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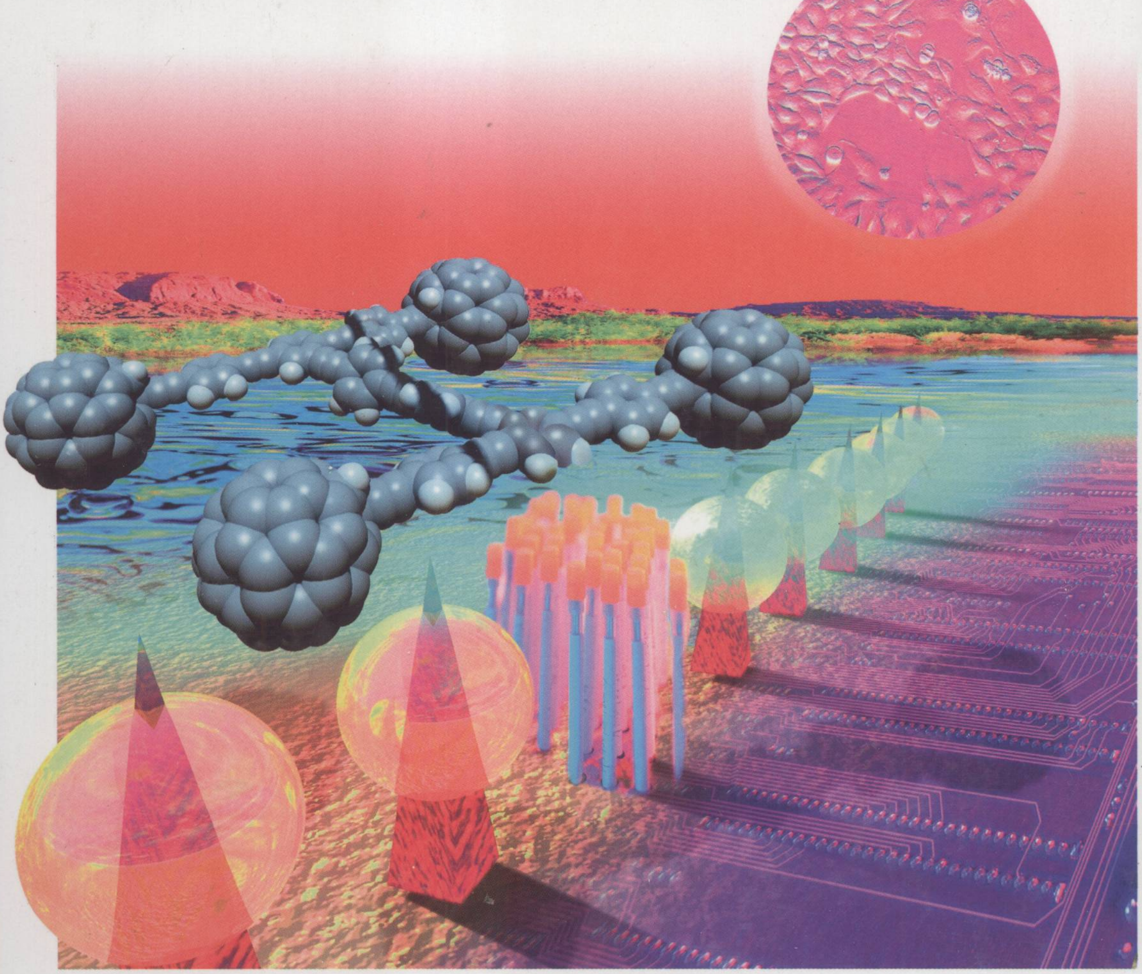
Volume 4: Information Technology II



G. Schmid, H. Krug, R. Waser, V. Vogel, H. Fuchs,
M. Grätzel, K. Kalyanasundaram, L. Chi (Eds.)

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The Editor

Prof. Dr.-Ing. Rainer Waser
RWTH Aachen
Institut für Elektrotechnik II
Sommerfeldstr. 24
52074 Aachen
Germany

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Preface

Beyond any doubt, Information Technology constitutes the area in which nanotechnology is most advanced. Since its origination during the 1960s, semiconductor technology as the driving force of information technology has advanced and continues to advance at an exponential pace. Today, semiconductor-based information technology penetrates almost all areas of contemporary society – and we are still only at the beginning of a new era. Within the coming decades completely new applications may emerge such as personal real-time translation systems, fully automatic navigation systems for cars, intelligent software agents for the internet, and autonomous robots to assist in our daily lives.

The main ingredient of the tremendous evolution of semiconductor circuitry has been the technological opportunity of ever-shrinking the minimum feature size in the fabrication of semiconductor chips. This led to a corresponding increase in the component density on the chips, decreasing energy consumption of the individual logic and memory cells, as well as higher clock frequencies and the development of multi-core architectures. All this added up to a doubling of the computer performance of chips approximately every 18 months, known as Moore's law. During the first decades of development, semiconductor technology was referred to as *microelectronics*, but this was changed to *nanoelectronics* a few years ago when the minimum feature size was reduced to below 100 nm. At about the same time, the component density has surpassed the one billion per chip mark and continues to progress at an unrestrained pace. Research areas related to nanoelectronics, however, comprise much more than simply the extension of current semiconductor technology to still smaller structures. More importantly, they cover the entire physics of nanosized objects with manifold properties that are unmatched in the macroscopic world and which might one day be exploited to store, to transmit, and to process information. In addition, they deal with technological approaches which are completely different to the *top-down* concept based on lithographical methods. The alternative *bottom-up* concept starts with the chemistry of, for example, organic molecules, nanocrystals, nanotubes, or nanowires, and strives for the self-organization of structures which can themselves act as assemblies of functional

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devices. Furthermore, nanoelectronics research investigates completely new computational concepts and architectures.

This text on *Information Technology* within the series *Nanotechnology*, is divided into two volumes and covers the concepts of potential future advances of the semiconductor technology right up to their physical limits, as well as alternative concepts which might one day augment the semiconductor technology, or even replace it in designated areas. Some readers may be familiar with the book *Nanoelectronics and Information Technology* (Wiley-VCH, 2nd edition, 2005) which I have edited. Although the topic of the present book is quite similar, the target is somewhat different. While the first volume represents an advanced text book, the present two volumes emphasize encyclopedic reviews in-line with the concept of the series. Yet, wherever possible, I have strived for a complementarity of the topics covered in the two texts.

This volume covers three parts:

Part One – *Basic Principles and Theory* – includes chapters on the mesoscopic transport of electrons, single electron effects and processes dominated by the electron spin. Furthermore, the fundamental physics of computational elements and its limits are covered.

Part Two – *Nanofabrication Methods* – starts with the prospects of various optical and non-optical lithography techniques, describes the manipulation of nanosized objects by probe methods, and closes with chemistry- and biology-based bottom-up concepts.

Part Three – *High-Density Memories* – begins with an outlook at the future potential of current memories such as Flash and DRAM, attributes magnetoresistive and ferroelectric RAM, and reports about the perspectives of resistive RAM such as phase-change RAM and electrochemical metallization RAM.

Nanotechnology Volume 4 will cover the following topics:

- *Logic Devices and Concepts* – ranges from advanced and non-conventional CMOS devices and semiconductor nanowire device, via various spin-controlled logic devices, and concepts involving carbon nanotubes, organic thin films, as well as single organic molecules, to the visionary idea of intramolecular computation.

- *Architectures and Computational Concepts* – covers biologically inspired structures, and quantum cellular automata, and finalizes by summarizing the main principles and current approaches to coherent solid-state-based quantum computation.

There are many people to whom I owe acknowledgments. First of all, I would like to express my sincere thanks to the authors of the chapters, for their dedication, their patience, and their willingness whenever I requested modifications.

Next, I must pay tribute to the following colleagues (in alphabetical order) for critically reviewing the concept of the text and for their advice on topic and author selection: George Bourianoff (Intel Corp.), Ralph Cavin (Semiconductor Research Corp.), U-In Chung (Samsung Electronics), James Hutchby (Semiconductor Research Corp.), Christoph Koch (Caltech), Phil Kuekes (Hewlett Packard Research Laboratories), Heinrich Kurz (RWTH Aachen University), Rich Liu (Macronix Intl.

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Aachen, January 2008 *Rainer Waser*

List of Contributors

Dan A. Allwood
Department of Engineering Materials
University of Sheffield
Sheffield S10 5NA
United Kingdom
d.allwood@sheffield.ac.uk

Supriyo Bandyopadhyay
Department of Electrical and Computer Engineering
Virginia Commonwealth University
Richmond, VA 23284
USA
sbandy@vcu.edu

Thomas Bjørnholm
Nano-Science Center
University of Copenhagen
The H. C. Ørsted Institute
Universitetsparken 5
DK-2100 Copenhagen Ø
Denmark
tb@nano.ku.dk

Tomas Bryllert
Lund University
Solid State Physics
P.O. Box 118
S-221 00 Lund
Sweden
Present address:
Jet Propulsion Laboratories
California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91109
California
USA

Russell P. Cowburn
Blackett Physics Laboratory
Imperial College London
Prince Consort Road
London SW7 2BW
United Kingdom
r.cowburn@imperial.ac.uk

André DeHon
Department of Electrical and Systems Engineering
200 South 33rd Street
Philadelphia, PA 19104
USA
andre@cs.caltech.edu; andre@acm.org

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Linus Fröberg
Lund University
Solid State Physics
P.O. Box 118
S-221 00 Lund
Sweden
and
Qumat Technologies AB
St. Fiskaregatan 13E
S-222 24 Lund
Sweden

Akira Fujiwara
NTT Basic Research Laboratories
NTT Corporation
3-1 Morinosato- Wakamiya
Atsugi
Kanagawa 243-0198
Japan

Edward Goldobin
Physikalisches Institut-
Experimentalphysik II
Universität Tübingen
Auf der Morgenstelle 14
76076 Tübingen
Germany
gold@uni-tuebingen.de

Dan Hammerstrom
Electrical and Computer Engineering
Department
Maseeh College of Engineering and
Computer Science
Portland State University
1930 SW 4th Street
Portland, OR 97207
USA
strom@cecs.pdx.edu

Hiroshi Inokawa
Research Institute of Electronics
Shizuoka University
3-5-1 Johoku
Hamamatsu 432-8011
Japan

Hagen Klauk
Max Planck Institute for Solid-State
Research
Heisenbergstr. 1
70569 Stuttgart
Germany
H.Klauk@fkf.mpg.de

Raphael D. Levine
The Fritz Haber Research Center for
Molecular Dynamics
The Hebrew University of Jerusalem
Jerusalem 91904
Israel
and
Department of Chemistry and
Biochemistry
The University of California Los Angeles
Los Angeles, CA 90095-1569
USA
rafi@fh.huji.ac.il

Erik Lind
Lund University
Solid State Physics
P.O. Box 118
S-221 00 Lund
Sweden
and
Qumat Technologies AB
St. Fiskaregatan 13E
S-222 24 Lund
Sweden

Björn Lüssem
Sony Deutschland GmbH
Hedelfinger Str. 61
70327 Stuttgart
Germany
luessem@sony.de

Massimo Macucci
Dipartimento di Ingegneria
dell'Informazione
Università di Pisa
Via Caruso 16
I-56122 Pisa
Italy
massimo.macucci@iet.unipi.it

M. Meyyappan
Center for Nanotechnology
NASA Ames Research Center
Moffett Field, CA 94035
USA
meyya@orbit.arc.nasa.gov or
mmeyyappan@mail.arc.nasa.gov

Katsuhiko Nishiguchi
NTT Basic Research Laboratories
NTT Corporation
3-1 Morinosato- Wakamiya
Atsugi
Kanagawa 243-0198
Japan

Yukinori Ono
NTT Basic Research Laboratories
NTT Corporation
3-1 Morinosato-Wakamiya
Atsugi
Kanagawa 243-0198
Japan
ono@aecl.ntt.co.jp

Françoise Remacle
Department of Chemistry, B6c
University of Liège
B-4000 Liège 1
Belgium
fremacle@ulg.ac.be

Lothar Risch
Tizianstrasse 27
85579 Neubiberg
Germany
lothar-risch@gmx.de

Lars Samuelson
Lund University
Solid State Physics
P.O. Box 118
S-221 00 Lund
Sweden
lars.samuelson@ftf.lth.se

Yasuo Takahashi
Graduate School of Information Science
and Technology
Hokkaido University
Sapporo
Hokkaido 060-0814
Japan

Claes Thelander
Lund University
Solid State Physics
P.O. Box 118
S-221 00 Lund
Sweden
and
Qumat Technologies AB
St. Fiskaregatan 13E
S-222 24 Lund
Sweden

Martin Weides
Institute for Solid State Research (IFF)
and
CNI - Center of Nanoelectronic Systems for Information Technology
Forschungszentrum Jülich
52425 Jülich
Germany
m.weides@fz-juelich.de

Lars-Erik Wernersson
Lund University
Solid State Physics
P.O. Box 118
S-221 00 Lund
Sweden

Contents

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