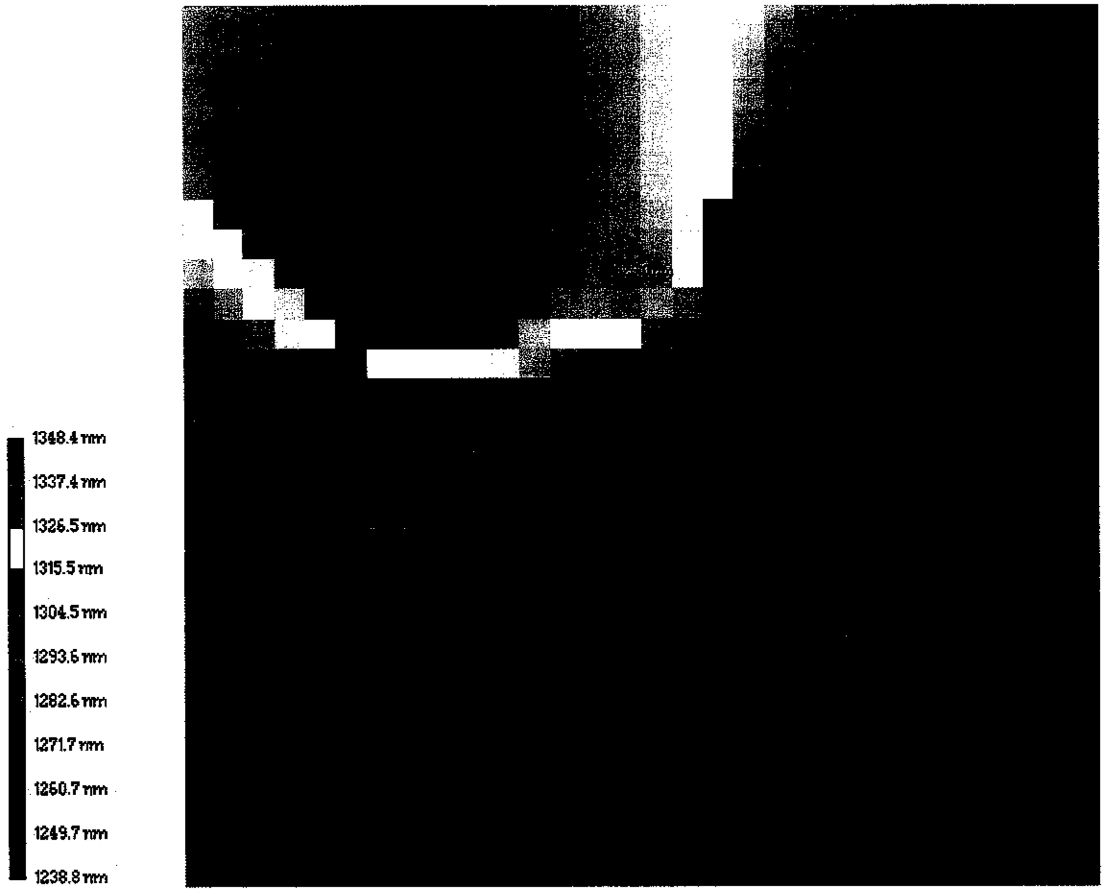
CTE: 34.90 nm

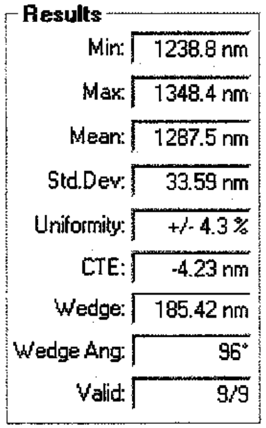
Wedge: 43.29 nm

Wedge Ang: 93°

Valid: 9/9

10. Si-wafer, 0.5mm/sec, dip 0sec., after firing




Results

Min: 1238.8 nm

Max: 1348.4 nm

Mean: 1287.5 nm

Std.Dev: 33.59 nm

Uniformity: +/- 4.3 %

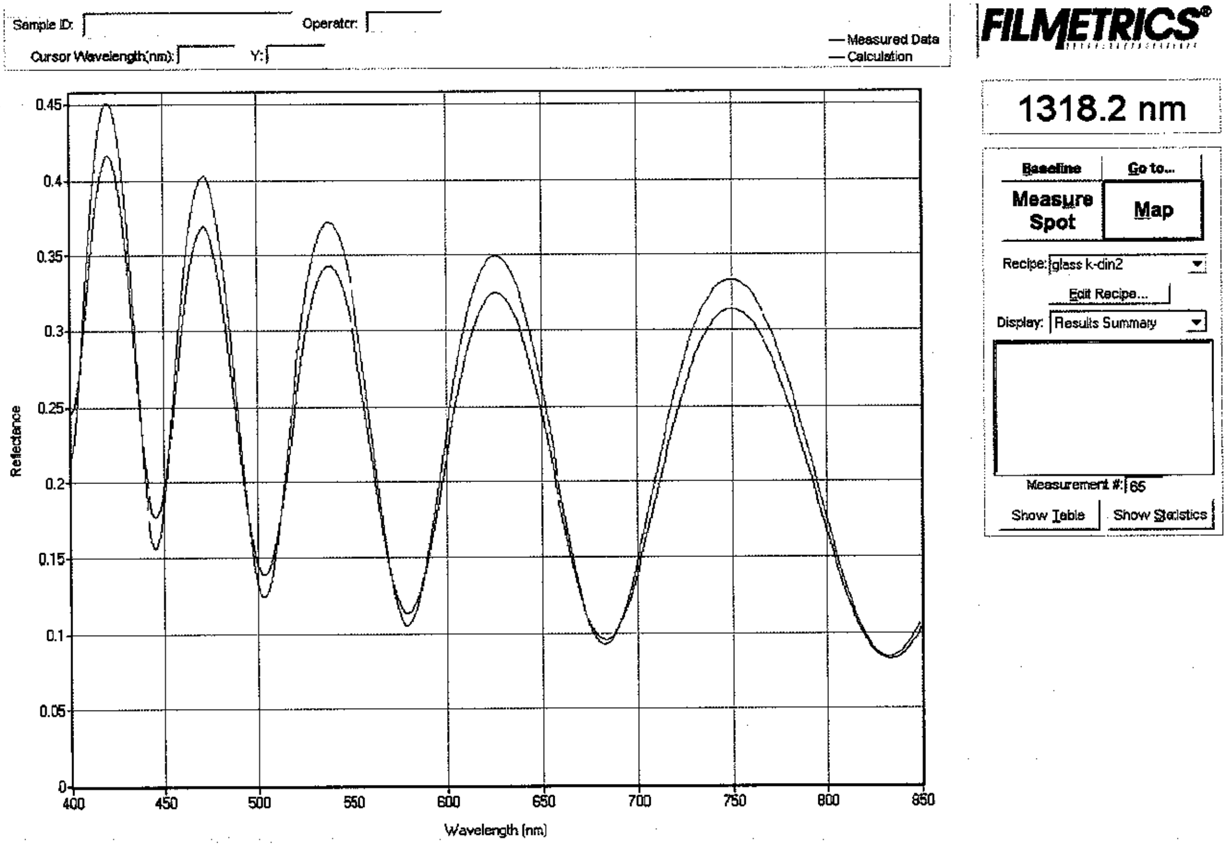
CTE: -4.23 nm

Wedge: 185.42 nm

Wedge Ang: 96°

Valid: 9/9

11. Single Spot Measured and Calculation



Sample ID:

Operator:

Cursor Wavelength(nm):

Y:

1318.2 nm

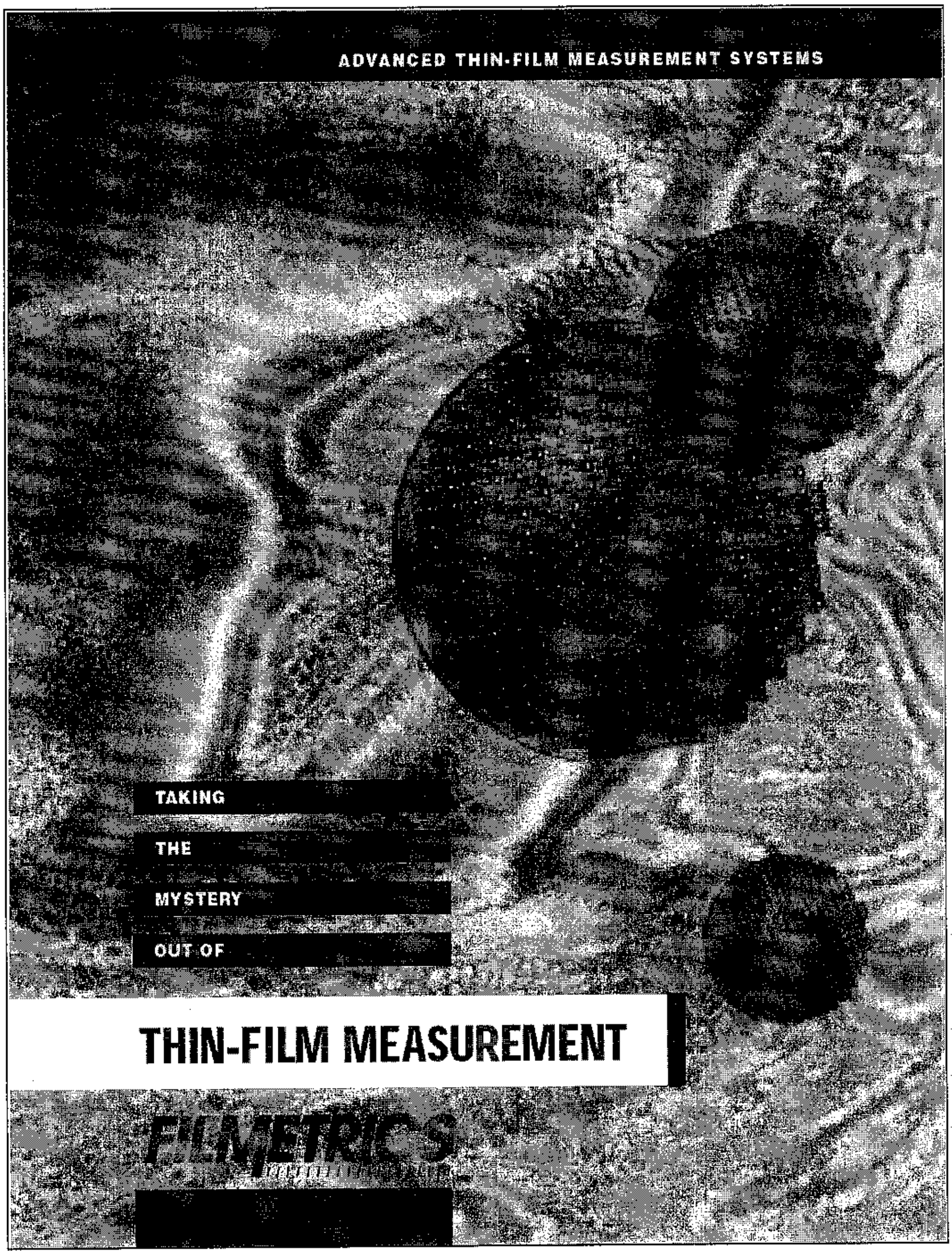
Recipe: glass k-din2

Display: Results Summary

Measurement #: 65

APPENDIX B

THIN-FILM MEASUREMENT: FILMETRICS



ADVANCED THIN-FILM MEASUREMENT SYSTEMS

TAKING
THE
MYSTERY
OUT OF

THIN-FILM MEASUREMENT

FILMETRICS

THIN-FILM MEASUREMENT

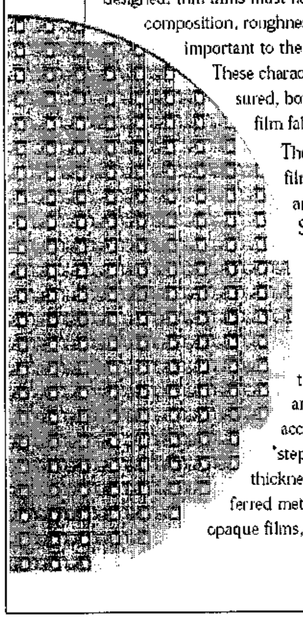
Introduction

Thin film

Very thin layers of material that are deposited on the surface of another material (thin films) are extremely important to many technology-based industries. Thin films are widely used, for example, to provide passivation, insulating layers between conductors, diffusion barriers, and hardness coatings for scratch and wear resistance. The fabrication of integrated circuits consists primarily of the deposition and selective removal of a series of thin films.

Films typically used in thin-film applications range from a few atoms (<10Å or 0.0001 µm) to 100 µm thick (the width of a human hair.) They can be formed by many different processes, including spin coating, vacuum evaporation, sputtering, vapor deposition, and dip coating.

To perform the functions for which they were designed, thin films must have the proper thickness, composition, roughness, and other characteristics important to the particular application. These characteristics must often be measured, both during and after thin-film fabrication.



The two main classes of thin-film measurement are optical and stylus based techniques. Stylus measurements measure thickness and roughness by monitoring the deflections of a fine-tipped stylus as it is dragged along the surface of the film. Stylus instruments are limited in speed and accuracy, and they require a "step" in the film to measure thickness. They are often the preferred method when measuring opaque films, such as metals.

Optical techniques determine thin-film characteristics by measuring how the films interact with light. Optical techniques can measure the thickness, roughness, and optical constants of a film. Optical constants describe how light propagates through and reflects from a material. Once known, optical constants may be related to other material parameters, such as composition and band gap.

Optical techniques are usually the preferred method for measuring thin films because they are accurate, nondestructive, and require little or no sample preparation. The two most common optical measurement types are spectral reflectance and ellipsometry. Spectral reflectance measures the amount of light reflected from a thin film over a range of wavelengths, with the incident light normal (perpendicular) to the sample surface. Ellipsometry is similar, except that it measures reflectance at non-normal incidence and at two different polarizations. In general, spectral reflectance is much simpler and less expensive than ellipsometry, but it is restricted to measuring less complex structures.

n and *k* Definitions

Optical constants (n and k) describe how light propagates through a film. In simple terms, the electromagnetic field that describes light traveling through a material at a fixed time is given by:

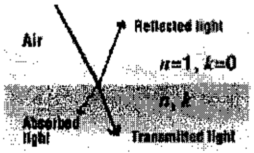
$$A \cdot \cos\left(n \frac{2\pi}{\lambda} x\right) \cdot \exp\left(-k \frac{2\pi}{\lambda} x\right)$$

where x is distance, λ is the wavelength of light, and n and k are the film's refractive index and extinction coefficient, respectively. The refractive index is defined as the ratio of the speed of light in a vacuum to the speed of light in the material. The extinction coefficient is a measure of how much light is absorbed in the material.

Spectral Reflectance Basics

Single Interface

Reflection occurs whenever light crosses the interface between different materials. The fraction of light that is reflected by an interface is determined by the discontinuity in n and k. For light reflected off of a material in air,

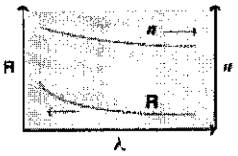


$$R = \frac{(n-1)^2+k^2}{(n+1)^2+k^2}$$

To see how spectral reflectance can be used to measure optical constants, consider the simple case of light reflected by a single nonabsorbing material (k=0). Then:

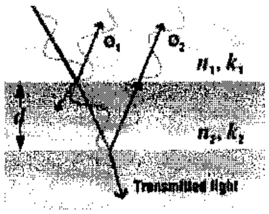
$$R = \left|\frac{n-1}{n+1}\right|^2$$

Clearly, n of the material can be determined from a measurement of R. In real materials, n varies with wavelength (that is to say, real materials exhibit dispersion), but since the reflectance is known at many wavelengths, n at each of these wavelengths is also known, as shown here.



Multiple Interfaces

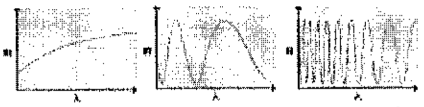
Consider now a thin film on top of another material. In this case both the top and bottom of the film reflect light. The total amount of reflected light is the sum of these two individual reflections. Because of the wavelike nature of light, the reflections from the two interfaces may add together either constructively (intensities add) or destructively (intensities subtract), depending upon their phase relationship. Their phase relationship is determined by the difference in optical path lengths of the two reflections, which in turn is determined by thickness of the film, its optical constants, and the wavelength of the light. Reflections are in-phase and therefore add constructively when the light path is equal to one integral multiple of the wavelength of light. For light perpendicularly incident on a transparent film, this occurs when $2nd = i\lambda$ where d is the thickness of the film and i is an integer (the factor of two is due to the fact that the light passes through the film twice.) Conversely, reflections are out of phase and add destructively when the light path is one half of a wavelength different from the in-phase condition, or when $2nd = (i + 1/2)\lambda$. The qualitative aspects of these reflections may be combined into a single equation:



From this, we can see that the reflectance of a thin film will vary periodically with 1/wavelength, which is illustrated below. Also, thicker films will exhibit a greater number of oscillations over a given wavelength range, while thinner films will exhibit fewer oscillations, and oftentimes only part of an oscillation, over the same range.

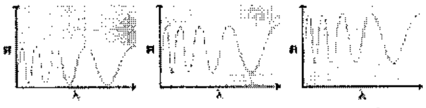
$$R = A + B\cos\left(\frac{2\pi}{\lambda}nd\right)$$

Determination of thickness ***(d)***



d = 500 Å d = 5000 Å d = 20,000 Å

Determination of refractive index ***(n)***



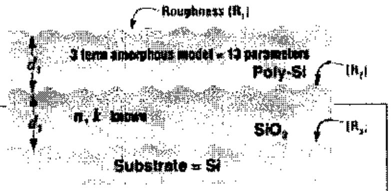
n = 3 n = 4 n = 5

Determining Film Properties from Spectral Reflectance

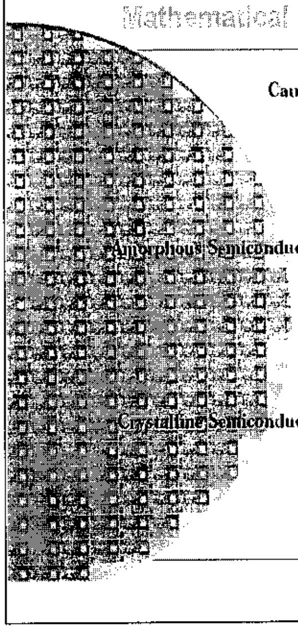
The amplitude and periodicity of the reflectance of a thin film is determined by the film's thickness, optical constants, and other properties such as interface roughness. In cases where there is more than one interface, it is not possible to solve for film properties in closed form, nor is it possible to solve for *n* and *k* at each wavelength individually. In practice, mathematical models are used that describe *n* and *k* over a range of wavelengths using only a few adjustable parameters. A film's properties are determined by calculating reflectance spectra based on trial values of thickness and the *n* and *k* model parameters, and then adjusting these values until the calculated reflectance matches the measured reflectance.

Models for *n* and *k*

There are many models for describing *n* and *k* as a function of wavelength. When choosing a model for a particular film, it is important that the model be able to accurately describe *n* and *k* over the wavelength range of interest using as few parameters as possible. In general, the optical constants of different classes of materials (e.g., dielectrics, semiconductors, metals, and amorphous materials) vary quite differently with wavelength, and require different models to describe them (see below.) Models for dielectrics (*k*=0) generally have three parameters, while nondielectrics generally have five or more parameters. Therefore, as an example, to model the two-layer structure shown below, a total of 18 adjustable parameters must be considered in the solution.



Mathematical Models for *n* & *k*



Cauchy: $n(\lambda) = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4}$

$k(\lambda) = 0$

Fitting parameters: A, B, C (total of 3)

Amorphous Semiconductor: $\varepsilon_2(E) = 2nk = \sum_{i=1}^{j=1,2\text{ or }3} \frac{A_iC_iE_{0i}(E-E_{gi})^2}{(E^2-E_{0i}^2)^2+C_i^2E^2} \cdot \frac{1}{E}$ If $E > E_g$, or $= 0$ if $E < E_g$

$\varepsilon_1(E) = n^2-k^2 = \varepsilon_1(\infty) + \frac{2P}{\pi}\int_0^\infty \frac{s\varepsilon_2(s)}{s^2-E^2}ds$ (Kramers-Kronig relationship)

Fitting parameters: $\varepsilon_1(\infty)$, A_1, C_1, E_{g1}, E_{01}, … (total of 5, 9 or 13)

Crystalline Semiconductor: $\varepsilon_2(E) = 2nk = \sum_{i=1}^{j=1,2\text{ or }3} \frac{A_i}{B_i+(E-E_{0i})^2}$

$\varepsilon_1(E) = n^2-k^2 = \varepsilon_1(\infty) + \frac{2P}{\pi}\int_0^\infty \frac{s\varepsilon_2(s)}{s^2-E^2}ds$ (Kramers-Kronig relationship)

Fitting parameters: $\varepsilon_1(\infty)$, A_1, B_1, E_{01}, … (total of 4,7 or 10)

Number of Variables, Limitations of Spectroscopic Reflectance

Spectral reflectance can measure the thickness, roughness, and optical constants of a broad range of thin films. However, if there is less than one reflectance oscillation (ie. the film is very thin), there is less information available to determine the adjustable model parameters. Therefore, the number of film properties that may be determined decreases for very thin films. If one attempts to solve for too many parameters, a unique solution cannot be found: more than one possible combination of parameter values may result in a calculated reflectance that matches the measured reflectance.

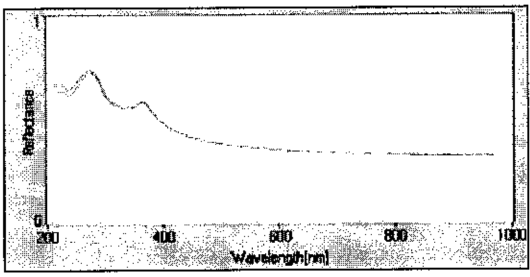
An example of the reflectance from a very thin film, 50Å of SiO_2 on silicon is shown below, where it is compared to the reflectance from a bare silicon substrate. In this case, measuring the thickness, roughness, and *n* of the SiO_2 requires five parameters to be determined. Clearly, the change in the spectra caused by adding 50Å of SiO_2 does not require five parameters to describe, and a unique solution cannot be found unless some additional assumptions are made.

Depending upon the film and the wavelength range of the measurement, the minimum single-film thickness that can be measured using spectral reflectance is in the 10Å to 300Å range. If one is trying to measure optical constants as well, the minimum thickness increases to between 100Å and 2000Å, unless minimal parameterization models can used. When solving for the optical properties of more than one film, the minimum thicknesses are increased even further.

Spectroscopic Reflectance versus Ellipsometry

Given the restrictions listed above, spectral reflectance can be used to measure a large percentage of technologically important films. However, when films are too thin, too numerous, or too complicated to be measured with spectral reflectance, oftentimes they can be measured with the generally more powerful technique of spectroscopic ellipsometry. By measuring reflectance at non-normal incidence (typically around 75° from normal) ellipsometry is more sensitive to very thin layers, and the two different polarization measurements provide twice as much information for analysis. To carry the idea even further, variable-angle ellipsometry can be used to take reflectance measurements at many different incidence angles, thereby increasing the amount of information available for analysis.

The following pages of this brochure describe spectral reflectance systems available from Filmetrics. If you are uncertain whether spectral reflectance or ellipsometry is appropriate for your film measurements, please call us to discuss your application. If spectral reflectance cannot satisfy your needs, we will be happy to refer you to a reputable source for ellipsometry.



Thin-Film Measurements on your bench top

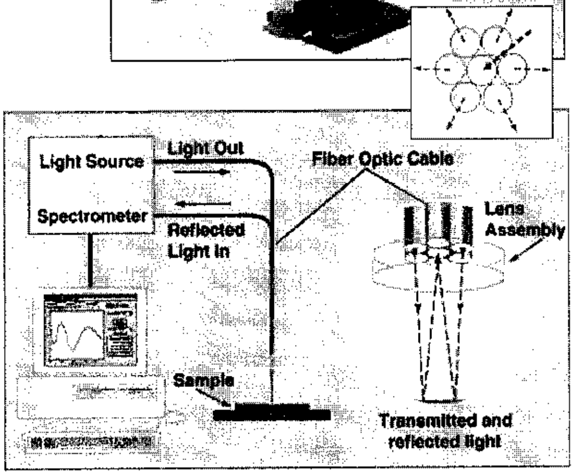
Thickness, refractive index, and extinction coefficients are measured quickly and easily with Filmetrics' advanced spectrometry systems. Simply plug the Filmetrics system into your computer's parallel port and start making measurements. The entire system sets up in minutes and measurements can be made by anyone with basic computer skills. This simple hardware and intuitive software provides thin-film knowledge to a whole new group of users.

From near infrared to ultraviolet

Systems are available with wavelengths from 215 nm to 1700 nm enabling thickness measurements of films 10 angstroms to 350 µm thick. The Filmetrics systems measure transparent thin films made from virtually all common materials.

Easy to use software

The familiar and user friendly interface provided by Filmetrics software is quickly mastered. Measurements are made at about one per second. Measured data, along with meaurement details, are easily saved and exportedd with standard Windows file saving and clipboard methods. Plus, Dynamic Data Exchange allow for easy integration with other programs.



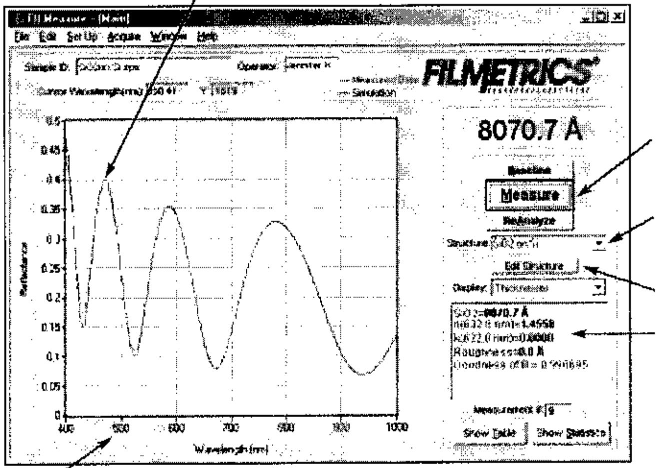
AWARD WINNING PRODUCTS

R&D 100 Award

The Filmetrics in-situ system, Model F30, was selected as one of the 100 most technologically significant new products of 1997 by R&D Magazine.

COMPLEX MEASUREMENTS MADE SIMPLE

Both the measured and calculated reflectance spectra are displayed so that the integrity of the measurement may easily be judged. The measured n and k curves may also be plotted.



One measurement – One mouse click

Choose from a list of common film types,

or define your own

Measurement results are displayed in an easy-to-read format

A wide range of reflectance wavelengths are available, from 220 to 1700 nm

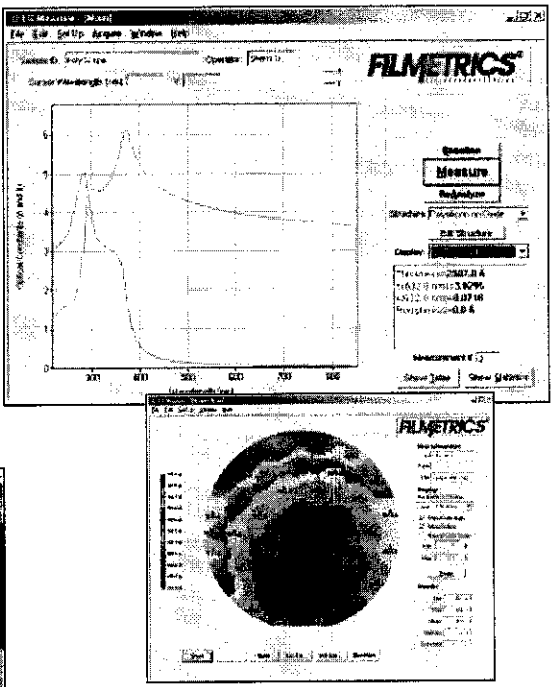
Photonics Spectra Circle of Excellence

The Filmetrics F20 was chosen as one of the 25 most significant new products of 1998 by Photonics Spectra Magazine.

REAL WORLD APPLICATIONS

Semiconductor Process Films— **Lab / Process**

Filmetrics measurement systems are routinely used to measure the thickness, roughness, and optical constants of oxides, SiN_x, photoresist, and other semiconductor process films. In addition to these single layer applications, many two- and three-layer film measurements are also possible. An example is polysilicon/SiO_2 on silicon, which is used in SOI applications. The screen to the right shows a typical measurement result for the structure modeled on page 4.

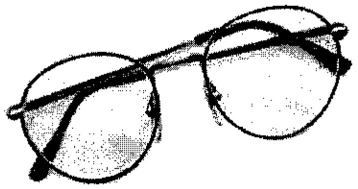


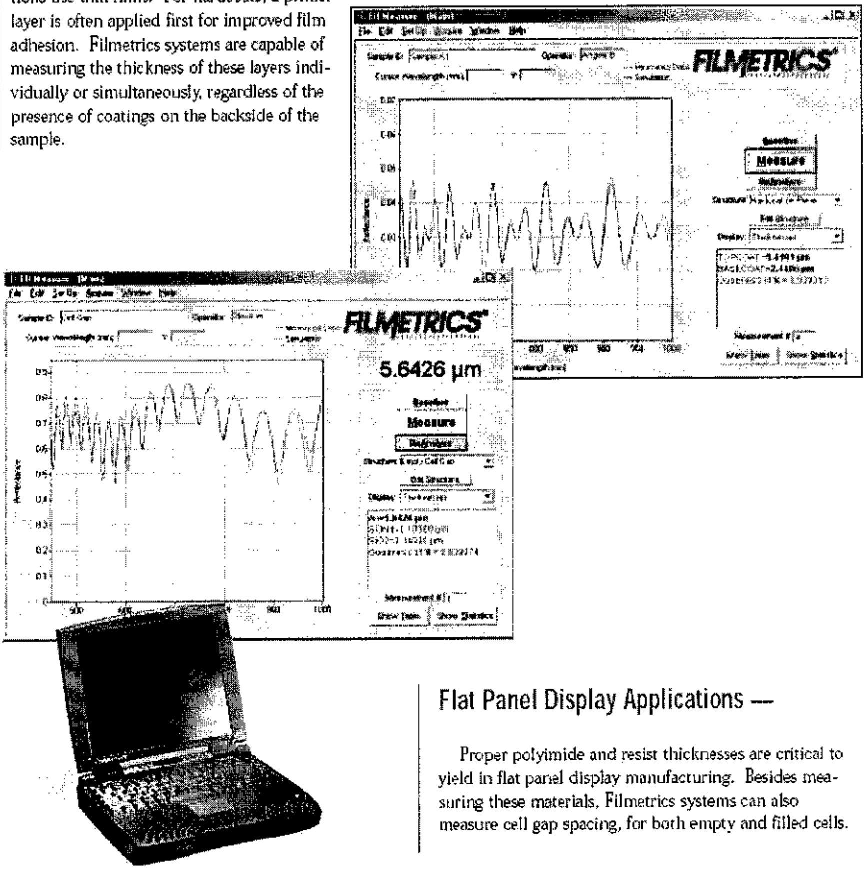
In-Situ Measurements —

The flexible optical probe assembly makes on-line and in-situ thickness measurements possible. All that is required is optical access for normal-incidence reflectance measurements. Call us for more details about interfacing with your production equipment.

Optical Coatings —

Thin films are used for scratch resistance and/or antireflection coatings in many industries. Automotive plastics, eyeglass lenses, and many plastics packaging applications use thin films. For hardcoats, a primer layer is often applied first for improved film adhesion. Filmetrics systems are capable of measuring the thickness of these layers individually or simultaneously, regardless of the presence of coatings on the backside of the sample.





Flat Panel Display Applications —

Proper polyimide and resist thicknesses are critical to yield in flat panel display manufacturing. Besides measuring these materials, Filmetrics systems can also measure cell gap spacing, for both empty and filled cells.

F20

Thin-Film Measurements in Seconds

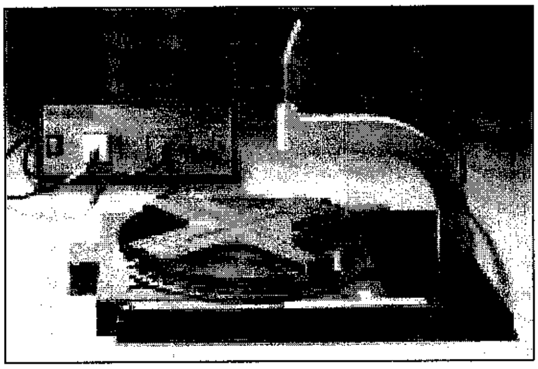
Bench top measurements of thickness, optical constants (n and k) and transmittance are made quickly and easily by the Model F20. This versatile hardware can be configured to measure transparent or translucent films that are 30 Å to 350 µm in thickness. Typical accuracy is within a few angstroms. Spot size is adjustable over a wide range.

Accessories

A wide variety of stages, chucks, and special measurement heads are available to fixture most sample geometries.

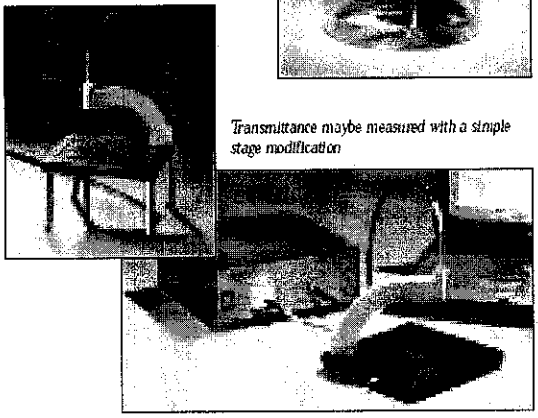
Surprisingly Low Price

Filmetrics is pleased to offer a breakthrough price. Complete F20 systems are available for less than $12,000. The difficult and expensive task of thin-film measurement is now simple and inexpensive.



Wafer chucks make sample handling easy

Accessories are available for measuring nonstandard samples



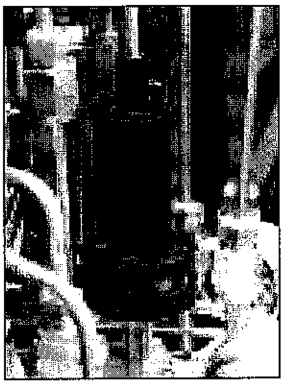
Transmittance maybe measured with a simple stage modification

FILMETRICS F30, F40 & F50

F30

In-Situ Measurements

For process applications, Filmetrics offers systems that need only optical access. Interfaces to a wide range of control systems are available.

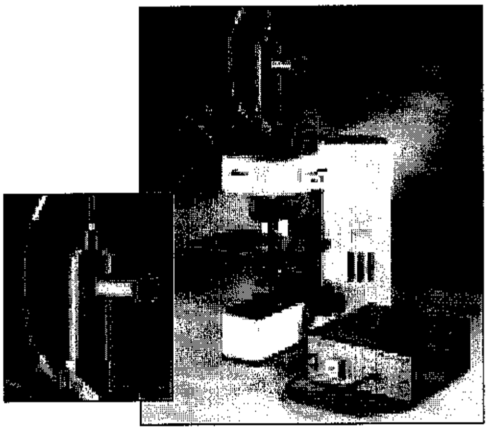


F40

Turns Your Microscope into a Film Thickness Measurement Tool

For thickness measurements on patterned surfaces and other applications that require a spot size as small as 10 microns.

For most common microscopes, the F40 is a simple bolt-on attachment. Standard c-mount adapter provided for CCD camera viewing of measurement location.

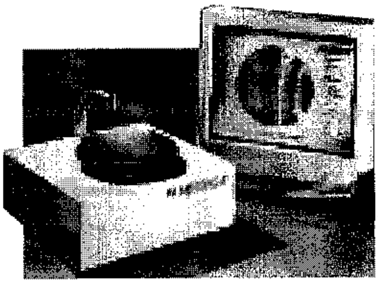


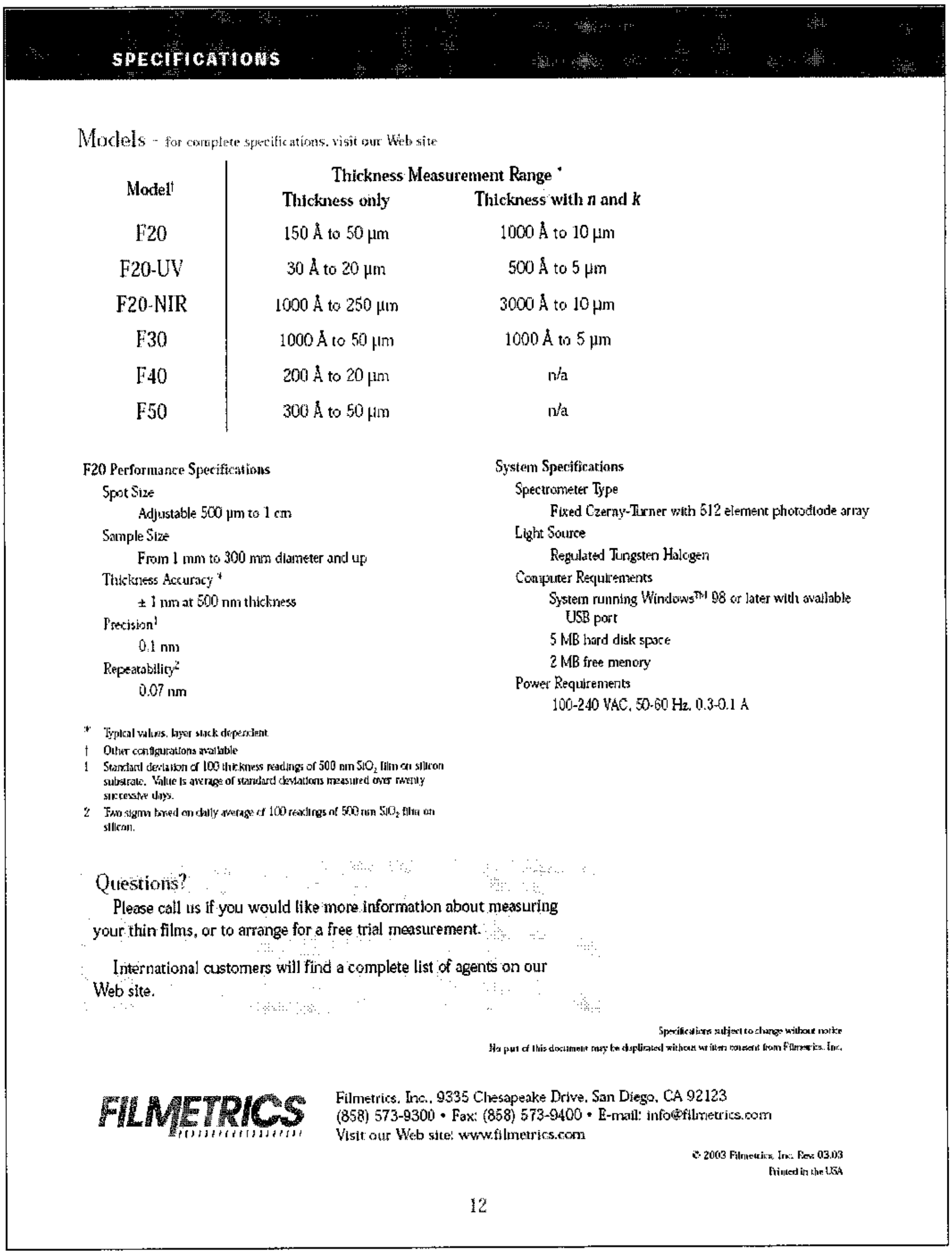
F50

Thickness Mapping System

Extends F20 thickness measurement functionality and intuitive operation to automated mapping of large area samples.

Map sample uniformity in minutes. Five points to hundreds of points as fast as one second per point. Standard chucks available for up to 12" diameter wafers. Custom chucks also available.





SPECIFICATIONS

Models - for complete specifications, visit our Web site

Model[†]	Thickness Measurement Range [*]	
	Thickness only	Thickness with *n* and *k*
F20	150 Å to 50 µm	1000 Å to 10 µm
F20-UV	30 Å to 20 µm	500 Å to 5 µm
F20-NIR	1000 Å to 250 µm	3000 Å to 10 µm
F30	1000 Å to 50 µm	1000 Å to 5 µm
F40	200 Å to 20 µm	n/a
F50	300 Å to 50 µm	n/a

F20 Performance Specifications
- Spot Size
  - Adjustable 500 µm to 1 cm
- Sample Size
  - From 1 mm to 300 mm diameter and up
- Thickness Accuracy [*]
  - ± 1 nm at 500 nm thickness
- Precision[1]
  - 0.1 nm
- Repeatability[2]
  - 0.07 nm

System Specifications
- Spectrometer Type
  - Fixed Czerny-Turner with 512 element photodiode array
- Light Source
  - Regulated Tungsten Halogen
- Computer Requirements
  - System running Windows™ 98 or later with available USB port
  - 5 MB hard disk space
  - 2 MB free menory
- Power Requirements
  - 100-240 VAC, 50-60 Hz, 0.3-0.1 A

[*] Typical values, layer stack dependent.

[†] Other configurations available

[1] Standard deviation of 100 thickness readings of 500 nm SiO_2 film on silicon substrate. Value is average of standard deviations measured over twenty successive days.

[2] Two sigma based on daily average of 100 readings of 500 nm SiO_2 film on silicon.

Questions?

Please call us if you would like more information about measuring your thin films, or to arrange for a free trial measurement.

International customers will find a complete list of agents on our Web site.

FILMETRICS

Filmetrics, Inc., 9335 Chesapeake Drive, San Diego, CA 92123
(858) 573-9300 • Fax: (858) 573-9400 • E-mail: info@filmetrics.com
Visit our Web site: www.filmetrics.com

12

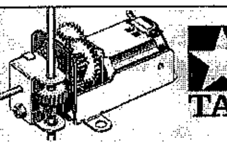
APPENDIX C
MOTOR AND GEARBOX

ITEM 70103

UNIVERSAL GEARBOX

楽しい工作シリーズNO.103

ユニバーサルギヤーボックス



TAMIYA

⚠注 意

●このキットは組み立て式です。
作る前にかならず説明書を最後までお読み下さい。また、小学生などの低年齢の方が組み立てる時は、保護者の方もお読み下さい。

●工具の使用には十分注意して下さい。

●部品はやむなくとがっているところがあります。取り扱いに注意して下さい。

●小さなお子様のいる場所での工作はやめて下さい。小さな部品の飲み込みや、ビニール袋を口に入れるなどの危険な状況が考えられます。

⚠WARNING:

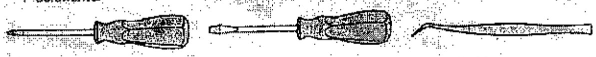
This set contains small parts which may be hazardous to children under three.
This toy is battery operated. Follow instructions for proper battery installation.
This set contains parts which have sharp points and edges. Sand jagged edges before use.
Keep fingers free from moving parts.
Product may overheat during prolonged use.

⚠CAUTION:

Read instructions carefully before use. Assembly required. Tools not included.

《組み立てる前に用意するもの》 TOOLS REQUIRED FOR ASSEMBLY

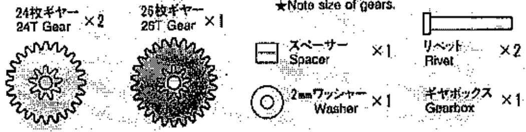
●プラスドライバー + Screwdriver
●マイナスドライバー − Screwdriver
●ピンセット Tweezers



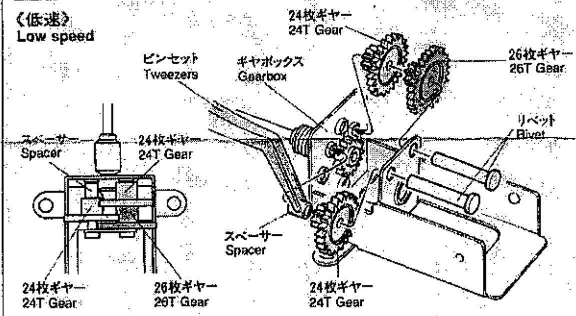
❶ ギヤボックスのくみたて GEARBOX ASSEMBLY

●ギヤーの並び方で3タイプのスピードが選べます。
●Select one of three speeds according to use.

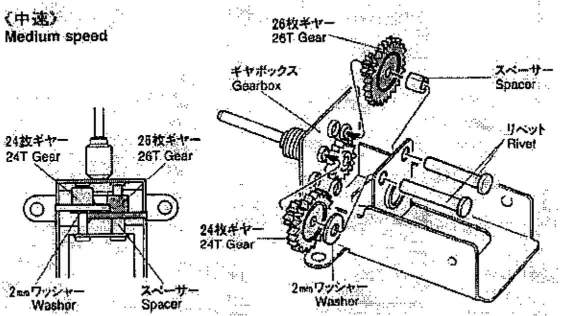
★ギヤーの大きさに注意します。
★Note size of gears.



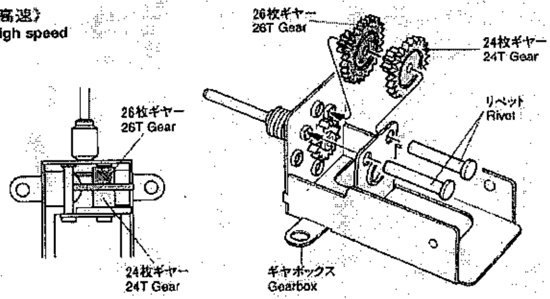
《低速》
Low speed



《中速》
Medium speed

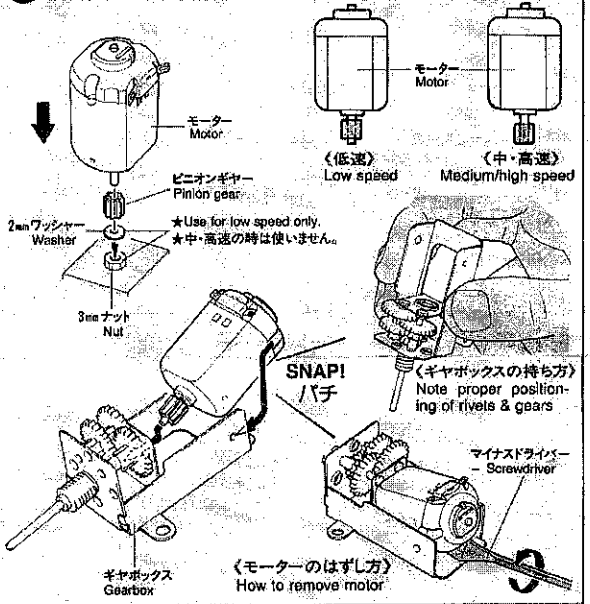


《高速》
High speed



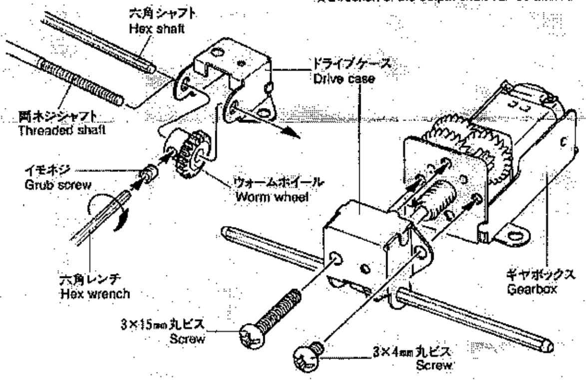
❷ モーターのとりつけ
ATTACHING MOTOR

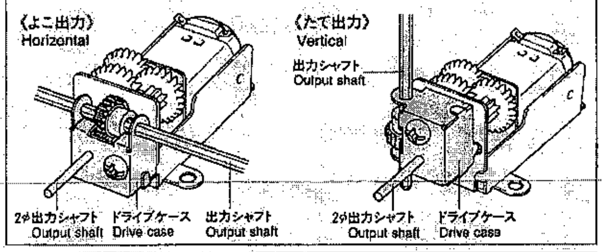
★ピニオンギヤーのとりつけ方に注意します。
★Note pinion gear position.



❸ ドライブケースのとりつけ
OUTPUT SHAFT

★ドライブケースのとりつけ位置によって出力シャフトの向きを変えられます。
★Direction of the output shaft can be altered.

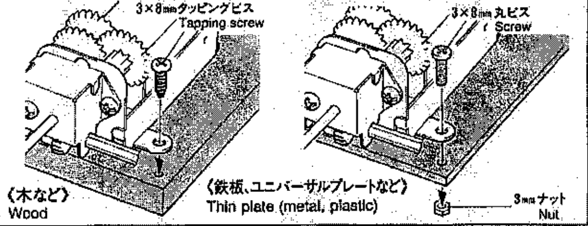




ギヤボックスのとりつけ
SECURING GEARBOX

★使用上の注意
- ●適正電圧は3Vです。
- ●出力シャフト(低速時)を無理に停止させると、ギヤーが破損する事があります。

★CAUTION
- ●Suitable voltage: 3V
- ●Do not hinder rotation of output shafts. May cause damage to gears.

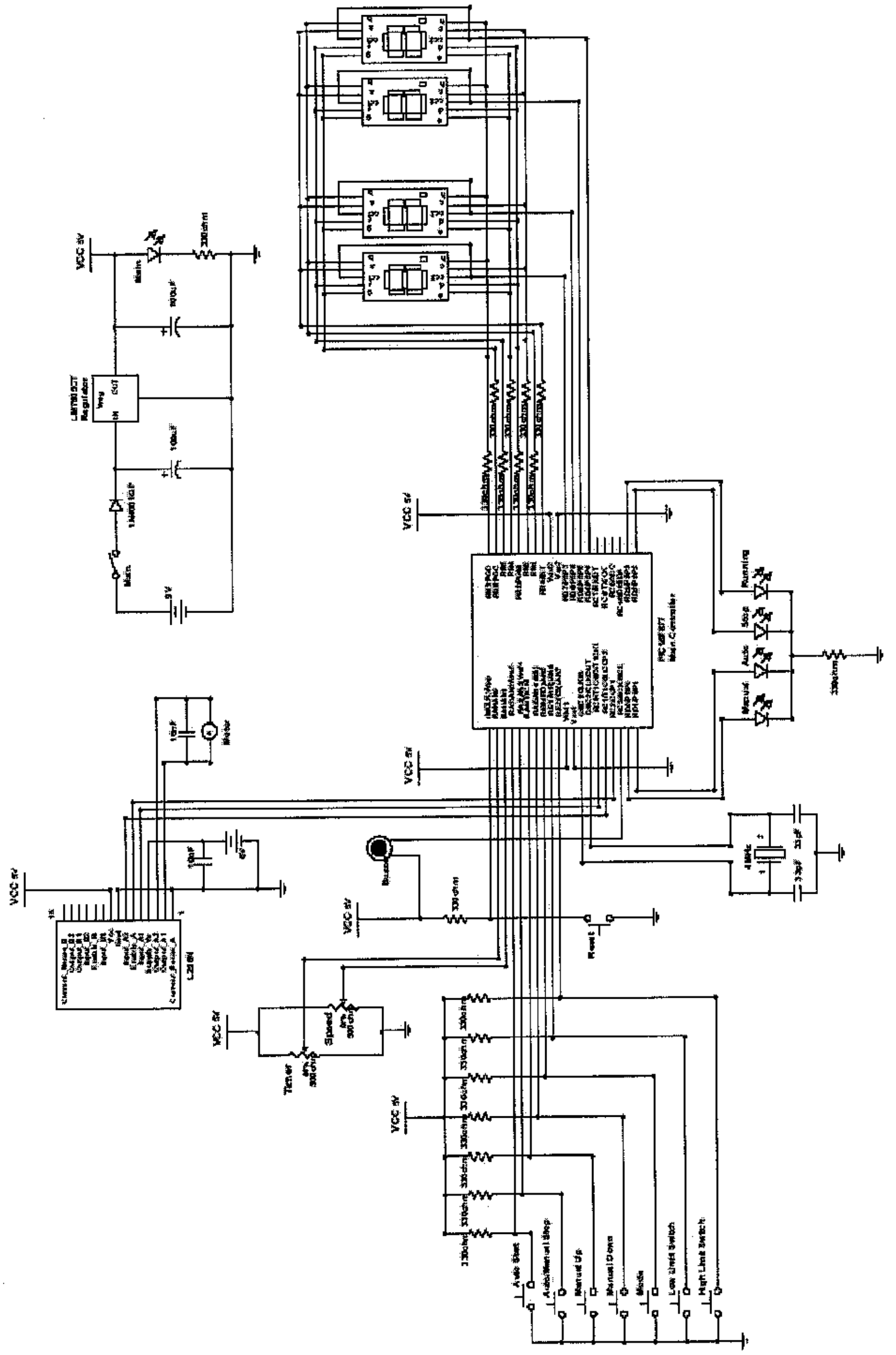


TAMIYA, INC.

PRINTED IN JAPAN

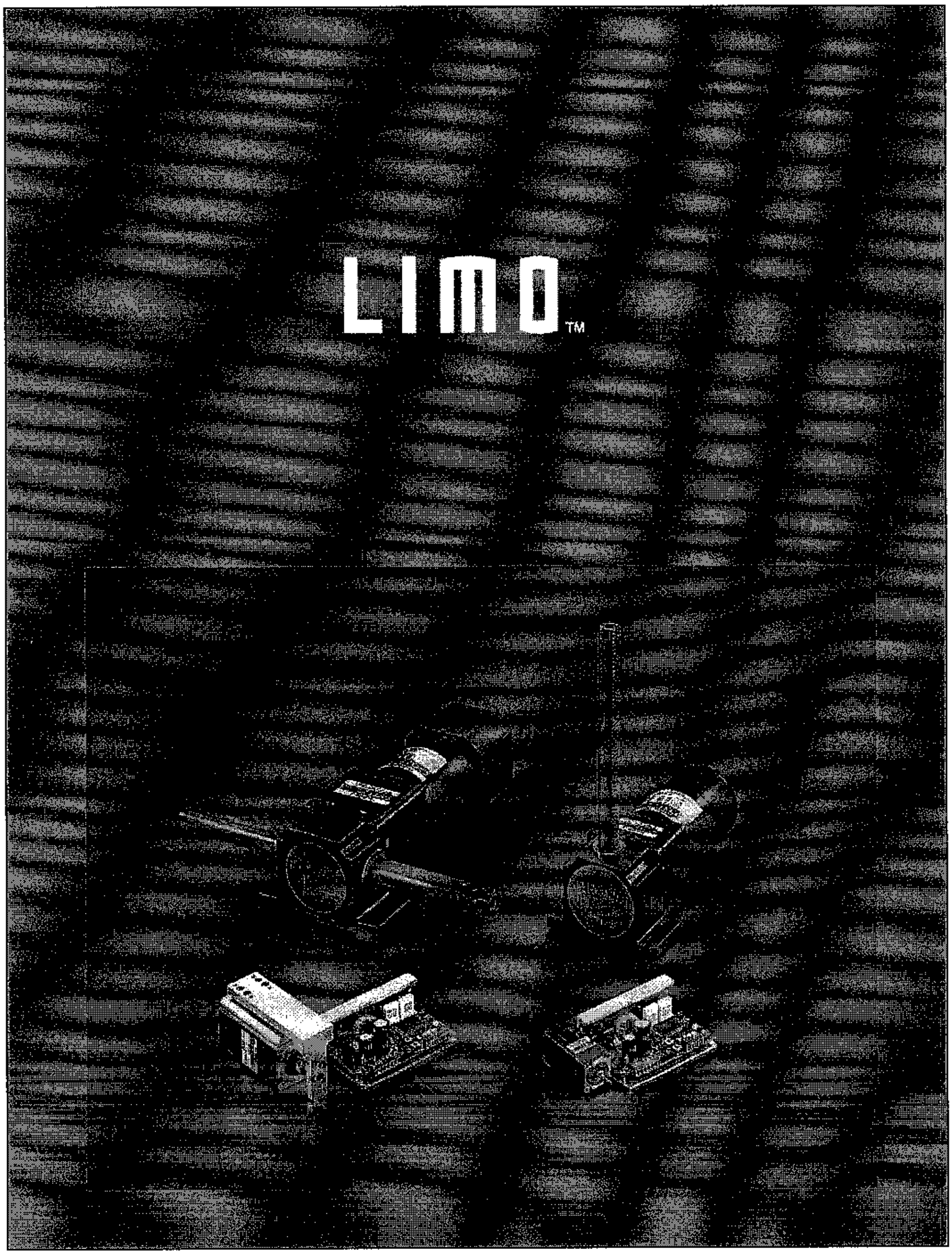
APPENDIX D

DIP COATER CONTROL CIRCUITRY


VCC 5V
9V
Main
1N4001GP
100uF
LM7805T Regulator
330ohm
PIC16F877 Main Controller
Running
Stop
Auto
Manual
4MHz
33pF
Reset
Buzzer
L293N
Motor
10nF
6V
Timer
Speed
Auto Start
Auto/Manual Stop
Manual Up
Manual Down
Mode
Low Limit Switch
High Limit Switch

APPENDIX E

LINEAR MOTION SYSTEM


LIMO™

Linear Motion

D

Introduction

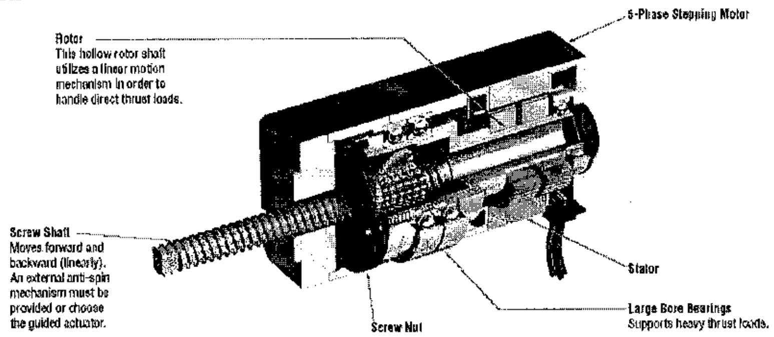
Introduction and Features of Linear Motion

Precision Linear Actuators

Compact Actuators

DRL Series

→Page D-5 for details



Features

The **DRL** Series linear actuator is a self-contained package consisting of a 5-phase stepping motor with a hollow shaft rotor connected to a ball screw nut. The actuator uses a microstepping driver to deliver extremely precise positioning.

- The compact and lightweight body houses the rotating components as well as the linear motion mechanism of the stepping motor. The **DRL** Series helps to achieve a significant reduction in the size of your equipment and system.
- The hollow rotor shaft incorporates large bore bearings to directly handle thrust loads. Minimizing the number of the parts involved in linear conversion results in higher reliability.
- Eliminates the need to design, acquire and assemble the parts necessary to convert rotary to linear motion.

Construction

Motor

The 5-phase stepping motor offers high-resolution and low-vibration.

Driver

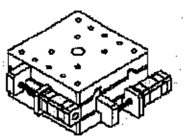
The driver features microstepping electronics that electronically divide the basic step angle of the motor, thus enabling higher resolution and lower vibration operation at low speeds.

Ball Screw

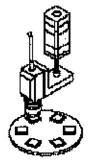
Both rolled and ground ball screws are available, depending on the accuracy required.

Application Examples

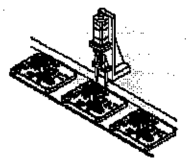
◆ Drive mechanism for a precision X-Y stage (micrometer head X-Y stage)



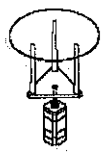
◆ **Focusing a CCD camera**



◆ **Centering a substrate**



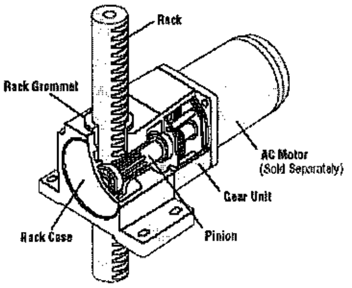
◆ **Silicon wafer pin lifter**



Rack & Pinion

Linear Heads
LH Series

→Page D-17 for detail



Features

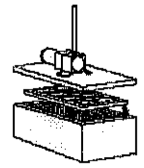
Linear heads are linear motion rack-and-pinion units for use with standard AC motors.

- Depending on the type of motor coupled directly to the linear head, various types of movements are possible.
- A wide range of products are available.
- Motors for direct coupling to the linear heads are sold separately.
- Decimal gearheads which reduce the basic speed by 10:1 are available.

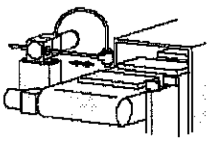
Application Examples

Linear heads provide a linear drive mechanism that can be used in a variety of applications for simpler mechanism design and easier wiring.

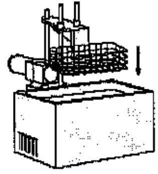
◆ Pressing operation



◆ Reversing operation



◆ Travelling operation



Construction

Linear heads use reduction gears to reduce motor speed and increase motor torque, while a reliable and low cost rack-and-pinion mechanism converts rotational motion into linear motion. The direction of rack movement is determined by the direction of motor rotation. When the rack reaches either end, it is necessary to reverse the direction of rack movement by changing the direction of motor rotation. Since linear heads do not have an automatic stop/reverse mechanism, it is necessary to attach limit switches or sensors to change the direction of motor rotation.

Motor

The ideal way to change the direction of rack movement instantaneously is to use a reversible motor.

Rack

Solid-drawn S45C steel is gear-cut and given a nitride finish to reduce sliding friction and provide rust-resistance.

Rack Grommet

The rack is supported by two grommets made by an oilless metal.

Note:
If the end of the rack should advance into the rack case and the rack is supported by only one grommet, it might cause the mechanism to malfunction. The rack movement should always be reversed before the edge of the rack reaches the rack grommet.

How to Read the Specifications Table

● Example Guide Actuator Specifications

Model		DRL28PA1G-03D	DRL28PB1G-03D
Motor Type		5-Phase Stepping Motor	
① Drive Method		Rolled Ball Screw	Ground Ball Screw
② Maximum Transportable Mass lb. (kg)	Horizontal (See Figure A)	2.2 (1)	2.2 (1)
③ Maximum Transportable Mass lb. (kg)	Vertical (See Figure B)	3.3 (1.5)	3.3 (1.5)
④ Acceleration	ft./s² (m/s²)	0.66 (0.2)	0.66 (0.2)
④ Acceleration/Deceleration Rate (Basic)	ms/kHz	10 or more	10 or more
⑤ Maximum Speed	in./s (mm/s)	0.94 (24)	0.94 (24)
⑥ Maximum Thrust Force	lb. (N)	6.7 (30)	6.7 (30)
⑦ Maximum Holding Force at Excitation	lb. (N)	6.7 (30)	6.7 (30)
⑧ Holding Force at Non-Excitation	lb. (N)	0	0
⑨ Maximum Load Inertia	oz-in (N·m)	Mp: 0 My: 0 Mr: 0	Mp: 0 My: 0 Mr: 0
⑩ Repetitive Positioning Accuracy	in. (mm)	±0.00079 (0.02)	① ±0.00039 (0.01) ② ±0.00079 (0.02)
⑪ Lost Motion	in. (mm)	0.0039 (0.1)	0.002 (0.05)
⑫ Resolution (Basic)	in. (mm)	0.000079 (0.002)	0.000079 (0.002)
⑬ Lead	in. (mm)	0.039 (1)	0.039 (1)
⑭ Stroke	in. (mm)	1.18 (30)	1.18 (30)
Weight	lb. (kg)	0.55 (0.25)	0.55 (0.25)
Ambient Temperature		32 °F～+104 °F (0 °C～+40 °C)	

① Drive Method

Mechanism used to convert motor rotation to linear motion.

② Maximum Transportable Mass (Horizontal direction)

Maximum mass that can be moved under rated conditions in the horizontal direction.

For the standard type the thrust force is reduced by the amount of frictional resistance of the sliding surface and the mass of a guide.

③ Maximum Transportable Mass (Vertical direction)

Maximum mass that can be moved under rated conditions in the vertical direction.

④ Acceleration

Maximum acceleration rate allowed to move with the maximum transportable mass in the horizontal direction.

⑤ Maximum Speed

Maximum speed allowed to be moved with the maximum transportable mass.

⑥ Maximum Thrust Force

Maximum thrust force at constant speed with no load.

⑦ Maximum Holding Force at Excitation

Maximum holding force with the power on.

⑧ Holding Force at Non-Excitation

Maximum holding force with the power off.

⑨ Maximum Load Inertia

Maximum force that can be applied to the guide when the center of gravity of the actuator and load has an offset.

⑩ Repetitive Positioning Accuracy

Error when moving to same position to the same direction.

⑪ Lost Motion

Positioning error that occurs when positioning to a specific point in the opposite direction.

⑫ Resolution

Distance the motor moves with one step pulse input.

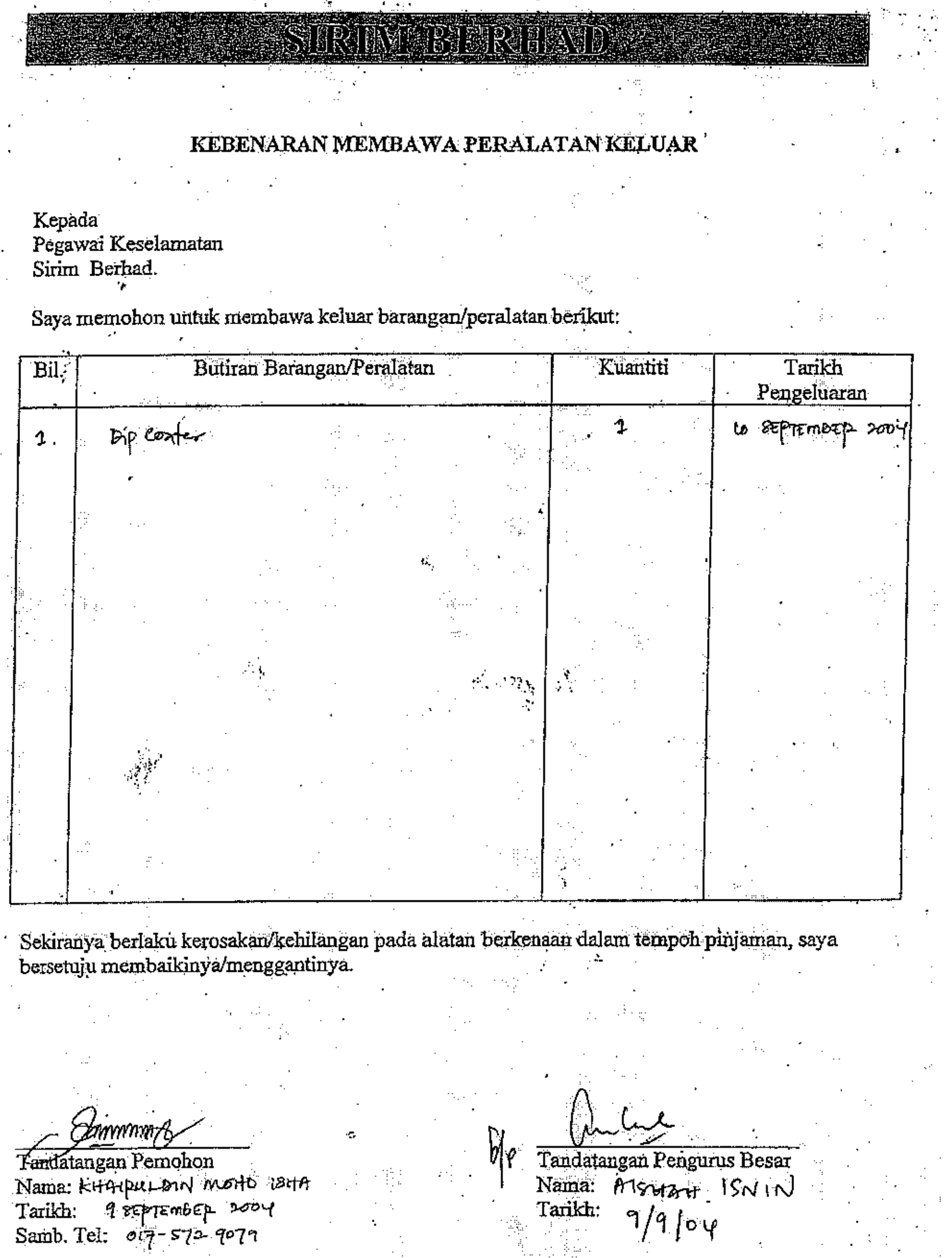
⑬ Lead

Distance the motor moves in one resolution.

⑭ Stroke

Maximum distance the load can be moved.

APPENDIX F
PERMISSION LETTER



SIRIM BERHAD

KEBENARAN MEMBAWA PERALATAN KELUAR

Kepada
Pegawai Keselamatan
Sirim Berhad.

Saya memohon untuk membawa keluar barangan/peralatan berikut:

Bil.	Butiran Barangan/Peralatan	Kuantiti	Tarikh Pengeluaran
1.	Dip Coater	1	10 SEPTEMBER 2004

Sekiranya berlaku kerosakan/kehilangan pada alatan berkenaan dalam tempoh pinjaman, saya bersetuju membaikinya/menggantinya.

Tandatangan Pemohon
Nama: KHAIRULDIN MOHD ISHA
Tarikh: 9 SEPTEMBER 2004
Samb. Tel: 017-572-9079

b/p Tandatangan Pengurus Besar
Nama: AISHAH ISNIN
Tarikh: 9/9/04

APPENDIX G

REFERENCE DIP COATER

Source: Mat Tamizi Zainuddin, Researcher, Photonic and Electronic Material Group, AMREC, SIRIM Bhd.