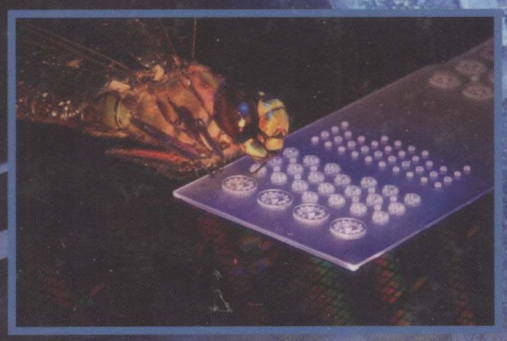
MICRO & NANO TECHNOLOGIES

Hot Embossing

Theory and Technology of Microreplication



Matthias Worgull

William

HOT EMBOSSING

Theory and Technology of Microreplication

Matthias Worgull

Institute for Microstructure Technology
Karlsruhe, Germany

William Andrew
Applied Science Publishers

William Andrew is an imprint of Elsevier
Linacre House, Jordan Hill, Oxford OX2 8DP, UK
30 Corporate Drive, Suite 400, Burlington, MA 01803, USA

First edition 2009

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data
A catalog record for this book is available from the Library of Congress

ISBN: 978-0-8155-1579-1

Printed and bound in United States of America

09 10 11 12 11 10 9 8 7 6 5 4 3 2 1

HOT EMBOSSING: THEORY AND TECHNOLOGY OF MICROREPLICATION

MICRO & NANO TECHNOLOGIES

Series Editor: Jeremy Ramsden
Professor of Nanotechnology
Microsystems and Nanotechnology Centre, Department of Materials
Cranfield University, United Kingdom

The aim of this book series is to disseminate the latest developments in small scale technologies with a particular emphasis on accessible and practical content. These books will appeal to engineers from industry, academia and government sectors.

This book is dedicated to my parents and my friends.

Series Editor's Preface

The concept of replication is fundamental to the era of industrial mass production, just as printing is fundamental to the era of universal knowledge dissemination. Printing is, of course, itself a form of replication, and it could well be said that this book is about the technology of extending printing to the third dimension. The range and variety of products in our contemporary world made by hot embossing is astonishing, and their very familiarity belies the extraordinary ingenuity that has gone into making the technology behind hot embossing into the sophisticated set of processes and materials that it is today. This book is an impressively comprehensive compendium of this technology. It examines every aspect likely to be of interest to the engineer who is highly charged with introducing the technology into a production environment, or further developing it for innovative new products. Furthermore, it includes clear explanations of the underlying science wherever appropriate, which the reader will find to be very valuable in order to understand the basis for making the choice of parameter, or between the different available materials and subprocesses.

Jeremy J. Ramsden
Cranfield University, UK
April 2009

Preface

Today the cost-effective replication of components in polymers is fundamental for the mass fabrication of a wide range of products, especially in the consumer market. The replication processes—especially the process of injection molding—are highly automated and optimized for the replication of products characterized by a large bandwidth of forms and dimensions. With the development of microsystem technology and, further, of nanotechnology, replication was to be faced with a new challenge—the replication of structures in the micro or even nano range. This requirement of cost-effective replication is underlined by the fabrication costs of micro and nanostructures and fuses on the complexity of the fabrication processes. The established replication technologies optimized for structures in macroscopic dimensions cannot be used for the replication of structures in microscopic dimensions without any modifications. The technological requirements are different, because a decreasing structure size is characterized by an increasing relation between surface and volume of a structure. Further, the structure sizes require replication processes and technologies based on high-precision manufacturing and precise control, which makes it necessary to adapt established techniques or to develop new molding techniques. Today hot embossing is, besides the micro injection molding process, one of the common replication technologies for the replication of microstructures in polymers. With the upcoming of nanoimprint technologies the importance of the embossing technique increases. The process of thermal nanoimprint and the hot embossing process are especially characterized by similar process steps.

This book will give the reader a fundamental background on the different aspects of hot embossing. Beginning first with an overview of the different replication technologies, the diversity of the hot embossing process for the fabrication of micro- and nanostructures will underline the flexibility of this replication technique. The implementation of this diversity will be supported by a technology of hot embossing machines, tools, and microstructured mold inserts. The fundamental background refers also to the theoretical knowledge of polymers as molding materials and also in the fundamentals of a theoretical process analysis. The versatility of hot embossing will be illustrated by applications where the process plays an important role in the fabrication line.

Hot embossing and thermal nanoimprint undergo constant development. The limits regarding structure size, molding area, complexity of the structures, and process times are not fixed. New applications requiring mass production will shift the limits in the future. With a fundamental theoretical knowledge of the hot embossing process and its technology, combined with practical experience,

the reader may be part of further developments of this technique and pave the way to new applications. If the book can make a contribution to this, its aim was achieved.

Matthias Worgull
Karlsruhe, Germany
April 2009

Acknowledgment

I would like to thank all the people who helped me to write this book: Miss Schröder, for the translation and correction of the language; Dr. Bastian Rapp, for the support in all aspects of TeX and in designing a number of pictures for this book. Especially I would like to thank Dr. Mathias Heckele for his scientific education in hot embossing and his support for my doctoral thesis, with the focus on the analysis and process simulation of the hot embossing process. A special thank-you goes to Mr. Biedermann, who taught me all the technical and practical aspects of hot embossing. Further, I would like to thank Professor Dr. Saile for his support and confidence in this project. And finally, my thanks to all the friends who motivated me to write.

Contents