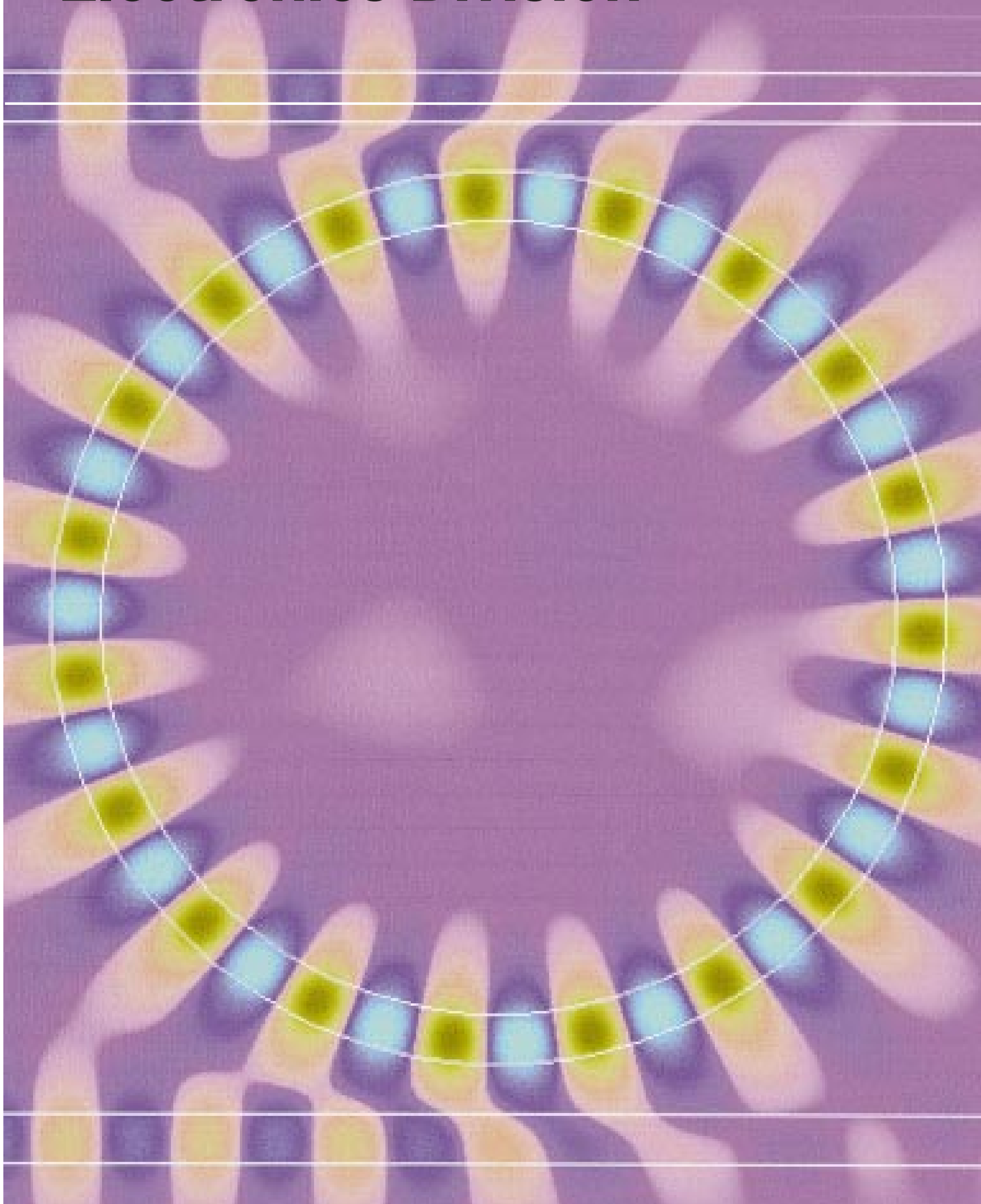
Our Featured Division

Electronics Division



Electronics, Optoelectronics, and Photonics are the Foundation of the Information Revolution

by George K. Celler

How many lasers are in your house? Do you live in a giga-transistor household yet? How many microprocessors and digital signal processors (DSPs) are installed in your car? Not so long ago, questions like these would have been ridiculous. Just a few decades ago, owning a 7-transistor radio was something to be proud of. Today a PC with an internal clock running at 1 GHz and with several hundreds of millions of transistors inside is a fairly common desk appliance. This computer also provides access, through telephone lines and fiber-optic cables, to a vast array of information and multimedia entertainment sources from all over the globe.

Almost all advanced electronic systems contain, as their core, silicon integrated circuits. Moore's law, which has described and guided the progress of silicon technology for over 35 years, states that the number of transistors on a chip doubles every 18 months. That is how we have progressed from a few transistors on the first integrated circuits to chips that now contain up to 50 million transistors. Miniaturization, which reduces the cost per function while it improves the circuit performance, is responsible for the clock frequency increase from a few megahertz in early PCs to the current 1 GHz. Silicon electronics provides computing power and signal processing, and also wireless communication (with some help from GaAs electronics); but the high speed, broadband communication for voice, data, and multimedia depend on optoelectronics and photonics. Optical signals are generated and detected by semiconductor devices, often made of GaAs, InP, and of epitaxially grown layers of various ternary and quaternary compounds. These signals are transmitted around the globe in glass fibers of incredible purity.

The ECS Electronics Division has been always involved with processing of semiconductor devices, starting with germanium and silicon, and later expanding its scope to compound semiconductors as well. The silicon materials science and technology symposium of ECS has been one of

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the premier technical conferences in the field for the last 30 years. The most recent symposium, held in 1998, commemorated the 50th anniversary of the commercial introduction of the point contact transistor by Bell Labs. The proceedings volume[1] includes papers by some of the founders of semiconductor electronics. Many of the key players in the semiconductor field (including Gordon Moore, the co-founder of Intel Corporation), have been active participants in the Society and the Division.

As the complexity of semiconductor technology has increased, topical symposia have been organized focusing on specific aspects of technology, such as crystal growth, wafer fabrication, surface cleaning, chemical vapor deposition, molecular beam epitaxy, plasma etching, ion implantation, rapid thermal annealing, silicon-on-insulator, wafer bonding, metallization, device modeling, etc. These are technical areas without which the technology, as we know it today, would not exist.

In this issue of the *Interface,* we highlight three topics: *Wafer Bonding: A Flexible Approach to Material Integration; Photons to the Rescue: Microelectronics Becomes Microphotonics;* and *GaN Electronics for High Power, High Temperature Applications.* All three papers aim beyond the traditional core of electronics science and technology, where processing of silicon chips is of paramount importance. The Electronics Division has and will continue its commitment to the issues associated with ultra large scale integration (ULSI), but at the same time many members are interested and involved in emerging new areas.

Wafer bonding is one such emerging area, the importance of which is rapidly increasing. The article, co-authored by Ulrich Gösele, winner of the 1999 Electronics Division Award, and Marin Alexe, reminds us that already in 1638 Galileo Galilei reported that flat glass plates stick together. Room temperature adhesion of silicon wafers and its strengthening by high temperature annealing have been intensely investigated for the last 20 years. This has led to the development of a commercial technology for fabrication of silicon-on-insulator or SOI substrates, which are attractive for high speed, low power electronics and many other applications. The authors discuss the science of wafer bonding and a broad range of applications, including bonding of compound semiconductors, bonding of dissimilar materials, and applications in the rapidly growing field of microelectromechanical systems or MEMS.

Silicon has an indirect electronic bandgap, in contrast to GaAs, InP, and many other compound semiconductors. For this reason silicon devices are not suitable for efficient generation of light. Nevertheless, silicon-based structures can provide an ideal medium for directing light signals over a short distance (< 10 cm). Lionel Kimerling, who received the 1995 Electronics Division Award, addresses this in the article on the photonic application of silicon. His paper describes optical waveguides, often made in silicon-on-insulator (SOI) wafers formed by bonding, and also optical filters, switches, and modulators made out of Si and SiO_2. These microphotonic devices have been fabricated using the processing tools of microelectronics, such as thin film deposition, photolithography, and etching. Because they have a forbidden energy gap for photons that is analogous to the band gap for electrons, periodic structures, known as photonic crystals, have also been constructed for wavelength division multiplexing (WDM) applications.

Power electronics has not been in the limelight as much as ULSI. But as we become more and more dependent on computers, e-commerce, and electronic gadgets, the importance of clean and extremely reliable power distribution is rapidly increasing. Some claim that the production and delivery of such power will be the next technological revolution. Steven Pearton and his co-authors, including S. N. G. (George) Chu, the recipient of the 2000 Electronics Division Award, describe their investigation of GaN based materials and devices for high voltage, high power devices, that also may be capable of operating at temperatures up to and exceeding 400°C. ■

The Electronics Division • Future Symposia Plans

Phoenix, AZ — October 2000

Fourth International Symposium on Chemical Mechanical Polishing (co-sponsored by the Dielectric Science and Technology Division); *Copper Interconnects, New Contact Metallurgies/Structures, and Low-k Interlevel Dielectrics* (co-sponsored by the Dielectric Science and Technology and the Electrodeposition Divisions); *First International Symposium on Cold Cathodes* (co-sponsored by the Dielectric Science and Technology and the Luminescence Display and Materials Divisions); *High Purity Silicon VI* (co-sponsored by SPIE); *High Speed Compound Semiconductor Devices for Wireless Applications II*; *State-of-the-Art Program on Compound Semiconductors*; *Integrated Ferroelectrics for Memory Applications* (co-sponsored by the Dielectric Science and Technology Division); *Thin Film Transistor Technologies V* (co-sponsored by the Dielectric Science and Technology Division); *Electronics/Dielectric Science and Technology Joint General Session* (co-sponsored by the Dielectric Science and Technology Division); and *Microfabricated Systems and MEMS V* (co-sponsored by the Sensor and the Dielectric Science and Technology Divisions).

Washington, DC — March 2001

Fourth International Symposium on Environmental Issues with Materials and Processes for the Electronics and Semiconductor Industries (co-sponsored by the Dielectric Science and Technology Division); *Sixth International Symposium on Low and High Dielectric Constant Materials: Materials Science, Processing, and Reliability Issues* (co-sponsored by the Dielectric Science and Technology Division); *Process Control, Diagnostics, and Modeling in Semiconductor Device Manufacturing IV* (co-sponsored by the Dielectric Science and Technology and the High Temperature Materials Divisions); *Sixth International Symposium on Silicon Nitride and Silicon Dioxide Thin Insulating Films* (co-sponsored by the Dielectric Science and Technology and the High Temperature Materials Divisions); *Electrochemical Processing in ULSI Fabrication and Electrodeposition of and on Semiconductors IV* (co-sponsored by the Electrodeposition and the Dielectric Science and Technology Divisions); *III-Nitride Based Semiconductor Electronic and Optical Devices; Implementation of the 300 mm Silicon Era; Second International Symposium on ULSI Process Integration II; State-of-the-Art Program on Compound Semiconductors XXXIV; Tenth International Symposium on Silicon-on-Insulator Technology and Devices; Electronics/Dielectric Science and Technology Joint General Session* (co-sponsored by the Dielectric Science and Technology Division);and *Rapid Thermal and Other Short-Time Processing Technologies II* (co-sponsored by the Dielectric Science and Technology and the High Temperature Materials Divisions).

References

1 *Semiconductor Silicon 1998*, edited by H. R. Huff, H. Tsuya, and U. Gösele, The Electrochemical SocietyProceedings Series PV 98-1, Pennington, NJ (1998).

About the Author

George Celler *is a former chairman of the Electronics Division, and a Distinguished Member of Technical Staff at Bell Laboratories, Lucent Technologies.*