

FUTURE TRENDS IN MICROELECTRONICS

JOURNEY INTO THE UNKNOWN

EDITED BY

SERGE LURYI

JIMMY XU

ALEXANDER ZASLAVSKY


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Published by John Wiley & Sons, Inc., Hoboken, New Jersey
Published simultaneously in Canada

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Library of Congress Cataloging-in-Publication Data:

Names: Luryi, Serge, editor. | Xu, Jimmy, editor. | Zaslavsky, Alex, 1963-
editor.

Title: Future trends in microelectronics. Journey into the unknown / edited
by Serge Luryi, Jimmy Xu, Alexander Zaslavsky.

Description: Hoboken, New Jersey : John Wiley & Sons, 2016. | Includes
bibliographical references and index.

Identifiers: LCCN 2016022488 (print) | LCCN 2016025093 (ebook) | ISBN
9781119069119 (cloth) | ISBN 9781119069171 (pdf) | ISBN 9781119069188
(epub)

Subjects: LCSH: Microelectronics--Technological innovations. |
Nanotechnology--Technological innovations. | Semiconductors--Technological
innovations.

Classification: LCC TK7874 .F887 2016 (print) | LCC TK7874 (ebook) | DDC
621.381--dc23

LC record available at <https://lcn.loc.gov/2016022488>

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

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Preface

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This book is a brainchild of the eighth workshop in the *Future Trends in Micro-electronics* series (FTM-8). The first of the FTM conferences, “*Reflections on the Road to Nanotechnology*,” had gathered in 1995 on Ile de Bendor, a beautiful little French Mediterranean island.¹ The second FTM, “*Off the Beaten Path*,” took place in 1998 on a larger island in the same area, Ile des Embiez.² Instead of going to a still larger island, the third FTM, “*The Nano Millennium*,” went back to its origins on Ile de Bendor in 2001.³ As if to compensate for small size of Bendor, the fourth FTM, “*The Nano, the Giga, the Ultra, and the Bio*,” took place on the biggest French Mediterranean island of them all, Corsica.⁴ Normally, the FTM workshops gather every 3 years; however, the FTM-4 was held 1 year ahead of the usual schedule, in the summer of 2003, as a one-time exception. Continuing its inexorable motion eastward, the fifth FTM workshop, “*Up the Nano Creek*,” had convened on Crete, Greece, in June of 2006.⁵ The inexorable motion was then interrupted to produce a semblance of a random walk in the Mediterranean and the FTM-6 “*Unmapped Roads*” went to the Italian island of Sardinia (June 2009).⁶ Then, FTM-7, “*Into the Cross Currents*” returned to our earlier venue on Corsica (June 2012).⁷ Finally, FTM-8 struck out toward new territories, jumping West all the way to the Spanish island of Mallorca.

The FTM workshops are relatively small gatherings (less than 100 people) by invitation only. If you, the reader, wish to be invited, please consider following a few simple steps outlined on the conference website. The FTM website at www.ece.stonybrook.edu/~serge/FTM.html contains links to all past and planned workshops, their programs, publications, sponsors, and participants. Our attendees have been an illustrious lot. Suffice it to say that among FTM participants, we find five Nobel laureates (Zhores Alferov, Herbert Kroemer, Horst Stormer, Klaus von Klitzing, and Harold Kroto) and countless others poised for a similar distinction. To be sure, high distinction is not a prerequisite for being invited to FTM, but the ability and desire to bring fresh ideas is. All participants of FTM-8 can be considered authors of this book, which in this sense is a collective treatise.

The main purpose of FTM workshops is to provide a forum for a free-spirited exchange of views, projections, and critiques of current and

future directions, among the leading professionals in industry, academia, and government.

For better or worse, our civilization is destined to be based on electronics. Ever since the invention of the transistor and especially after the advent of integrated circuits, semiconductor devices have kept expanding their role in our lives. Electronic circuits entertain us and keep track of our money, they fight our wars and decipher the secret codes of life, and one day, perhaps, they will relieve us from the burden of thinking and making responsible decisions. Inasmuch as that day has not yet arrived, we have to fend for ourselves. The key to success is to have a clear vision of where we are heading. In the blinding light of a bright future, the FTM community has remained mindful of the fact that what controlled the past will still control the future – the basic principles of science. Thus, the trendy, red-hot projections of any given epoch deserve and require critical scrutiny.

Some degree of stability is of importance in these turbulent times and should be welcome. Thus, although the very term “*microelectronics*” has been generally rechristened “*nanoelectronics*,” we have stuck to the original title of the FTM workshop series.

The present volume contains a number of original papers, some of which were presented at FTM-8 in oral sessions, others as posters. From the point of view of the program committee, there is no difference between these types of contributions in weight or importance. There was, however, a difference in style and focus – and that was intentionally imposed by the organizers. All speakers were asked to focus on the presenter’s views and projections of future directions, assessments or critiques of important new ideas/approaches, and *not* on their own achievements. This latter point is perhaps the most distinctive feature of FTM workshops. Indeed, we are asking scientists not to speak of their own work! This has proven to be successful, however, in eliciting powerful and frank exchange. The presenters are asked to be provocative and/or inspiring. Latest advances made and results obtained by the participants are to be presented in the form of posters and group discussions.

Each day of the workshop was concluded by an evening panel or poster session that attempted to further the debates on selected controversial issues connected to the theme of the day. Each such session was chaired by a moderator, who invited two or three attendees of his or her choice to lead with a position statement, with all other attendees serving as panelists. The debate was forcefully moderated and irrelevant digressions were cut off without mercy. Moderators were also assigned the hopeless task of forging a consensus on critical issues.

To accommodate these principles, the FTM takes a format that is less rigid than usual workshops to allow and encourage uninhibited exchanges and sometimes confrontations of different views. A central theme is designed together with the speakers for each day. Another traditional feature of FTM workshops is a highly informal vote by the participants on the relative importance of various fashionable current topics in modern electronics research. This tradition owes its

origin to Horst Stormer, who composed the original set of questions and maintained the results over four conferences. These votes are perhaps too bold and irreverent for general publication, but they are carefully maintained and made available to every new generation of FTM participants. Another traditional vote concerned the best poster. The 2015 winning poster was by Michael Shur on “New ideas in smart lighting.”

A joyful tradition of FTM meetings is the settling of scientific bets, a custom that dates back to the 1998 wager between Nikolai Ledentsov (pro) and Horst Stormer (con) about the putative future dominance of quantum dot-based lasers – a bet that Horst collected in 2004, at FTM-4. Another risky bet on the future dominance of SOI technology was adjudicated at the FTM-8 workshop. The precise statement of this bet (worth a six-magnum case of very good champagne) was the proposition that, by 2015, SOI would cover more than 35% of the complementary metal-oxide-semiconductor (CMOS) market, including memories, by value. This bet, proposed by Sorin Cristoloveanu, attracted three cons: Detlev Grützmacher, Dimitris Ioannou, and Enrico Sangiorgi. At FTM-8, Sorin Cristoloveanu conceded that his bet on SOI was premature – the vintage of the champagne remains to be determined.

Not every contribution presented at FTM-8 has made it into this book (not for the lack of persistence by the editors). Perhaps most sorely we miss the exciting contribution by Mihai Banu of Blue Danube Systems, Inc., in which he told us “How to increase the capacity of mobile wireless networks without changing anything (well, almost anything)!” Abstracts of his and all other presentations can be found at www.ece.stonybrook.edu/~serge/ARW-8/program.html.

The FTM meetings are known for the professional critiques – or even demolitions – of fashionable trends, that some may characterize as hype. The previous workshops had witnessed powerful assaults on quantum computing, molecular electronics, and spintronics, usually waged by the fearless Michel Dyakonov. It seems that by now most of the hype associated with some of these trends has dissipated and perhaps we can take some credit for the more balanced outlook that has emerged since. This time Michel waged no wars but gave a friendly overview of ubiquitous surface waves, a subject to which he has contributed so much that some of these waves bear his name.

We have grouped all contributions into three chapters: one dealing with the future of digital silicon technology, another with new materials and new physics, and still another with applications of microelectronics to health, energy harvesting, and communications. The breakdown could not be uniquely defined because some papers fit more than one category!

To produce a coherent collective treatise out of all of this, the interaction between FTM participants had begun well before their gathering at the workshop. All the proposed presentations were posted on the web in advance and could be subject to change up to the last minute to take into account peer criticism and suggestions. After the workshop is over, these materials (not all of which have

made it into this book) remain on the web indefinitely, and the reader can peruse them starting at the www.ece.stonybrook.edu/~serge/FTM.html home page.

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Acknowledgments

The 2015 FTM workshop on Mallorca and therefore this book were possible owing to support from the following:

- US National Science Foundation
- US Department of Defense: Army Research Office
- Industry: KoMiCo Technologies, Korea
- Academia: SUNY–Stony Brook, Brown University.

On behalf of all workshop attendees, sincere gratitude is expressed to the above organizations for their generous support and especially to the following individuals whose initiative was indispensable: William Clark, Sun-Q. Jeon, Y.-T. Kim, and Dimitris Pavlidis.

Finally, the organizers wish to thank all of the contributors to this volume and all the attendees for making the workshop a rousing success.

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