Laser-Induced Plasmas and Applications

edited by

Leon J. Radziemski

Department of Physics New Mexico State University Las Cruces, New Mexico

David A. Cremers

Chemical and Laser Sciences Division Los Alamos National Laboratory Los Alamos, New Mexico

MARCEL DEKKER, INC.

New York and Basel



ASML 1206

Library of Congress Cataloging-in-Publication Data

Laser-induced plasmas: physical, chemical, and biological applications / edited by Leon J. Radziemski, David A. Cremers.

p. cm. Includes bibliographies.

ISBN 0-8247-8078-7 (alk. paper)

1. Plasma engineering. 2. High power lasers. I. Radziemski, Leon J., II. Cremers, David A.

TA2020.L37 1989 620.044--dc20

89-7883

CIP

This book is printed on acid-free paper.

Copyright © 1989 MARCEL DEKKER. INC. All Rights Reserved

Neither this book nor any part may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, microfilming, and recording, or by any information storage and retrieval system, without permission in writing from the publisher.

MARCEL DEKKER, INC. 270 Madison Avenue, New York, New York 10016

Current printing (last digit): 10 9 8 7 6 5 4 3 2 1

PRINTED IN THE UNITED STATES OF AMERICA



Contents

Preface Contributors		iii xi
	nysics of Laser-Induced Breakdown: An Update uy M. Weyl	1
1.1 1.2 1.3 1.4 1.5	Introduction Creation of Initial Electrons Electron Growth in Gases Laser-Induced Breakdown of Solids and Liquids Concluding Remarks References	1 3 8 36 58 59
	Codeling of Post-Breakdown Phenomena Obert G. Root	69
2.1	Introduction	69
2.2	Creation of a Propagating Plasma	70
2.3	Absorption Characteristics of Heated Gases	72
2.4	Features of Propagating Plasmas	75
2.5	One-Dimensional Laser-Supported Combustion Waves	77
2.6	One-Dimensional Laser-Supported Detonation Wave	88
2.7	One-Dimensional Laser-Supported Radiation Wave	92
2.8	Transition Regions	93
2.9	Radial Expansion	95
2.10	Thermal Coupling	99
2.11	* ~	100
2.12	Summary	101
	References	101
	ntroduction to Laser Plasma Diagnostics Ulan A. Hauer and Hector A. Baldis	105
3.1	Introduction	105
3.2	Introduction to Optical Diagnostics	110

3.3 Introduction to X-ray Diagnostics References	131 161
4 Laser-Sustained Plasmas Dennis R. Keefer	169
 4.1 Introduction 4.2 Principles of Operation 4.3 Analytical Models 4.4 Experimental Studies 4.5 Applications of the Laser-Sustained Plasma References 	169 172 182 189 196 203
5 Inertially Confined Fusion Robert L. McCrory and John M. Soures	207
 5.1 Historical Overview 5.2 Laser-Fusion Scaling Laws 5.3 Coronal Physics 5.4 X-ray Generation by Laser-Produced Plasmas 5.5 Laser-Driven Ablation 5.6 Hydrodynamic Stability of Ablatively Driven Shells 5.7 Irradiation Uniformity Requirements 5.8 Implosion Experiments References 	207 211 217 224 227 239 243 251 260
6 Laser-Based Semiconductor Fabrication Joseph R. Wachter	269
 6.1 Aspects of Semiconductor Fabrication 6.2 Applications of Lasers in the Semiconductor Industry 6.3 Research Areas 6.4 Outlook References 	269 276 283 290 291
7 Spectrochemical Analysis Using Laser Plasma Excitation Leon J. Radziemski and David A. Cremers	295
 7.1 Review 7.2 Methods and Properties of Analysis Using Laser Plasma 7.3 Analysis of Gases 7.4 Analysis of Bulk Liquids 7.5 Analysis of Particles 7.6 Analysis of Solids 7.7 Advances in Instrumentation 	295 s 296 302 306 309 313



Cont	Contents	
7.8	Prognosis References	321 323
J	Fundamentals of Analysis of Solids by Laser-Produced Plasmas Yong W. Kim	327
8.1 8.2	Chapter Organization Introduction Phenomenology of Laser Heating of Condensed-Phase	327 327
8.3 8.4	Targets Quantitative Spectroscopy	330 336
8.5 8.6	Intensity Measurements and Elemental Analysis Summary References	341 344 345
3	Laser Vaporization for Sample Introduction in Atomic and Mass Spectroscopy Joseph Sneddon, Peter G. Mitchell, and Nicholas S. Nogar	347
9.1	Conventional Solid Sample Introduction for Atomic Spectroscopy	347
9.2 9.3	Laser Ablation of Solid Samples Laser Ablation for Sample Introduction in Atomic	350
9.4	Spectroscopy Relative Merits of Laser Ablation for Sample Introduction	353
9.5	in Atomic Spectroscopy Laser Sources for Mass Spectrometry	363 365 369
9.69.79.8	Applications of Laser Microprobe Applications of Laser Desorption and Postionization Conclusion	372 376
	References	376
10	Current New Applications of Laser Plasmas Allan A. Hauer, David W. Forslund, Colin J. McKinstrie, Justin S. Wark, Philip J. Hargis, Jr., Roy A. Hamil, and Joseph M. Kindel	385
10.2 10.2		385
10.3	Particles 3 Laser-Plasma Acceleration of Particles	386 413



DOCKET

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.

