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Dr. Christian Caron
Springer Heidelberg
Physics Editorial Department I
Tiergartenstrasse 17
69121 Heidelberg/Germany
christian.caron@springer-sbm.com

G. Cuniberti G. Fagas K. Richter (Eds.)

Introducing Molecular Electronics

Springer

Editors

Gianaurelio Cuniberti
Klaus Richter

Institut für Theoretische Physik
Universität Regensburg
Universitätsstr. 31
93053 Regensburg, Germany
E-mail: g.cuniberti@physik.uni-regensburg.de
klaus.richter@physik.uni-regensburg.de

Giorgos Fagas
National Microelectronics
Research Center (NMRC)
Nanotechnology Group
Lee Maltings, Cork, Ireland
E-mail: gfagas@nmrc.ie

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Foreword

Klaus von Klitzing

Max-Planck-Institut für Festkörperforschung, Heisenbergstraße 1, 70569 Stuttgart, Germany

Already many Cassandras have prematurely announced the end of the silicon roadmap and yet, conventional semiconductor-based transistors have been continuously shrinking at a pace which has brought us to nowadays cheap and powerful microelectronics. However it is clear that the traditional scaling laws cannot be applied if unwanted tunnel phenomena or ballistic transport dominate the device properties. It is generally expected, that a combination of silicon CMOS devices with molecular structure will dominate the field of nanoelectronics in 20 years.

The visionary ideas of atomic- or molecular-scale electronics already date back thirty years but only recently advanced nanotechnology, including e.g. scanning tunneling methods and mechanically controllable break junctions, have enabled to make distinct progress in this direction. On the level of fundamental research, state of the art techniques allow to manipulate, image and probe charge transport through uni-molecular systems in an increasingly controlled way. Hence, molecular electronics is reaching a stage of trustable and reproducible experiments. This has lead to a variety of physical and chemical phenomena recently observed for charge currents owing through molecular junctions, posing new challenges to theory. As a result a still increasing number of open questions determines the future agenda in this field.

Both, related pioneering experiments and corresponding new theoretical approaches are featured in the present volume of the Springer Series of Lecture Notes in Physics. The contributions to this volume, written by many of the international leaders in the field, span the whole range from single molecules to molecular materials, from carbon nanotube-based devices to organic molecular bridges and proposals for future architectures. The theoretical chapters cover elaborate ab initio calculations as well as novel complementary model-based approaches.

The chapters of the present volume start from an introductory, tutorial level, ideal for graduate students, but also cover many timely aspects of quantum transport at the molecular scale and thereby represent the state of the art in the field, relevant for experts and researchers attracted to this discipline.

The complementary view of authors from chemistry and physics re ects the need for a strong transdisciplinary ert to make clear advances in molecular electronics. This book constitutes a coherent and balanced account of

this rapidly progressing field. It will serve as an important reference volume filling the existing gap between specialized research papers and proceedings, and closed- disciplinary research reviews. I consider this book as a valuable addition to the Springer Series of Lecture Notes in Physics.

Preface

In recent years molecular electronics, particularly the investigation of charge transport processes at molecular scales, has become an immensely vivid field of cross-disciplinary blend encompassing more traditional condensed-matter, mesoscopic, molecular and chemical physics, as well as chemistry. The aim of this book is to provide, on the one hand, an introduction into the mature experimental and theoretical foundations, techniques, and ideas which have been driving this subject. On the other hand, it is to present a balanced overview over the state-of-the-art research in this rapidly progressing discipline.

The present Lecture Notes in Physics volume is addressed to young scientists with a basic background in condensed-matter or chemical physics, and it may serve as an orientation for scientists who are interested in or are planning to enter the exciting field of molecular electronics. Moreover, many of the presented results and viewpoints are certainly also new and of interest to specialists in the field. In order to cover a broad range of both experimental and theoretical topics the book has been written by several authors. Each chapter of the volume is aimed at an own introduction and at a reasonably self-contained account of the respective subtopic. A more general introduction to the contents of each chapter and survey of the field, as well as a compilation of further related introductory and review literature, is given in the first chapter.

This book grew out of the very stimulating international workshop *Advances in Molecular Electronics: From Molecular Materials to Single-Molecule Devices* held in February 2004 in Dresden (Germany) at the *Max Planck Institute for the Physics of Complex Systems*, which also sponsored the event. Most of the volume contributions arose from lectures presented there. We thank all the speakers and participants who contributed to the great success of that meeting and particularly Katrin Lantsch for the superb organization. We greatly thank all authors of the chapters of the present Lecture Notes for their enthusiasm, efforts, and, finally, patience during the different stages of this project. Furthermore, the comments by the referees and the valuable advice from the scientific editors of the Springer Lecture Notes, which contributed significantly towards the coherence and readability of the volume, are greatly acknowledged.

We are grateful to *Max Planck Institute for the Physics of Complex Systems* and the *German Research Foundation* through the "University Graduate Training Programme DFG-GRK-638: *Nonlinearity and Nonequilibrium in Condensed Matter*" for additional financial support. We also thank Markus Gaa"s who helped us to prepare the final version of this volume.

Finally we would like to thank Drs. Claus Ascheron, Angela Lahee and Christian Caron at Springer Verlag for their valuable help and cooperation.

Regensburg and Cork
March 2005

G. Cuniberti
G. Fagas
K. Richter

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List of Contributors

Gianaurelio Cuniberti
Institute for Theoretical Physics
University of Regensburg, 93040
Regensburg, Germany

Giorgos Fagas
Tyndall National Institute
Lee Maltings, Prospect Row
Ireland

Klaus Richter
Institute for Theoretical Physics
University of Regensburg, 93040
Regensburg, Germany

Joshua Jortner
School of Chemistry
Tel Aviv University
Tel Aviv, 69978, Israel

Abraham Nitzan
School of Chemistry
Tel Aviv University
Tel Aviv, 69978, Israel

Mark A. Ratner
Department of Chemistry
and Institute
for Nanotechnology Northwestern
University, Evanston
Illinois 60208, U.S.A.

Peter Hänggi
Institut für Physik
Universität Augsburg
Universitätsstraße 1
86135 Augsburg, Germany

Sigmund Kohler
Institut für Physik, Universität
Augsburg Universitätsstraße 1
86135 Augsburg, Germany

Jörg Lehmann
Institut für Physik, Universität
Augsburg Universitätsstraße 1
86135 Augsburg, Germany

Michael Strass
Institut für Physik, Universität
Augsburg Universitätsstraße 1
86135 Augsburg, Germany

Rosa Di Felice
INFM National Center on
nanoStructures and bioSystems
at Surfaces (S3), Modena, Italy
rosa@unimore.it

Arrigo Calzolari
INFM National Center on
nanoStructures and bioSystems
at Surfaces (S3), Modena
Italy

Daniele Varsano
Departamento de Fisica de
Materiales, Facultad de Quimicas
Universidad del Pais Vasco
Centro Mixto CSIC-UPV/EHU and
Donostia
International Physics Center (DIPC)
San Sebastian, Spain
arubio@sc.ehu.es

Angel Rubio
Departamento de Fisica de
Materiales Facultad de Quimicas
Universidad del Pais Vasco
Centro Mixto CSIC-UPV/EHU and
Donostia
International Physics Center (DIPC)
San Sebastian, Spain
arubio@sc.ehu.es

K. Stokbro
Nanoscience Center
Universitetsparken 5d, 2100
Copenhagen East Denmark
ks@nano.ku.dk

J. Taylor
Atomistix Inc, Juliane Maries Vej 30
DK-2100 Copenhagen East
Denmark
jt@atomistix.com

M. Brandbyge
Department of Micro and
Nanotechnology (MIC)
Technical University of Denmark
Building 345 East
DK-2800 Kongens Lyngby, Denmark
mbr@mic.dtu.dk

H. Guo
Department of Physics McGill
University Montreal (Quebec)
PQ H3A 2T8, Canada
guo@phys.mcgill.ca

A. Di Carlo
Dept. Elect. Eng., University of
Rome "Tor Vergata", Via del
Politecnico 1, I-00133 Roma, Italy
dicarlo@ing.uniroma2.it

A. Pecchia
Dept. Elect. Eng., University of
Rome "Tor Vergata", Via del
Politecnico 1, I-00133 Roma
Italy

Th. Frauenheim
Dept. of Theoretical Physics
University of Paderborn
33098 Paderborn, Germany

G. Seifert
Institut f. Physikalische Chemie
Technische Universität Dresden
01062 Dresden
Germany

Neil Bushong
Department of Physics
University of California
San Diego La Jolla
CA 92093-0319, USA
bushong@physics.ucsd.edu

Massimiliano Di Ventra
Department of Physics
University of California
San Diego, La Jolla
CA 92093-0319, USA
diventra@physics.ucsd.edu

Maarten R. Wegewijs
Institut für Theoretische Physik A
RWTH Aachen, 52056 Aachen
Germany

Matthias H. Hettler
Forschungszentrum Karlsruhe,
Institut für Nanotechnologie
76021 Karlsruhe, Germany

Christian Romeike
Institut für Theoretische Physik A
RWTH Aachen, 52056 Aachen
Germany

Axel Thielmann
Forschungszentrum Karlsruhe
Institut für Nanotechnologie
76021 Karlsruhe, Germany

Katja Nowack
Institut für Theoretische Physik A
RWTH Aachen, 52056 Aachen
Germany

Jürgen König
Institut für Theoretische Physik III
Ruhr-Universität Bochum
44780 Bochum, Germany

M. Thorwart
Institut für Theoretische Physik
Heinrich-Heine-Universität
Universitätsstr. 1
40225 Düsseldorf, Germany

R. Egger
Institut für Theoretische Physik
Heinrich-Heine-Universität
Universitätsstr. 1
40225 Düsseldorf, Germany

M. Grifoni
Institut für Theoretische Physik
Universität Regensburg
Universitätsstr. 31
93035 Regensburg, Germany

Jan van Ruitenbeek
Kamerlingh Onnes Laboratorium
Universiteit Leiden
Postbus 9504, 2300 RA Leiden
The Netherlands
`Ruitenbeek@physics.leidenuniv.nl`

Elke Scheer
Universität Konstanz
Fachbereich Physik
Universitätsstr. 10
78464 Konstanz, Germany
`Elke.Scheer@uni-konstanz.de`

Heiko B. Weber
Institut für Angewandte Physik
Universität
Erlangen-Nürnberg
91058 Erlangen, Germany
Forschungszentrum Karlsruhe
Institut für Nanotechnologie
76021 Karlsruhe, Germany
`Heiko.Weber@physik.uni-erlangen.de`

Wenyong Wang
Semiconductor Electronics Division
National Institute of
Standards and Technology
M.S. 8120, Gaithersburg
MD 20899-8120, USA

Takhee Lee
Department of Materials Science and Engineering, Gwangju Institute of Science and Technology, Gwangju 500-712 Korea

Mark A. Reed
Departments of Electrical Engineering and Applied Physics, Yale University
P.O. Box 208284, New Haven CT 06520, USA
mark.reed@yale.edu

J. Tomfohr
Department of Physics and Astronomy

G.K. Ramachandran
Department of Physics and Astronomy

O.F. Sankey
Department of Physics and Astronomy

S.M. Lindsay
Department of Physics and Astronomy
The Biodesign Institute Arizona State University, Tempe
AZ 85287, USA

Robert M. Metzger
Department of Chemistry
Box 870336, University of Alabama
Tuscaloosa, AL 35487-0336
USA

Elsa Thune and Christoph Strunk
Institute of Experimental and Applied Physics, University of Regensburg
Universitätsstr. 31
93040 Regensburg, Germany
elsa.thune@physik.uni-regensburg.de
christoph.strunk@physik.uni-regensburg.de

S. Heinze
Institute of Applied Physics
University of Hamburg
Jungiusstrasse 9a, 20355 Hamburg
Germany
heinze@physnet.uni-hamburg.de

J. Tersoff
IBM Research Division,
T. J. Watson Research Center
Yorktown Heights, New York 10598
USA
tersoff@us.ibm.com

Ph. Avouris
T. J. Watson Research Center
Yorktown Heights, New York 10598
USA
avouris@us.ibm.com

Danny Porath
Department of Physical Chemistry
The Hebrew University
Jerusalem 91904, Israel
porath@chem.ch.huji.ac.il

Noa Lapidot
Department of Physical Chemistry
The Hebrew University
Jerusalem 91904, Israel

Julio Gomez-Herrero
Departamento Física
de la Matería Condensada
Universidad Autónoma de
Madrid, Madrid 28049, Spain

Konstantin. K. Likharev
Stony Brook University, Stony
Brook
NY 11794, USA

Dmitri. B. Strukov
Stony Brook University
Stony Brook, NY 11794, USA

Shamik Das
The MITRE Corporation, M/S
H619
7525 Colshire Drive
McLean, VA 22102
{sdas,grose,picconatto,ellenbgn}
@mitre.org

Garrett Rose
The MITRE Corporation, M/S
H619
7525 Colshire Drive
McLean, VA 22102

Matthew M. Ziegler
IBM T. J. Watson Research Center
1101 Kitchawan Road
P. O. Box 218
Yorktown Heights, NY 10598
zieglerm@us.ibm.com

Carl A. Picconatto
The MITRE Corporation, M/S
H619
7525 Colshire Drive
McLean, VA 22102

James C. Ellenbogen
The MITRE Corporation, M/S
H619
7525 Colshire Drive
McLean, VA 22102