Nick Holonyak Jr

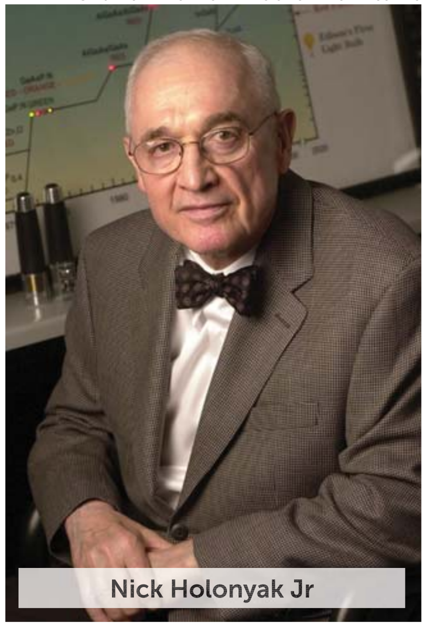
Known as the father of the LED and semiconductor visible laser, Nick Holonyak Jr, the John Bardeen Endowed Chair Emeritus in Electrical and Computer Engineering and Physics at the University of Illinois at Urbana-Champaign, died in Urbana on 18 September 2022 at the age of 93.

Holonyak was born on 3 November 1928 in the southern-Illinois coal-mining town of Zeigler. He attended the University of Illinois and earned his BS in 1950, MS in 1951, and PhD in 1954, all in electrical engineering. During his PhD, he worked for John Bardeen—two-time Nobel laureate in physics—as his first graduate student and set up germanium semiconductor research.

After getting his PhD, Holonyak went to work at Bell Labs in Murray Hill, New Jersey. Under John Moll, he developed diffused p–n junction technology for silicon transistors. Holonyak was drafted into the US Army in 1955 and assigned to the Signal Corps at Fort Monmouth in New Jersey and then to Yokohama, Japan. During his duty in Japan, he often participated in informal technical seminars on germanium and silicon device technology with Japanese scientists and engineers.

After his discharge, Holonyak joined General Electric in Syracuse, New York, and began an investigation of the closed-ampoule vapor-phase transport growth of $GaAs_{1-x}P_x$ alloy semiconductors. He used his apparatus to make a small single-crystal sample and produce a diffused p–n junction for his studies of tunneling in III–V semiconductors. Many of the GaAsP alloys covered a region of compositions where the energy bandgap was direct. Holonyak developed the first visible red LEDs. He also identified the direct–indirect transition composition in those alloys.

In October 1962 Holonyak demonstrated the first alloy semiconductor laser diode, a $GaAs_{1-x}P_x$ diffused p–n junction emitting in the red spectral region at around 710 nm at 77 K. Those results established definitively that semiconductor alloys were not simple physical mixtures but had a defined bandgap energy—the first bandgap engineering. Today, III–V heterojunction devices with at least one ternary alloy layer are widely employed for several generations of novel devices that could not otherwise be realized.



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Holonyak was invited by Bardeen in 1963 to join the faculty at the University of Illinois. He was appointed a full professor in the departments of electrical and computer engineering and physics and established a small research laboratory to study III–V compound semiconductor materials and devices. He set it up in the Electrical Engineering Annex, one of the early buildings on campus. His group developed liquid-phase epitaxy and grew bulk crystals using the closed-ampoule approach to study various III–V alloys. In 1970 Holonyak and his students developed the first quaternary-alloy semiconductor, $Al_xGa_{1-x}As_{1-y}P_y$; such quaternaries are now widely used in many devices. Seven years later Holonyak demonstrated the first quantum-well laser diodes, composed of multiple thin layers about 50 nm thick of $In_{1-x}Ga_xP_{1-z}As_z$ quantum wells. Today every semiconductor LED and laser diode incorporates similar quantum wells.

From 1980 to 1990, Holonyak investigated various postgrowth processes that included impurity-induced layer disordering and the controlled oxidation of aluminum-bearing III–V alloys to selectively form stable native-oxide insulating regions inside a device structure. Today those innovative methods are used for the commercial manufacture of advanced laser diodes, including oxide-defined aperture for vertical-cavity surface-emitting lasers, which are used for energy-efficient high-speed optical data links in mega data centers, 3D sensing in smartphones, and new applications in autonomous vehicles and cryogenic computing.

Holonyak, with one of us (Feng), realized in 2003 that the photon energy from direct-bandgap transistor-base electron–hole recombination (spontaneous and stimulated) could be a new signal optical output in addition to the transistor collector current output. With quantum wells embedded in the base of heterojunction bipolar transistors, they demonstrated the first laser operation in a transistor in 2004. The transistor-laser-based integrated photonics technology could open a new front of inter- and intrachip optical data links and all-optical logic processors to alleviate the latency and overhead associated with massive data movement by today's network fabrics.

Holonyak's many pioneering semiconductor materials and device innovations underpin much of the technology supporting high-efficiency lighting, high-speed communications and information processing, and advanced solar-power systems used in space, laser processing systems, and lidar systems for autonomous vehicles. In his 50-year career at Illinois, Holonyak published more than 600 refereed technical articles and directed 60 PhD students, many of whom have made important contributions of their own to the field. The world is a brighter and safer place because of Holonyak's engineering contributions. He is missed by his students and many of his colleagues who knew or collaborated with him.

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