Si-based Resonant Interband Tunnel Diodes for Quantum Functional and Multi-level Circuitry (Mixed-Signal, Logic, and Low Power Embedded Memory) to Extend CMOS

Paul R. Berger
Department of Electrical Engineering and Department of Physics
The Ohio State University, Columbus, OH 43210

Abstract

The dawn of tunnel diodes, commonly attributed to Leo Esaki in the late 1950's, predates much of the innovation and infrastructure investment into CMOS technology. But, the lack of a mass production process and inability to monolithically integrate these devices into complex circuits paved the way for the CMOS juggernaut seen today.

However, the unique negative differential resistance (NDR) systemic to all tunnel diodes provides a pathway to exploit new hybrid-CMOS circuit topologies with compact latches and reduced power consumption that could mitigate some of the bottlenecks perceived for scaled CMOS. A new paradigm of computing is possible, capitalizing upon transistor/tunnel diode integration if a viable Si-based tunnel diode could be developed. This talk will explore these opportunities.

This talk will provide a background on Si-based tunnel diode devices and circuits and summarize the results of Si-based RITD device optimization, their monolithic integration with Si-based transistors and present a range of circuit prototyping. The extension of NDR to ultra-low voltage memory will also be discussed.

Paul R. Berger (S'84 M'91 SM'97 F'11) is a Professor in Electrical & Computer Engineering at Ohio State University and Physics (by Courtesy). He is also a Distinguished Visiting Professor at Tampere University in Finland. He received the B.S.E. in engineering physics, and the M.S.E. and Ph.D. (1990) in electrical engineering, respectively, all from the University of Michigan, Ann Arbor. Currently, Dr. Berger is actively working on quantum tunneling devices, printable semiconductor devices & circuits for IoT, bioelectronics, novel devices, novel semiconductors and applied physics.

Formerly, he worked at Bell Laboratories, Murray Hill, NJ (1990-'92) and taught at the University of Delaware in Electrical and Computer Engineering (1992-2000). In 1999, Prof. Berger took a sabbatical leave while working first at the Max-Planck Institute for Polymer Research, Mainz, Germany and then moved on to Cambridge Display Technology, Ltd., Cambridge, United Kingdom. In 2008, Prof. Berger spent an extended sabbatical leave at IMEC (Interuniversity Microelectronics Center) in Leuven, Belgium while appointed as a Visiting Professor in the Department of Metallurgy and Materials Engineering, Katholieke Universiteit Leuven, Belgium. Prof. Berger was also a Finnish Distinguished Professor (FiDiPro) at Tampere University of Technology (2014-2019), and he continues as a Fulbright-Nokia Distinguished Chair in Information and Communications Technologies (2020-2022) with the newly merged Tampere University.

He has authored over 240 referred publications and presentations with another ~100 plenary, keynote, invited talks, 5 book sections and been issued 25 patents with 3 more pending from 60^{+} disclosures with a Google Scholar H-index of 36. Some notable recognitions for Dr. Berger were an NSF CAREER Award (1996), a DARPA ULTRA Sustained Excellence Award (1998), Lumley Research Awards (2006, 2011), a Faculty Diversity Excellence Award (2009) and Outstanding Engineering Educator for State of Ohio (2014). He has been on the Program and Advisory Committees of numerous conferences, including the IEDM, DRC, ISDRS, EDTM and IFETC meetings. He will be hosting the IFETC in '21 as General Chair. He currently is the Chair of the Columbus IEEE EDS/Photonics Chapter; Vice Chair of IEEE Columbus (2021-2022) and Faculty Advisor to Ohio State's IEEE Student Chapter. In addition, he is an elected member-at-large to the IEEE EDS Board of Governors (19'-21'), where he is also Vice President of Strategic Directions (20'-21') and a member of the EDS Finance Committee.

He is an IEEE EDS Fellow (2011) and Distinguished Lecturer (since 2011), as well as a Senior member of the Optical Society of America.