Advanced Micro & Nanosystems
Volume 3

Microengineering of Metals and Ceramics

Part I
Design, Tooling
and Injection Molding

Volume Editors
Detlef Löhe and Jürgen Haußelt

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Edited by H. Baltes, O. Brand, G.K. Fedder, C. Hierold, J. Korvink, O. Tabata

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Preface

Machines and their design and production have fascinated mankind from the very beginnings of culture. The last decades have shown mechanical contraptions decreasing in size to almost invisible dimensions. The implementation of micromechanics has become not only a technological challenge, but also a necessity for a successful future development of whole industrial branches. Adequate design and replication techniques of micromechanical components as well as a deep knowledge of their properties are indispensable for further progress in this field. At the same time the variety of materials used in micro system technology has increased significantly. Today not only silicon and polymers, but also metals and ceramics are of increasing interest for a large number of applications. In contrast to silicon and polymers, however, which can be structured by technologies well known from microelectronics, metals and ceramics require new forming and structuring techniques for dimensions in the sub millimeter range. In addition, mechanical properties of metallic and ceramic microparts are of special interest because they differ significantly from those measured in macroscopic dimensions.

It is because of these considerations that the German Research Council (Deutsche Forschungsgemeinschaft, DFG) has decided to fund a collaborative research center (SFB 499) with approximately 2 million euros p.a. which tackles the problems arising when trying to design, produce and characterize advanced microstructures made of metals and ceramics.

The two-volume book in hand presents the results of five years of research on micro engineering utilizing metallic and ceramic materials. It comprises the whole process chain from design and modeling of microcomponents along production preparation and two central replication techniques (micro powder injection molding and micro casting) to characterization and quality insurance, the scope encompassing both theoretical and experimental topics. The book is structured roughly according to the project groups which form SFB 499:

The first volume contains sections on design, tooling and replication techniques based on injection molding. The first section focuses on *micro-component design* including design environment, design flow, modeling and validation as well as on the modeling of micro powder injection molding (cf. chapters 1 to 3).

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The second section on *tooling* describes preparatory steps for the production process. The production of mold inserts by micro milling, laser ablation, micro electro discharge machining and techniques based on lithography and electroforming is investigated, surface treatment methods using shot peening and ultrasonic energy are presented, and optimized mold materials for micro casting are identified (cf. chapters 4 to 9).

The third section on *micro injection molding* (chapters 10 to 12) is concerned with the production itself, focusing on the actual molding processes. Following an introductory chapter on general aspects of micro injection molding, micro injection molding of metals and ceramics including the challenging process steps of debinding and sintering (cf. chapters 11 and 12) are described.

The second volume comprises three sections on replication techniques other than injection molding, on automation and on properties of the components produced.

The section on special replication techniques focuses on microcasting (chapter 13) and electroforming (chapter 14) of metals and on selected techniques for the manufacturing of ceramic microcomponents (chapter 15).

The second section of volume 2 deals with *automation and quality insurance* and includes chapters on the automation of μPIM, on assembly and on quality insurance and dimensional measuring techniques (chapters 16 to 18).

The last section addresses the *properties* of metals and ceramics and of the components produced. Microstructure and mechanical properties including micromechanical testing under quasi-static and cyclic loading as well as tribology are investigated and numerical wear simulation is performed (cf. chapters 19 to 22).

Working groups concerned with aspects touching all five project sections (e.g. on relationships between manufacturing processes) act as links between the projects. Cooperation within SFB 499 is further enforced by concerted work on a demonstration device consisting of a micro-turbine and a sun-and-planet gearing.

For a comprehensive treatment the chapters which directly deal with the research projects of SFB 499 are supplemented by several important research topics concerning micromechanical components (e.g. laser structuring, lithographic processes, electroforming, assembly) which are not part of the collaborative research center. In these cases guest authors have been asked to contribute. They come from Bremen University (Institut für angewandte Strahltechnik, BIAS), from Braunschweig University (Institut für Werkzeugmaschinen und Fertigungstechnik, IWF) and several scientific institutes of Forschungszentrum Karlsruhe.

By covering most aspects of the design, production, and properties of micromechanical components outside the silicon world, the authors hope to present a useful guide to students and readers looking for a comprehensive overview as a starting point of in-depth research in this field. However, the detailed presentation of latest SFB 499 research results as well as contributions from literature should also be a source of new insights and inspiration for micro-engineering experts from research institutions and industry.

May 2005, Karlsruhe *Detlef Löhe and Jürgen Haußelt, Volume Editors*

Foreword

We are proud to present the third and fourth volumes of *Advanced Micro & Nanosystems* (*AMN*), entitled *Microengineering of Metals and Ceramics*.

Although microtechnology is often associated with semiconductor cleanroom processes, this is by no means the only means of production available. The processes we associate with traditional mechanical engineering mass production have also been the focus of microtechnologists, with tremendous successes already in place and a huge potential for further progress. Of course, every new technology pairs the development of suitable materials with that of production technology, and in the sub-millimeter range the challenges become immense. Not only must raw materials be produced in particulate form fine enough to reproduce the molds they are formed into, and molds need to be prepared at the correct dimensions and surface quality, but new ideas are needed to make use of machine parts produced in this manner, and new methods to assemble parts into complete systems. In these two volumes you will find a comprehensive treatment of a variety of challenges that arise in the process of producing microparts from metals and ceramics, from materials, testing, production, computer aided engineering all the way to assembly. We hope that these volumes will inspire the transfer of these fascinating techniques not only to other research groups, but also to industry and so broaden the range of items that can be successfully miniaturized.

Covering recent advances from the world of micro and nanosystems, future *AMN* issues will either focus on a particular subject, such as *CMOS-MEMS* and the present twin topical volumes *Microengineering of Metals and Ceramics*, or be a carefully chosen set of cutting-edge overview and review articles like the first *AMN* volume on *Enabling Techniques for MEMS and Nanodevices*.

Looking ahead, we hope to welcome you back, dear reader, to the upcoming fifth member of the *AMN* series, in which we take a close look at the fascinating field of *Micro Process Engineering*. The articles will range from the fundamentals and engineering over device conception and simulation to fabrication strategies and techniques, and finally cover application and operational issues. To cover such a wide spectrum, we are very glad to have the support of Dr. Nor-

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bert Kockmann from the University of Freiburg, Germany, who will edit this volume.

Henry Baltes, Oliver Brand, Gary K. Fedder, Christofer Hierold, Jan G. Korvink, and Osamu Tabata
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