

PHYSICS OF THIN FILMS

PLASMA SOURCES
FOR THIN FILM
DEPOSITION
AND ETCHING

Edited by
Maurice H. Francombe
John L. Vossen

VOLUME 18

2-530-121-18/1



2-530-121-18/1

Physics of Thin Films

Advances in Research and Development

PLASMA SOURCES FOR THIN FILM DEPOSITION AND ETCHING

Edited by

Maurice H. Francombe

*Department of Physics
The University of Pittsburgh
Pittsburgh, Pennsylvania*

John L. Vossen

*John Vossen Associates
Technical and Scientific Consulting
Bridgewater, New Jersey*

VOLUME 18



Academic Press
San Diego New York Boston
London Sydney Tokyo Toronto

Contents

Contributors	ix
Preface	xi

Design of High-Density Plasma Sources for Materials Processing

Michael A. Lieberman and Richard A. Gottscho

I. Introduction	2
A. Capacitively Coupled Radio Frequency Discharge Sources	5
B. Limitations of Capacitively Coupled Radio Frequency Discharges	9
C. Overview of High-Efficiency Sources	10
II. Principles of Low-Pressure, High-Efficiency Source Design	13
A. Unified Analysis of Source Operation	19
B. Discharge Heating	23
III. Electron Cyclotron Resonance (ECR) Discharges	25
A. Source Configurations	26
B. Electron Heating	31
C. Resonant Wave Absorption	34
IV. Helicon Discharges	40
A. Helicon Configurations	41
B. Helicon Modes	42
C. Antenna Coupling	46
D. Helicon Mode Absorption	50
V. Inductive Discharges	52
A. Inductive Source Configurations	52
B. Power Absorption and Operating Regimes	54
C. Source Operation and Coupling	56
D. Low-Density Operation and Source Efficiency	58
VI. Helical Resonator Discharges	60
VII. Surface Wave Discharges	65

VIII.	Plasma Transport	69
	A. The Ion Energy Distribution Function	71
	B. Methods for Measuring Ion Energy Distribution Functions	76
	C. Methods for Measuring Plasma Potentials	80
	D. Measurements of Energy Distributions and Potentials	81
	E. Ion Energy Control	90
IX.	Device Damage	96
	A. Atomic Displacement Damage	96
	B. Contamination	98
	C. Charging	98
	D. Radiation	104
X.	Summary and Remaining Questions	105
XI.	Symbol Definitions	108
	Acknowledgments	112
	References	112

Electron Cyclotron Resonance Plasma Sources and Their Use in Plasma-Assisted Chemical Vapor Deposition of Thin Films

Oleg A. Popov

I.	Introduction	122
II.	ECR Fundamentals and Microwave Power Absorption	126
	A. Principles of Electron Cyclotron Resonance	126
	B. Microwave Power Absorption in ECR Plasmas	129
III.	ECR Plasma Sources: Designs and Characteristics	152
	A. Basic Types of ECR Plasma Sources	152
	B. Hitachi/NTT ECR Plasma Source	157
	C. ECR Plasma Source Characteristics and Parameters	183
IV.	ECR Plasma Sources in PA CVD of Thin Films	208
	A. Silicon Nitride Film ECR CVD	209
	B. Silicon Oxide Films	216
	C. ECR Plasma Planarization with Silicon Dioxide Films	221
V.	Conclusion	226
	Acknowledgments	227
	References	227

Unbalanced Magnetron Sputtering

Suzanne L. Rohde

I.	Introduction	235
II.	Motivation for Unbalanced Magnetron Sputtering	236
	A. Sputtering in General	236
	B. Electron Motion in a Magnetic Field	240

CONTENTS

vii

C.	Magnetron Sputtering	241
D.	Ion-Assisted Deposition	243
III.	Development of Unbalanced Magnetron Based Techniques	249
A.	Precursors to the Unbalanced Magnetron	249
B.	Unbalanced Magnetron Sputtering	255
IV.	Principles of Unbalanced Magnetron Sputtering	259
V.	Applications of UBM Sputtering	272
A.	Elemental Thin Films	272
B.	Films for Electronic and Optical Applications	274
C.	Films for Corrosion Protection	275
D.	Films for Wear and Abrasion Resistance	277
VI.	Commercial Applications of UBM Sputtering	281
VII.	Potential Future of UBM Sputtering	283
	Acknowledgments	285
	References	285

The Formation of Particles in Thin-Film Processing Plasmas

Christoph Steinbrüchel

I.	Introduction	289
II.	General Phenomena	291
III.	Particles in Deposition Plasmas	294
IV.	Particles in Sputtering Plasmas	301
V.	Particles in Reactive Ion Etching Plasmas	309
VI.	Modeling of Particles in Plasmas	312
VII.	Particle Contamination and Equipment Design	314
VIII.	Conclusions	314
	Acknowledgment	317
	References	317
	<i>Author Index</i>	319
	<i>Subject Index</i>	323