

**DESIGN AND DEVELOPMENT OF A UNIFORM SPRAY
COATER FOR SPIN COATING**

Walithara Guruge Ganesh Amal

(168652T)

Degree of Master of Science

Department of Electrical Engineering

University of Moratuwa

Sri Lanka

April 2021

DESIGN AND DEVELOPMENT OF A UNIFORM SPRAY COATER FOR SPIN COATING

Walithara Guruge Ganesh Amal

(168652T)

Thesis/Dissertation submitted in partial fulfillment of the requirements for the degree
Master of Science

Department of Electrical Engineering

University of Moratuwa

Sri Lanka

April 2021

DECLARATION

I declare that this is my own work and this thesis does not incorporate any material previously submitted for a Degree or Diploma in any other University or Institute of higher learning without acknowledgement. Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my thesis, in whole or in part in print, electronic or other medium. I retain the right the right to use this content in whole or part in future works such as articles or books.

Signature:

Date:

.....

W.G.G. Amal

The above candidate has carried out research for the Masters thesis under my supervision.

Signature of the supervisor:

.....

Date:

Prof. D. P. Chandima

ACKNOWLEDGEMENT

First, my sincere thanks must go to my advisor, Prof. D.P. Chandima for his continuous advice, guidance, encouragement and patience throughout the course of this work. It has been a privilege to work under his guidance. I am also thankful to the course coordinator, Prof. Buddhika Jayasekara and the staff of the Department of Electrical Engineering, University of Moratuwa for their continuous encouragement.

Further, I am thankful to my mother for believed that I can always do better than I believed in myself. A special thank goes to my wife for encouraged me to reach for a successful end.

W.G.G. Amal

April 2021

University of Moratuwa.

ABSTRACT

Semiconductor coating is a principle technique which is used to fabricate semiconductors. Spin coating is the commonly use technique to coat the semiconductors among the several coating techniques such as spin coating, spray coating, physical vapor deposition (PVD) and chemical vapor deposition (CVD). Spin coating is a process used to deposit uniform thin films to flat substrates by applying a small amount of coating material on the centre of the substrate, which is either spinning at low speed or not spinning at all and the substrate is rotated at high speed in order to spread the coating material by centrifugal force. Although there are few researches done with spin coating technique and its improvements, there are several defects such as limited to flat surfaces, high material wastage and etc. Hence, to overcome from the limitations based on spin coating, this thesis presents designing of a spray coating machine which is better than the existing spin coating technique and to be used in multiple applications.

CONTENTS

1. INTRODUCTION.....	1
1.1. Photolithography.....	2
1.1.1. Photoresist	3
1.1.2. Spin Coating	4
1.2. Limitations of the existing coating methods	6
1.2.1. Conventional spin coating	6
1.2.2. Extrusion spin coating	8
1.2.3. Conventional spray coating.....	9
1.3. Objective of the research.....	10
1.4. Thesis Outline.....	11
2. METHODOLOGY	12
2.1. Testing of existing spray coating method.....	12
2.2. Designing the prototype spray chamber with spray head.....	12
2.3. Identify the required improvements	13
2.4. Implementation of proposed spray coating machine.....	13
3. DESIGNING AND DEVELOPING OF THE SPRAY COATING MACHINE	14
3.1. Testing of existing spray coating method.....	14
3.1.1. Importance of coating thickness in thin film deposition.....	14
3.1.2. Importance of particle size in thin film deposition	15
3.2. Designing the prototype spray chamber with spray head.....	15
3.2.1. Prototype spray chamber	15
3.2.2. Spray head	16
3.2.3. X-Y Plotter.....	17
3.3. Testing of the spray chamber with X-Y plotter.....	18
3.3.1. Required process improvements for the prototype spray chamber	19
3.4. Implementing the proposed spray coating machine	20
3.4.1. Spray mechanism	21
3.4.2. Wafer chuck assembly	23
3.4.3. Enclosure	25
3.4.4. Liquid circulation system	28
3.4.5. Combined design.....	29
3.5. Working procedure.....	32
4. TESTING AND TROUBLESHOOTING.....	37
4.1. Spray head testing for uniform particle distribution.....	37
4.1.1. Spraying done perpendicular to the spray head	37

4.1.2. Spraying done parallel to the spray head	39
4.1.3. Spray head testing for uniform flow.....	42
4.1.3.1. Spray head model one.....	42
4.1.3.2. Spray head model two.....	44
4.1.4. Comparison of test results with two spray head models	46
4.1.5. Comparison of test results with spin coated wafer	47
5. CONCLUSION	50

FIGURES

Figure 1.1: Process of photolithography	02
Figure 1.2: Photolithography with positive and negative photoresist.....	03
Figure 1.3: Spin coating.....	05
Figure 1.4: Steps of conventional spin coating.....	07
Figure 1.5: Extrusion spin coating.....	08
Figure 1.6: Top view of spiral shaped coating.....	09
Figure 1.7: Conventional spray coating.....	10
Figure 2.1: XY plotter.....	13
Figure 3.1: Developed spray chamber.....	16
Figure 3.2: Developed spray head.....	17
Figure 3.3: X-Y plotter used for testing.....	17
Figure 3.4: Front view and isometric view of test apparatus with X-Y plotter.....	18
Figure 3.5: Assembling of test apparatus with X-Y plotter.....	19
Figure 3.6: Top view of spray mechanism.....	21
Figure 3.7: Side view of spray mechanism.....	22
Figure 3.8: Implemented assembly of spray mechanism.....	23
Figure 3.9: Side view of wafer chuck assembly.....	24
Figure 3.10: Sectional view of wafer chuck assembly.....	24
Figure 3.11: Implemented wafer chuck assembly.....	25
Figure 3.12: Front view of enclosure.....	26
Figure 3.13: Isometric view of enclosure.....	26
Figure 3.14: Enclosure with naming all the parts.....	27
Figure 3.15: Implemented enclosure.....	28
Figure 3.16: Liquid circulation system.....	29
Figure 3.17: Isometric view of combined design.....	30
Figure 3.18: Implemented spray mechanism of spray coater machine.....	31
Figure 3.19: Implemented wafer chuck assembly of spray coater machine.....	31
Figure 3.20: Side view of implemented spray coater machine.....	31
Figure 3.21: A complete coating cycle of spray coater machine.....	32
Figure 3.22: Inserting silicon wafer to the spray coater.....	33
Figure 3.23: Closing of spray coater to initiate coating.....	33
Figure 3.24: Initiation of coating.....	35
Figure 3.25: Internal view of spray coater while coating.....	35
Figure 3.26: Completion of coating.....	36
Figure 4.1: Spraying perpendicular to the spray head.....	37
Figure 4.2: Vapor flowing path of 3D printed spray head.....	38

Figure 4.3: Test results after 1000 cycles with perpendicular spraying (1)	3838
Figure 4.4: Test results after 1000 cycles with perpendicular spraying (2)	3939
Figure 4.5: Spraying parallel to the spray head	3939
Figure 4.6: Implemented spray head for parallel spraying	40
Figure 4.7: Ansys flow simulation results of spray head used for parallel spraying	40
Figure 4.8: Test results after 1000 cycles with parallel spraying (1)	41
Figure 4.9: Test results after 1000 cycles with parallel spraying (2)	41
Figure 4.10: Sectional view spray head model one.....	42
Figure 4.11: 3D printed spray head model one	43
Figure 4.12: Test results after 1000 cycles with spray head model one (1).....	43
Figure 4.13: Test results after 1000 cycles with spray head model one (2).....	44
Figure 4.14: Ansys flow simulation result of spray head model two.....	44
Figure 4.15: 3D printed spray head model two.....	45
Figure 4.16: Test results after 1000 cycles with spray head model two (1).....	45
Figure 4.17: Test results after 1000 cycles with spray head model two (2).....	46
Figure 4.18: Test results after 1000 cycles with spray head model two (3).....	46
Figure 4.19: View from magnification camera of coating layer with spray head model one	47
Figure 4.20: View from magnification camera of coating layer with spray head model two.....	47
Figure 4.21: Magnified images of silicon wafer coated by spin coater	48
Figure 4.22: Magnified images of silicon wafer coated by spray head model two.....	48
Figure 4.23: A comet defect happened during spin coating.....	49
Figure 4.24: Large particles on the indirect spray coated wafer surface.....	49

TABLES

Table 1.1: Advantages of using positive photoresist and negative photoresist.....	04
Table 4.1: Results comparison of perpendicular spraying with parallel spraying	42

LIST OF ABBREVIATIONS

UV	Ultraviolet
CMOS	Complementary Metal-Oxide Semiconductor
PZT	Lead Zirconate Titanate
AC	Analog Current
DC	Digital Current