Memristive Devices and Circuits for Computing, Memory, and Neuromorphic Applications

by

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Thesis submitted for the degree of

Doctor of Philosophy

in

School of Electrical & Electronic Engineering
Faculty of Engineering, Computer & Mathematical Sciences
The University of Adelaide, Australia

December, 2011

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CENTRE FOR HIGH
PERFORMANCE INTEGRATED
TECHNOLOGIES AND SYSTEMS

THE UNIVERSITY
of ADELAIDE

Contents

Abstract

A memristor, *memory resistor*, is a two-terminal nanodevice that can be made as thin as a single-atom-thick that has become of tremendous interest for its potential to revolutionise electronics, computing, computer architectures, and neuromorphic engineering. This thesis encompasses two major parts containing original contributions, (**Part I**) modelling and fabrication, and (**Part II**) circuit application and computing. Each part contains three chapters. The fundamentals necessary for understanding the main idea of each chapter are provided therein. A background chapter revolving around memristors and memristive devices is given. A system overview links the two parts together. A brief description of the two parts is as follows:

Part I—modelling and fabrication is relevant to modelling and fabrication of memristors. A basic modelling approach following the early modelling by Hewlett-Packard is presented and tested with several simple circuits. Memristor fabrication process and materials are discussed and two different fabrication runs along with initial measurement results are presented. SPICE modelling for two memristive devices, (i) the memristor and (ii) the complementary resistive switch are also provided.

Part II—nanocrossbar array and memristive-based memory and computing provides an analytical approach for crossbar arrays based on memristive devices. Proposed designs for memristor-based content addressable memories and their analysis are given. This part provides a binary/ternary content addressable memory structure based on a new complementary resistive switch. A number of fundamental building blocks for analogue and digital computing are also presented in this section. The observation of implementing a learning process based on a pair of spikes is also shown and an extension of such a process to a relatively large scale structure based on SPICE simulation is reported.

In addition to these original contributions, the thesis offers an introductory background on memristors, in the area of materials and applications. The thesis also provides a system overview of the targeted system (a CMOS-memristor imager system),

which provides a the link between the two parts of the thesis. In addition to the original contributions in the area of modelling and characterisation, an overview on the understanding of the memristor element via the quasistatic expansion of Maxwell's equations is discussed.

Statement of Originality

This work contains no material that has been accepted for the award of any other degree or diploma in any university or other tertiary institution to Omid Kavehei and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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December 28, 2011

Signed

Date

Acknowledgements

The research presented in this thesis has been carried out in the School of Electrical and Electronic Engineering at the University of Adelaide. The path towards this thesis spans three years of a multidisciplinary research covering nanoelectronics, materials engineering, and circuit design. It has been an honour and great privilege to be the first Ph.D. student on the emerging topic of memristive devices and systems in Australia at a university with a solid and strong background in microelectronics. From the outset, many people have been involved and have contributed to the presented ideas and understanding gained. I gratefully acknowledge those who have helped along the way and influenced the formation of the understanding and the approach to representation of materials presented in this thesis.

First and foremost I would like to express my gratitude to my principle supervisor, Dr Said Al-Sarawi. He greatly helped with his open and respectful attitude toward science and technology. He provided me with his quick, thoughtful, effective, and also critical comments upon the drafts. I would like to gratefully acknowledge enthusiastic supervision and encouraging attitude of my co-supervisor, Prof Derek Abbott, who inspired me with his wide range of interests and unconventional thinking, which most of the time turn 'impossible' to be feasible. I appreciate all their contributions, time, ideas, strict requirements, funding, and answering quickly all questions I had about topics of their expertise to make my Ph.D. experience productive and stimulating.

Another key person whom I am strongly indebted to is Prof Kamran Eshraghian. He has been a great influential mentor to my scientific career throughout the past three years. His way of thinking inspires me to approach problems in different ways. I wish to express my deep gratitude for his continued encouragement and invaluable suggestions during this work. He provided me with direction, technical support and became more of a mentor and friend, than an advisor. I would also like to include my gratitude to Profs Kyoungrok Cho, Younggap You, Yeong-Seuk Kim, and Sung-Jin Kim, at Chungbuk National University, Cheongju, South Korea, who have enabled part of this research work together with Prof Eshraghian.

I wish to express my warm and sincere thanks to Drs Sharath Sriram, Madhu Bhaskaran, and Prof Arnan Mitchell at the Functional Materials and Microsystems Research Group at RMIT University, Melbourne, Australia, for their fabrication support and thoughtful discussions.

I am indebted to Drs Azhar Iqbal and Nicolangelo Iannella, outstanding scholars at the University of Adelaide, for their kindness, passionate, and patience in discussing long hours around different research issues and also their critical suggestions. I also benefited by works of Drs Azhar Iqbal and James M. Chappell on electromagnetic theory of the memristor. I owe to other great scholars at the university, including Prof Reg Coutts, Assoc Profs Christophe Fumeaux, Cheng Chew Lim, and Drs Withawat Withayachumnankul, Yingbo Zhu, Akhilesh Verma, Thomas Kaufmann, Andrew Allison, Shaghik Atakaramians, Gretel M. Png, and Ajay Tikka for their useful scientific and technical discussions. Drs Jegathisvaran 'Jega' Balakrishnan, Don Wenura Dissanayake and Mr Muammar Kabir also provided me with their Ph.D. thesis LaTeX style files, which has tremendously helped me in preparing this dissertation. I would like to, again, thank Mr Muammar Kabir for his tremendous help for assisting for printing of this thesis while I was in Melbourne.

I also acknowledge help and support Prof Sung Mo Kang and Dr Sangho Shin at the University of California, Merced, through answering questions and providing valuable comments on several topics related to memristive devices. I also acknowledge Profs Yael Nemirovsky and Amine Bermak help and openness in answering my questions regarding image sensors.

Looking back at my *alma mater*, I am surprised and at the same time very grateful for all I have achieved. I can by no means thank Assoc Prof Keivan Navi enough for all the hope he has put on me, before I thought I could do any research at all. It has certainly shaped me as researcher and has led me where I am now. Other scholars who contributed to my academic background are Drs Omid Hashemipour, Tooraj Nikoubin, Ali Zaker-Alhosseini, Islam Nazemi, Mohammad Eshghi, Mohammad Javad Sharifi, Namdar Saniei, Ramak Ghavami Zadeh, Farshad Safaei, Ali Jahanian, Ali Movaghar Rahimabadi, Mohammad Taghi Manzuri Shalmani, Somayeh Timarchi, Ebrahim Afjei, and Fereidoon Shams.

A very special thanks goes out to Mr Ron Seidel for his invaluable suggestions, motivation, encouragement, scientific discussions, and sharing his life experiences, and Mrs Marilyn Seidel for her kindness and general support.

During my candidature, administrative work has been assisted by Rose-Marie Descalzi, Colleen Greenwood, Ivana Rebellato, Stephen Guest, Danny Di Giacomo, Philomena Jensen-Schmidt, and Gail Hemmings. Other supporting people include the technical officers, Ian Linke and Pavel Simcik, and the IT support officers, David Bowler, Greg Pullman, Ryan King, and Mark J. Innes. It became normal for David to receive an email from me every day and I am deeply indebted to his supportive attitude and patience in providing and setting up all the CAD tools used in this dissertation.

I would also like to thank friends and colleagues, including Sang Jin Lee, an incredible friend who provided so much help during my visit to South Korea, Soon-Ku Kang, for his help on memristive-based content addressable memory, Shiva Balendhran, Charan Manish, and Guanrong Xu, for their support during my visit from RMIT and providing technical fabrication support, Seok-Man Kim, Hyeon-Seok Na, and Kyung-Chang Park, for their useful discussions around technical issues, Shahar Kvatinsky, for his critical review on the crossbar structure, Robert Moric, Benjamin Ung, Hungyen Lin, Ali Karami, Henry Ho, Shaoming Zhu, Hui Min Tan, Darryl Bosch, and Yik Ling Lim, for making such a friendly research environment. I should also thank Hossein Pishgar for his effective collaboration in building a technical ground for CAD tools at my *alma mater*, which helped me a lot.

I recognise that this research would not have been possible without the financial assistance of Australian Government via Endeavour International Postgraduate Scholarship (EIPRS) and the University of Adelaide Scholarship for Postgraduate Research. Travel grants and awards were from the School of Electrical & Electronic Engineering (the University of Adelaide), the D.R. Stranks Postgraduate Travelling Fellowship, Research Abroad Scholarship, World Class University program (South Korea) through the Chungbuk National University, and the Australia's Defence Science and Technology Organisation (DSTO) through the Simon Rockliff Supplementary Scholarship.

Beyond memristors, my wife and I are in indebted to our lovely Australian friends, in particular, Marie and Peter Wood, and Anne Spencer. We are extremely grateful for everything they have done to us. It is just impossible to put into words how much energy and happiness they have brought into our lives.

My endless appreciation goes to my family, my mother, my father, and my brothers, who always endow me with infinite support, wishes, continuous love, encouragement, and patience. I would like to thank my mother- and father-in-law for their guidances and wishes.

Last but not least, the warmest thank to my dear wife, *Taraneh*. I dedicate this dissertation to her not just because she has given up so much to make my career a priority in our lives, but for being a truly wonderful friend during the entire amazing journey with me.

O. Kavehei

Conventions

Typesetting This thesis is typeset using the LaTeX2e software. TeXnicCenter is used as an effective interface to LaTeX.

Referencing The Harvard style is used for referencing and citation in this thesis.

Spelling Australian English spelling is adopted, as defined by the Macquarie English Dictionary (Delbridge 2001).

System of units The units comply with the international system of units recommended in an Australian Standard: AS ISO 1000—1998 (Standards Australia Committee ME/71, Quantities, Units and Conversions 1998).

Physical constants The physical constants comply with a recommendation by the Committee on Data for Science and Technology: CODATA (Mohr and Taylor 2005).

Publications

Journal publications

KAVEHEI-O., AL-SARAWI-S.F., CHO-K.R., ESHRAGHIAN-K., AND ABBOTT-D. (2011). An analytical approach for memristive nanoarchitectures, *IEEE Transactions on Nanotechnology*, (Accepted on 28th October, 2011), *arXiv preprint: 1106.2927*.*

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Note: Articles with an asterisk (*) are directly relevant to this thesis.

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