Introduction to the Issue on Silicon-Based Optoelectronics

SILICON-BASED optoelectronics (OE's) is a wide-ranging technology that is gaining maturity. This technology aims to leverage the cost-effectiveness and renowned performance of Si-based electronic circuits by integrating photonic components on digital and wireless silicon integrated circuits (IC's). Commercialization efforts going on within the R&D community should allow Si-based OE's to participate in key aspects of the global photonics industry, such as the 1.31- and 1.55-μm fiber-optic-systems area.

The considerable potential of Si-based optoelectronic integrated circuits (OEIC's) is beginning to be realized and this area holds promise for a wide range of applications from high-capacity on-chip optical interconnects to optical communications receivers and ultimately transmitters. In single-crystal Si-based materials, it may be possible to realize active devices that generate, process, and detect optical signals. Both silicon and glass-on-silicon have proven successful for low-loss optical waveguiding, passive signal processing, and interfacing to glass optical fibers.

This issue documents recent developments in the science, technology, and applications of Si-based optoelectronic materials, structures, and processing. We are fortunate to have a collection of significant invited and contributed papers on materials, devices, subsystem chips, and processing techniques.

Monolithic and hybrid integration on Si are the two contending integration techniques. Hybrid integration has moved forward smartly during 1996–1998, while monolithic group-IV integration has lagged behind due to the lack of efficient Si-based light-emitting diodes (LED's), lasers, and optical amplifiers. In addition, the speed and efficiency of present monolithic group-IV infrared photodiodes and electrooptic modulators are not optimum. These challenges are addressed in this Issue.

The review article of Krishnamoorthy *et al.* illustrates the tremendous progress that is being made in heterogeneous III–V photonic integration on silicon VLSI. Their OE-VLSI hybrid offers substantial improvement over conventional wire-bonded optoelectronic packaging. The current status of the powerful silica-on-silicon technology is described in an invited paper by Himeno *et al.* They review the sophisticated, commercialized, silica planar lightwave circuits, both photonic integrated circuits (PIC's) and hybrid OEIC's, for fiber-to-the-home and internet WDM optical network applications. In another invited paper, Madsen *et al.* demonstrate an on-chip optical spectrum analyzer made with silica waveguide technology and UV writing. Silicon oxynitride is discussed as an alternative to silica by de Ridder *et al.* who cover integrated waveguide filters, multiplexers, and second-harmonic generators in SiON–Si. The invited paper of Jalali *et al.* presents important experimental results on silicon-on-insulator (SOI) guided-wave PIC's and on monolithic SOI optical receivers for fiber-optic applications.

Optical-microwave interactions are described in two papers: an optically controlled terminator for a Si microwave microstrip line (Serres *et al.*) and a wide-band SOI coplanar traveling-wave photodiode (Huynen *et al.*).

Photodetector papers include those on GeC–Si diodes (Kolodzey *et al.*) and Cr–Si–$CoSi_2$–Si ultrafast metal–semiconductor–metal (MSM) photodiodes coupled to integral polymer strip waveguides on Si (Siegert *et al.*, invited). Optical waveguide papers cover the novel visible-and-IR porous Si guides made by implants and epitaxy (Arrand *et al.*), the arsenic-implanted Si-on-Si guides (Cocorulla *et al.*), and the versatile pseudomorphic Si–SiGe–Si waveguides (Janz *et al.*). Several new optical modulators have been investigated: the thermooptic waveguided heterostructure of α-SiC–α-Si–Si (Cocorulla *et al.*), the three-terminal bipolar free-carrier waveguide and the electrically controlled Bragg reflector (Breglio *et al.*), and the SiGe–Si multiquantum-well (MQW) modulator on SOI (Vonsovici *et al.*). Nanocrystalline Si LED's integrated with Si microelectronic circuits are reviewed by Fauchet in his invited paper on porous-silicon progress, while Friedman *et al.* examine a Si-based Ge–Si superlattice laser. Regretably, the important erbium–silicon LED technology is not represented in this Issue, although recent progress on Er:Si and related topics is presented, for example, in the *MRS Proceedings* (vol. 486, 1998). The category of Si-based optical receivers is represented by papers on low-cost 900-Mb/s NMOS receiver chips for 850 nm (Schow *et al.*) and CMOS-integrated receivers intended for chip-to-chip optical interconnects (Kuijk *et al.*). All told, the papers in this issue show that the elements of a complete photonics technology on silicon are beginning to appear.

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In 1975, he was awarded an SRC Personal Post-Doctoral Research Fellowship for the study of anodic oxides on GaAs for microwave MOSFET's and in 1977 he was appointed as a Research Fellow at University College London, U.K., where he worked on acoustic nondestructive testing and ZnO acoustic transducers. In 1979, he was appointed as a Lecturer in Electronic Engineering at the University of Surrey, Surrey, U.K., where he established a research group in integrated optical devices in $LiNbO_3$ and he was promoted to Senior Lecturer, Reader, and Professor in 1986, 1993, and 1996, respectively. Currently, he is Deputy Head of the School of Electronic Engineering, Information Technology, and Mathematics. His research is concerned with modeling the optical properties of III–V semiconductor quantum-well structures and devices, optoelectronic devices in silicon-based materials and photosensitivity in glass. In 1991, he spent six months sabbatical leave at the University of Cincinnati, OH. In 1994–1995, he was a DFG Visiting Professor at the Technische Hochschule Darmstadt, Germany. He is currently an Honorary Professor at the University of Hong Kong. He has published more than 150 papers and edited several conference proceedings and journal special issues.

Dr. Weiss was awarded the IEE J. Langham Thompson Premium for a paper on optoelectronic quantum-well devices and the Medal of the Warsaw University of Technology for contributions to the joint TEMPUS project. He is a Fellow of the Institution of Electrical Engineers (U.K.), a Fellow of the Institute of Physics (U.K.). He is a past chairman of the IEE Scholarships Committee and a member of the Books, Distance Learning and Professional Publications Committees of the IEE, Associate Editor of the *International Journal of Optoelectronics* and Editor of the IEE EMIS book series.

Richard A. Soref (S'58–M'63–SM'71) was born in Milwaukee, WI, in 1936. He received the B.S.E.E. and M.S.E.E. degrees from the University of Wisconsin, Madison, in 1958 and 1959, repectively, and the Ph.D. degree in electrical engineering from Stanford University, Stanford, CA, in 1963.

He served as a Staff Member at MIT Lincoln Laboratory during 1963–1965 and was a Member of the Technical Staff at Sperry Research Center, Sudbury, MA, from 1965 to 1983. In 1983, he joined the Air Force's Rome Air Development Center (now AFRL), Hanscom AFB, MA, where he is presently a Research Scientist in the Electromagnetics Technology Division of the Sensors Directorate. Early work on 8-20 μm impurity-doped-silicon infrared detectors was followed by the invention of liquid-crystal displays, *LC* optical switches, $LiTaO_3$ switches, and optical-microwave devices. For the past ten years, he has investigated the basic and more exotic aspects of silicon-based optoelectronics in studies that ranged from waveguides to quantum wells—and he has been an enthusiatic advocate of this technology. He has authored or coauthored more than 120 refereed journal articles, has given numerous invited talks at international conferences, and has written four book chapters. He holds 46 U.S. patents.

In 1991, Dr. Soref won the U.S. Air Force Basic Research Award for pioneering work on semiconductor guided-wave optics. Professional activities include: Chairman, Boston IEEE Electron Devices Group (1969); Editorial Advisor, SPIE Optical Engineering (1986-1987); Session Chairman, DoD Fiber Optic Conf. (1992), AFCEA (1994), MRS (1995 and 1997), OSA-IPR (1998); Organizer, Silicon Photonics Symposium OSA-IPR (1996 and 1998); Organizer, MRS Symposium H (1997); Organizer, Silicon Integrated Optics Symposium, OSA Annual Meeting (1998). He is a Member of Optical Society of America, the American Physical Society, MRS, and SPIE, and is a Fellow of AFRL.