Springer Series in ***Materials Science*** 2

Edited by Ulrich Gonser

Springer-Verlag Berlin Heidelberg GmbH

Springer Series in *Materials Science*

Volumes 1–26 are listed at the end of the book.

Martin von Allmen Andreas Blatter

Laser-Beam Interactions with Materials

Physical Principles and Applications

Second, Updated Edition

With 78 Figures and 7 Tables

Springer

Dr. Martin von Allmen

Dr. GRAF AG
CH-4563 Gerlafingen
Switzerland

Dr. Andreas Blatter

PX Holding
Bd. des Eplatures 42
CH-2304 La Chaux-de-Fonds
Switzerland

Series Editors:

Prof. Dr. U. Gonser

Fachbereich 12.1, Gebäude 22/6
Werkstoffwissenschaften
Universität des Saarlandes
D-66041 Saarbrücken, Germany

M. B. Panish, Ph. D.

AT&T Bell Laboratories
600 Mountain Avenue
Murray Hill, NJ 07974-2070, USA

Prof. R. M. Osgood, Jr.

Microelectronics Science Laboratory
Department of Electrical Engineering
Columbia University
Seeley W. Mudd Building
New York, NY 10027, USA

Prof. H. Sakaki

Institute of Industrial Science
University of Tokyo
7-22-1 Roppongi, Minato-ku
Tokyo 106, Japan

Managing Editor:

Dr.-Ing. Helmut K. V. Lotsch

Springer-Verlag, Tiergartenstrasse 17
D-69121 Heidelberg, Germany

Second Edition 1995
Updated Printing 1998

ISSN 0933-033X

ISBN 978-3-540-59401-7 ISBN 978-3-642-57813-7 (eBook)
DOI 10.1007/978-3-642-57813-7

Library of Congress Cataloging-in-Publication Data.

Von Allmen, M. Laser -beam interactions with materials: physical principles and applications / Martin von Allmen, Andreas Blatter. – 2nd updated ed. p. cm. – (Springer series in materials science; v.2) Includes bibliographical references and index. ISBN 978-3-540-59401-7(softcover: alk. paper) 1. Materials-Effect of radiation on. 2. Laser beams-Industrial applications. I. Blatter, Andreas, 1960 - . II. Title. III. Series. TA418.6.V63 1995 620.1'1228–dc20 95-32586

Originally published by Springer-Verlag Berlin Heidelberg New York in 1995

Typesetting: PS[TM] Technical Word Processor
SPIN: 10663729 54/3144-5 4 3 2 1 0 – Printed on acid-free paper

Preface

Eight years after the appearance of the first edition of *Laser-Beam Interactions with Materials*, the topic seems far from losing any of its vigour and fascination - if the rate of papers published is any indication. A number of interesting new applications have appeared in the meantime, and a tremendous amount of work on process characterisation has been done. Nevertheless, the main ideas of eight years ago are still there, and so are some of the old puzzles.

This second edition, which owes its existence to the friendly reception of the first one, comes with a number of corrections, updates and timely additions (notably a new section on laser deposition) but preserves both the original layout of the monograph and its emphasis on the physics behind the phenomena.

Bern, September 1994

M. von Allmen
A. Blatter

Preface to the First Edition

Lasers, having proven useful in such diverse areas as high-resolution spectroscopy and the guiding of ferryboats, are currently enjoying great popularity among materials scientists and engineers. As versatile sources of "pure" energy in a highly concentrated form, lasers have become attractive tools and research instruments in metallurgy, semiconductor technology and engineering. This text treats, from a physicist's point of view, some of the processes that lasers can induce in materials.

The field of laser-material interactions is inherently multidisciplinary. Upon impact of a laser beam on a material, electromagnetic energy is converted first into electronic excitation and then into thermal, chemical and mechanical energy. In the whole process the molecular structure as well as the shape of the material are changed in various ways. Understanding this sequence of events requires knowledge from several branches of physics. A unified presentation of the subject, for the benefit of the materials researcher as well as the advanced student, is attempted here. In order to keep the book reasonably trim, I have focused on laser effects in solids such as thin films and technological materials. Related topics not covered are laser-induced chemical reactions in gases and liquids and laser effects in organic or biological materials.

This monograph grew out of a series of lectures which I gave for graduate-level students in applied physics at the University of Bern. Its layout reflects the diversity of the subject - Chapter 2 draws essentially from physical optics, Chapters 3 and 4 from materials science, and Chapter 5 from fluid dynamics and plasma physics. While experts in certain fields covered here may find the treatment of their speciality rather less than exhaustive, I hope that the integrated treatment attempted will serve at least two purposes: It should provide access and orientation for students and newcomers in the large and diverse field of laser-material interactions, and it may, perhaps, uncover certain relations and connections not always obvious to the specialist. Readers' comments pointing out errors or inconsistencies will, in any case, be most welcome.

It is a pleasant duty to thank all those who have contributed to this book: colleagues who have given me access to and education on their work, as well as critical readers of preliminary versions of the manuscript who helped in eliminating some of its shortcomings. Finally, this book would not have appeared without the dedicated work of R. Flück and E. Krähenbühl

who made most of the drawings and kept track of the paperwork, H.P. Weber who gave support, and - most important of all - my wife who smoothed the atmosphere and brewed many, many cups of coffee.

Bern, August 1986 *M. von Allmen*

Contents