Gregory E. Stillman

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1936-1999

BY NICK HOLONYAK, JR.

GREGORY EUGENE STILLMAN, professor of electrical engineering and member of the University of Illinois Center for Advanced Study, a renowned researcher on semiconductor materials and devices, died in Urbana on July 30, 1999. His death was caused by metastatic cancer resulting from a melanoma.

Born in Scotia, Nebraska, on February *15,* 1936, Gregory Stillman grew up in rural Nebraska, where he completed his elementary and high school education. He earned his bachelor's degree in electrical engineering in 1958 at the University of Nebraska and entered the U.S. Air Force, where he served (1958 to 1963) as an officer and pilot in the Strategic Air Command. This started his life in flying, everything from the heaviest jets to the smallest single-engine, propeller-driven aircraft. His calm, cool demeanor served him well in taking off with fully loaded KC-135 tanker planes, then flying with inefficient engines at low altitude. In 1963 he entered graduate school at Urbana and completed his M.S. degree in 1965 and Ph.D. in 1967 in electrical engineering. His thesis research in the newly formed laboratory of N. Holonyak, Jr., a laboratory formed because of John Bardeen's wish to expand semiconductor work in Urbana, was concerned with synthesizing and studying III-V compounds and devices (light-emitting devices, lasers, and LEDs). This began Greg Stillman's thirty-five-year involvement with III-V

semiconductors and devices and with optoelectronics, where he made important contributions and helped define the field.

In Stillman's Ph.D. work we find the first study and identification of the notorious so-called DX center in III-V alloy semiconductors, a problem beginning in 1960 at General Electric with the prototype III-V alloy laser and LED material GaAsP. This work was done in a masterly manner on crystals grown by Stillman with the help of J.A. Rossi using a vapor phase epitaxial (VPE) process developed earlier by Holonyak at GE (Syracuse, 1960). If there was a “failure” in this work, it was that of inventing a name, i.e., “donor-unknown” (DX), which was a name that came later when other workers, indeed, rediscovered the DX center. This has become a classic, a continuing area of study, a fundamental defect problem in the region of the direct-indirect transition of the energy gap of III-V alloys. Stillman and M.G. Craford in their thesis work (Urbana) were the first to mount an attack on this major problem in wide bandgap III-V alloys. Craford's entry into the field of III-V semiconductor and LED science and technology began with his work with Stillman, who was known for his generosity and was willing to share, as it turned out, the study of a large problem. Stillman and Craford's “DX center” data have stood the test of time for over thirty years.

After his doctoral work, Stillman carried his talents to the Applied Physics Group at Massachusetts Institute of Technology Lincoln Laboratory, to a project led by R.H. Rediker. There he began a series of studies on GaAs and other related III-V materials (optoelectronic and photonic materials) that have taken on the character of a tour de force. He established sensitive techniques for the evaluation of compound semiconductor materials that are now employed universally. Because of problems with the Gunn oscillator, Stillman and his colleague C.M. Wolfe in Rediker's group set out to make ultrapure GaAs and to study its properties. They were the first to achieve purity levels that made possible the observation and identification of the discrete donor in GaAs, the basic III-V extension from Ge and prototype for all the III-Vs. This opened the door in general to rigorous III-V semiconductor characterization. Stillman and Wolfe defined the standards—including magnitude of carrier mobility, far-in

frared light emission, low-temperature selection rules, photoconductivity properties, and false indications—that now apply to the whole field of assessing the purity and properties of compound semiconductors. Greg Stillman's interest and background in this area of work led him to the early application of the photothermal method of measurement to study and identify impurities in III-Vs. He was a leader in this field of work. He was known more generally for the elegance of his experimental work and the reliability of his data, as well as for the soundness of his ideas.

Because GaAs and the III-Vs in general are the basic materials of optoelectronics and photonics, it was inevitable that Greg Stillman would contribute also to the problem of making and studying III-V devices. Specifically, he made fundamental measurements and studies on avalanche (photon) detectors and their asymmetry in respect to hole and electron multiplication. He was a ranking expert in this area of work and in the study of photodetectors in general—including quantum well heterostructure devices. Not only was he heavily published and referenced, but also his data were considered the most substantial, least in error, more nearly a standard. He was known for the accuracy of his results, which made him frequently the most cited source, the most sought source of advice. At Lincoln Laboratory his identity as an authority on III-V materials and devices became firmly established, and over the years steadily increased.

In 1975 he returned to the University of Illinois and brought all of these areas of III-V study to Urbana. He was successful in teaching these and other methods and work to forty-two Ph.D. students (electrical engineers, physicists, materials scientists) and continued to expand all of this activity. In 1951 John Bardeen brought semiconductor work to Urbana; in 1963 Holonyak extended this work from Ge and Si to the III-V semiconductors; and in 1975 Stillman expanded the Urbana III-V work even further. Urbana became known as a center of III-V studies. Greg Stillman introduced sophisticated methods (LPE, VPE, MOCVD) into his laboratory to grow and study a whole range of III-V materials and heterostructures. His considerable knowledge of how impurities behaved in III-V semiconductors led him to identify and exploit an important new acceptor in GaAs and in AlGaAs,

carbon, which is not usually known as or regarded as a dopant. Carbon doping turned out to be unique in terms of its doping density and stability against diffusion. This made it possible for Stillman and his students to introduce a new family of high-performance microwave heterojunction bipolar transistors (HBTs) that now are of great importance in wireless communications and in digital-analog converters.

Stillman was a rare example of the materials and device scientist who, in building and studying electronic devices, uncovered fundamental properties of crystal systems, specifically the III-V family of semiconductors. He was an internationally known authority on III-V materials and devices. He was one of the most senior organizers of international conferences and meetings dealing with III-V's and their use in optoelectronics. Over the course of his thirty-five years of work and contributions to III-V materials and devices, he witnessed the field (III-V's and optoelectronics) go from a primitive state to a sophisticated multibillion-dollar industry. His life and work were an important part of this development.

Greg Stillman had a major effect also on teaching, first on his graduate students and, in addition, on hundreds of undergraduates who took his course, a basic course, on semiconductor devices and electronics. His graduate students, under his kind and steady hand, received many awards for their conference presentations, which was directly attributable to how he instructed and guided them. Stillman's lecturing and teaching were known internationally. He was in constant demand to prepare review volumes and chapters on all aspects of III-V materials and devices. His research work resulted in more than 300 publications. He was the coauthor with Wolfe and Holonyak of the textbook and reference, *Physical Properties of Semiconductors* (Prentice-Hall, 1989). He was the editor with M.R. Brozel of the major reference *Properties of Gallium Arsenide* (Inspec, 1996). His was one of the most sought-after voices counseling and leading the field of III-V materials and device study. He was one of the wisest and gentlest counselors of this field of work. He was known for his friendly nature and generosity, products of his small-town upbringing. As stated recently by M. Kikuchi (Sony's retired re

search director, 1974 to 1989), "I remember he was a thoughtful person with [a] warm mind."

Greg Stillman was chairman of leading groups and meetings in the field and, for example, served as president (1984 to 1986) of the Institute of Electrical and Electronics Engineers (IEEE) Electron Devices Society. He was an IEEE fellow and for many years helped organize and lead IEEE Device Research Conferences and TMS Electronic Materials Conferences. He was the founding director (1986) of the University of Illinois Microelectronics Laboratory, which in its inception was supported by a National Science Foundation Engineering Research Center grant. He was indefatigable in the search for a microelectronics facility and its project support at the University of Illinois. He understood the argument, and reality, that there would be no electronics without the semiconductor.

In spite of his many scientific and professional activities, Greg Stillman somehow managed to maintain an active interest in flying. Because of his extensive knowledge of flying, as well as electronics, he was called on many occasions for expert testimony in court proceedings involving aircraft accidents, including major airline disasters. He had a strong sense of right versus wrong, worked and lived accordingly, and in his own kindly manner exercised his abilities to the fullest.

Besides receiving the IEEE Jack A. Morton Award and the International Gallium Arsenide Conference Award with Heinrich Welker Gold Medal for his research on III-V materials and devices, in 1985 Greg Stillman was elected a member of the National Academy of Engineering. He served on numerous university, national, and international committees, including the National Research Council. For his teaching he received the Tau Beta Pi Drucker Award, and for his research contributions was made a permanent member of the University of Illinois Center for Advanced Study, the highest position accorded a University of Illinois professor.

Greg Stillman gave much to his fellow man, and, for thirty-five years, to the study of III-V semiconductors. He will be missed. His passing leaves the planet lonelier for all of us.