Thin Film Diamond

Thin Film Diamond

Edited by A. Lettington
and J.W. Steeds

The Royal Society

SPRINGER-SCIENCE+BUSINESS MEDIA, B.V.

First edition 1994

© 1994 Springer Science+Business Media Dordrecht

Originally published by Chapman & Hall in 1994

Typeset by Thomson Press, India

ISBN 978-94-010-4312-0

Apart from any fair dealing for the purposes of research or private study, or criticism or review, as permitted under the UK Copyright Designs and Patents Act, 1988, this publication may not be reproduced, stored, or transmitted, in any form or by any means, without the prior permission in writing of the publishers, or in the case of reprographic reproduction only in accordance with the terms of the licences issued by the Copyright Licensing Agency in the UK, or in accordance with the terms of licences issued by the appropriate Reproduction Rights Organization outside the UK. Enquiries concerning reproduction outside the terms stated here should be sent to the publishers at the London address printed on this page.

The publisher makes no representation, express or implied, with regard to the accuracy of the information contained in this book and cannot accept any legal responsibility or liability for any errors or omissions that may be made.

A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication data

Thin film diamonds / edited by A. Lettington and J.W. Steeds. - 1st ed.

p. cm.

Includes index

ISBN 978-94-010-4312-0

ISBN 978-94-011-0725-9 (eBook)

DOI 10.1007/978-94-011-0725-9

1. Diamonds, Artificial 2. Diamond thin films. I. Lettington, Alan H. II. Steeds, J. W. III. Royal Society (Great Britain)

TP873.5.D5T47 1994

666.88—dc20

93-33950

CIP

Printed on permanent acid-free text paper, manufactured in accordance with the proposed ANSI/NISO Z39.48-1992 and ANSI/NISO Z39.48-1984 (Permanence of Paper).

Contents

Contributors	vii
Preface	ix
1 Chemical vapour deposition of diamond <i>John C Angus, Alberto Argotta, Roy Gat, Zhidan Li, Mahendra Sunkara, Long Wang and Yaxin Wang</i>	1
2 Thin film diamond growth mechanisms <i>James E Butler and Richard L Woodin</i>	15
3 Microwave plasma CVD and related techniques for low pressure diamond synthesis <i>Peter K Bachmann</i>	31
4 Local epitaxial growth of diamond on nickel from the vapour phase <i>Y Sato, H Fujita, T Ando, T Tanaka and M Kamo</i>	55
5 The optical and electronic properties of semiconducting diamond <i>Alan T Collins</i>	63
6 The thermal conductivity of CVD diamond films <i>T R Anthony</i>	75
7 Electron irradiation and heat treatment of polycrystalline CVD diamond <i>C D Clark and C B Dickerson</i>	83
8 Strength, fracture and erosion properties of CVD diamond <i>J E Field, E Nicholson, C R Seward and Z Feng</i>	91
9 Deposition of diamond-like carbon <i>J Robertson</i>	107
10 Applications of diamond-like carbon thin films <i>Alan H Lettington</i>	117
11 Diamond as a wear-resistant coating <i>B Lux and R Haubner</i>	127
12 Thermal and optical applications of thin film diamond <i>M Seal</i>	143
Index	153

Contributors

T. Ando National Institute for Research in Inorganic Materials, 1-1 Namiki, Tsukuba, Ibaraki 305, Japan

John C. Angus Department of Chemical Engineering, Case Western Reserve University, Cleveland, Ohio 44106, USA

T. R. Anthony GE Research & Development Center, P.O. Box 8, Schenectady, New York 12309, USA

Alberto Argoitia Department of Chemical Engineering, Case Western Reserve University, Cleveland, Ohio 44106, USA

Peter K. Bachmann Philips Research Laboratories, Solid Films and Deposition Technologies, P.O. Box 1980, D-5100 Aachen, Germany

James E. Butler Code 6174, Naval Research Laboratory, Washington, DC 20375-5000, USA

C.D. Clark J. J. Thomson Physical Laboratory, University of Reading, Whiteknights, Reading RG6 2AF, UK

Alan T. Collins Wheatstone Physics Laboratory, King's College London, Strand, London WC2R 2LS, UK

C. B. Dickerson J. J. Thomson Physical Laboratory, University of Reading, Whiteknights, Reading RG6 2AF, UK

Z. Feng Computer Mechanics Laboratory, University of California at Berkeley, USA

J. E. Field Cavendish Laboratory, Madingley Road, Cambridge CB3 0H3, UK

H. Fujita Central Research Laboratory, Onoda Cement Co. Ltd, 2-2-1 Ishikawa, Sakura, Chiba 285, Japan

Roy Gat Department of Chemical Engineering, Case Western Reserve University, Cleveland, Ohio 44106, USA

R. Haubner Technical University Vienna, Institute for Chemical Technology of Inorganic Materials, Getreidemarkt 6/161, A-1060 Vienna, Austria

M. Kamo National Institute for Research in Inorganic Materials, 1-1 Namiki, Tsukuba, Ibaraki 305, Japan

Alan H. Lettington J J Thomson Physical Laboratory, University of Reading, Whiteknights, Reading RG6 2AF, UK

Zhidan Li Department of Chemical Engineering, Case Western Reserve University, Cleveland, Ohio 44106, USA

B. Lux Technical University Vienna, Institute for Chemical Technology of Inorganic Materials, Getreidemarkt 6/161, A-1060 Vienna, Austria

E. Nicholson Cavendish Laboratory, Madingley Road, Cambridge CB3 0HE, UK

J. Robertson National Power Labs, Leatherhead, Surrey KT22 7SE, UK

Y. Sato National Institute for Research in Inorganic Materials, 1-1 Namiki, Tsukuba, Ibaraki 305, Japan

M. Seal Sigillum B.V., P.O. Box 7129, Amsterdam 1007 JC, The Netherlands

C. R. Seward Cavendish Laboratory, Madingley Road, Cambridge CB3 0HE, UK

Mahendra Sunkara Department of Chemical Engineering, Case Western Reserve University, Cleveland, Ohio 44106, USA

T. Tanaka National Institute for Research in Inorganic Materials, 1-1 Namiki, Tsukuba, Ibaraki 305, Japan

Long Wang Department of Chemical Engineering, Case Western Reserve University, Cleveland, Ohio 44106, USA

Yaxin Wang Department of Chemical Engineering, Case Western Reserve University, Cleveland, Ohio 44106, USA

Richard L. Woodin Norton Diamond Film, Northboro, Massachusetts 01532-1545, USA

Preface

This volume contains a selection of invited review papers presented at a Royal Society Discussion meeting on Thin Film Diamond held in London on 15 and 16 July 1992

The topic of low pressure synthesis has attracted world wide interest and become increasingly active in recent years due to the possible use of diamond films in commercial applications

Until recently commercial diamond synthesis was almost entirely by the high pressure high temperature technique in which diamond is precipitated as an equilibrium phase from a carbon-containing liquid metal catalyst. In this way crystals may be formed up to 10 mm or so in size. The metastable low pressure techniques cannot compete in cost but can be used to fabricate large area wafers or predetermined shapes not possible by other means.

Most of the low pressure techniques stem from the work of Eversole which was first reported in 1962. He exposed a hot diamond substrate alternately to a hydrocarbon gas, which deposited a mixture of diamond and graphite, and then to hydrogen, which preferentially etched away the graphite. In later developments these two stages have been combined to form a continuous process and differ only in the way the etchant is generated. In this volume an historical overview of these low pressure growth techniques and a description of diamond and crystal morphology is given by John Angus and his co-authors in their paper on the chemical vapour deposition of diamond. James Butler and Richard Woodin discuss the kinetics and gas phase chemistry involved in thin film growth and Peter Bachmann reviews the current deposition techniques. He also summarizes the results of various deposition conditions and shows that diamond growth is possible only in a narrow range of gas compositions. Y. Sato and co-workers report on the local epitaxial growth of diamond on nickel substrates.

Other papers discuss the electronic, optical, thermal and mechanical properties of thin diamond films. The relationship between diamond and diamond-like carbon (DLC) is now better understood and this volume also contains papers on the electronic structure, deposition techniques and applications of DLC films.

The final paper in this volume discusses the various thermal and optical infrared and X-ray applications of diamond thin films. They have also been used in cutting and grinding and as the active element in semiconducting devices.

The subject is advancing rapidly, with many patents being taken out each year. It is nevertheless an opportune time to review the field since there is much fundamental and applied research that needs to be undertaken before this topic can realize its full potential. It is hoped that this volume will provide a valuable overview of thin film diamond for years to come.

A. H. LETTINGTON
J. W. STEEDS