DOCKET
ALARM
Find authenticated court documents without watermarks at docketalarm.com.

ne

ZANNE L. ROHDE

IRISTOPH STEINBRÜCHEL

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

531.082
P569
vol. 18
1994
SCIENCE
AUG 25 1994

Academic Press
San Diego New York Boston
London Sydney Tokyo Toronto

Find authenticated court documents without watermarks at docketetalarm.com.

R00272 74361

ATE DUE

0 0 PM

97

1 1998

AM

Printed in USA

This book is printed on acid-free paper ♾

Copyright © 1994 by Academic Press, Inc.

All rights reserved.
No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopy, recording, or any information storage and retrieval system, without permission in writing from the publisher.

ACADEMIC PRESS, INC.
A Division of Harcourt Brace & Company
525 B Street, Suite 1900
San Diego, California 92101-4495

United Kingdom Edition published by
ACADEMIC PRESS LIMITED
24-28 Oval Road, London NW1 7DX

Library of Congress Catalog Card Number: 63—16561
ISBN: 0-12-533018-9

94 95 96 97 98 99 9 8 7 6 5 4 3 2 1

PRINTED IN THE UNITED STATES OF A...

Contents

Contributors . . . .
Preface . . . .

Design of High-Density Plasma Sources for

Michael A. Lieberman and Richard

I. Introduction . . . .
A. Capacitively Coupled Radio Frequency Discharg
B. Limitations of Capacitively Coupled Radio Frequ
C. Overview of High-Efficiency Sources . . . . .
II. Principles of Low-Pressure, High-Efficiency Source D
A. Unified Analysis of Source Operation . . . .
B. Discharge Heating . . . .
III. Electron Cyclotron Resonance (ECR) Discharges .
A. Source Configurations . . . .
B. Electron Heating . . . .
C. Resonant Wave Absorption . . . .
IV. Helicon Discharges . . . .
A. Helicon Configurations . . . .
B. Helicon Modes . . . .
C. Antenna Coupling . . . .
D. Helicon Mode Absorption . . . .
V. Inductive Discharges . . . .
A. Inductive Source Configurations . . . . .
B. Power Absorption and Operating Regimes . .
C. Source Operation and Coupling . . . . .
D. Low-Density Operation and Source Efficiency

DOCKET ALARM
Find authenticated court documents without watermarks at docketalarm.com.

Design of High-Density Plasma Sources for Materials Processing

MICHAEL A. LIEBERMAN

Department of Electrical Engineering and Computer Sciences, University of California, Berkeley, California

and

RICHARD A. GOTTSCHO

AT&T Bell Laboratories, Murray Hill, New Jersey

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 Sources Operation 19
1. Electron Temperature 19
2. Ion Bombarding Energy 19
3. Plasma Density and Ion Current Density 22
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

Copyright © 1994 by Academic Press, Inc.
All rights of reproduction in any form reserved.
ISBN 0-12-533018-9

DOCKET ALARM
Find authenticated court documents without watermarks at docketalarm.com.

VIII. Plasma Transport 69
A. The Ion Energy Distribution Function 71
1. Ion Transport and Etching Anisotropy 73
B. Methods for Measuring Ion Energy Distribution Functions 76
C. Methods for Measuring Plasma Potentials 80
D. Measurements of Energy Distributions and Potentials 81
1. Ion Acceleration Outside the Sheath 81
2. Transverse Ion Energy 87
E. Ion Energy Control 90
1. Plasma Anodization 96
IX. Device Damage 96
A. Atomic Displacement Damage 96
B. Contamination 98
C. Charging 98
1. Plasma Uniformity 99
2. Biasing 102
D. Radiation 104
X. Summary and Remaining Questions 105
XI. Symbol Definitions 108
Acknowledgments 112
References 112

I. Introduction

The advent of sub-micron electronic device fabrication has brought unprecedented demands for process optimization and control (*1*,*2*) which, in turn, have led to improved plasma reactors for the etching and deposition of thin films. As a result, we have witnessed the introduction of a new generation of plasma systems based on electron cyclotron resonance (ECR) heating (*3*–*6*). ECR plasma etching of polycrystalline Si, single crystalline Si, silicides, Al, Mo, W, SiO_2, polymers, and III–V compound semiconductors have all been reported in recent years (*7*–*33*). Similarly, ECR plasmas have been used to deposit amorphous Si, silicon nitride, boron carbide, and SiO_2, to name just a few materials (*34*–*40*). Applications of ECR plasmas beyond etching and deposition have also been reported and include ion implantation (*41*–*45*), surface cleaning (*46*–*59*), surface passivation (*60*), and oxidation (*53*,*61*–*63*). Besides ECR, many other "novel" plasma generation schemes are now being offered to satisfy manufacturers' needs in these materials processing areas. All these schemes purport to offer advantages over conventional approaches such as the capacitively coupled radio frequency discharge now used in many factories for etching and deposition of thin films during integrated circuit manufacturing.

DOCKET ALARM Find authenticated court documents without watermarks at docketalarm.com.

DOCKET ALARM

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.

WHAT WILL YOU BUILD? | sales@docketalarm.com | 1-866-77-FASTCASE

fastcase®
Smarter legal research.