New York City's Times Square at night, 1934.

Source: Library of Congress

OSA Centennial Snapshots

Broadway Lights Inspire Innovation

PATRICIA DAUKANTAS

Edwin Land (left) first publicly demonstrated his landmark Polaroid instant-photography system at a 1947 meeting of OSA—but the stirrings of his entrepreneurial drive began two decades earlier, with an effort to produce a cheap polarizing filter to solve the problem of headlight glare.

OSA Historical Archives

During the height of the Roaring Twenties, New York's avenues blazed with cacophonous lights: red neon bulbs twisting themselves into advertising messages; flashing incandescent lamps swirling around theatrical marquees; broad automotive headlights swerving around pedestrians dodging their way through traffic; smooth store windows and street puddles randomly reflecting glare. Into this visual din stepped a college student nicknamed Din, temporarily blinded by the glare from oncoming cars, but permanently inspired by it.

The young Din—soon to be known at the U.S. Patent Office by his full name, Edwin Herbert Land—turned his obsession for improving

Before he dreamed up instant photography, OSA Honorary Member Edwin Land invented the first inexpensive synthetic polarizer. But that was only part of a larger mission.

vehicle headlights into a new kind of material for polarizing light. In the process, he swam against the tide of the increasing professionalization of U.S. science in the early 20th century and started his own industrial laboratory without bothering to graduate from college first.

Land took a serendipitous 19th-century discovery, the polarizing properties of iodine-based crystals, and combined it with 20th-century materials science to create versatile polarizing sheets. His invention brought new methods of exploiting polarized light to the optics laboratory and gave the young entrepreneur a financial footing, plus technical and business expertise, for even larger projects in the future.

An early fascination with science

Born in 1909 to a Connecticut businessman dealing in scrap metal and real estate, Edwin Land (who acquired his nickname Din from his sister) had an early fascination with science, garnered from books and his own experiments with kaleidoscopes and stereoscopes. Perhaps his greatest influence was the second edition of OSA Honorary Member R.W. Wood's textbook *Physical Optics*, which Land later said he read nightly, as some families might read the Bible. From Wood's writings, the young Land first learned about polarization, the Zeeman effect and the Kerr effect.

Though scientists had known about the polarization of light since the days of Erasmus Bartholin (1625-1698) and Étienne-Louis Malus (1775-1812), creating and manipulating polarized light in early-20th-century laboratories was still a bit of a challenge. One tool for doing so was the Nicol prism, invented by the Scottish geologist William Nicol in 1828, and consisting of a single parallelpiped of Iceland spar (calcite), cleaved at an angle of 68° with respect to the crystal axis and cemented back together. The Englishman William Hyde Wollaston had a few years earlier devised a similar device, which consisted of two orthogonal calcite prisms cemented together. These and similar prisms worked well in microscopes and other systems requiring a narrow beam, but not for designs requiring large, flat surfaces. The prisms were also expensive.

One summer at Camp Mooween, a nature and science camp for boys in Lebanon, Conn., counselor Barney "Cap" Girden showed the 13-year-old Land and other youngsters how to

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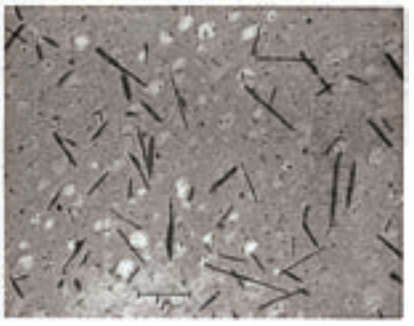
use a Nicol prism to reduce the glare off a table top. Land's fascination with the physics of light, especially polarization and photometry, increased. His conversation with another camp counselor—and a near-accident between the counselor's automobile and a farm wagon—got the young man thinking about car headlights and visibility.

Solving the headlight glare problem

In the fall of 1926, Land arrived at Harvard University, but he quickly grew frustrated with the life of an undergraduate. Already he was accustomed to independent thinking on nearly intractable problems. After only one term, he took a leave of absence.

Land traveled around the United States for a few months and ended up in Manhattan. Nominally he enrolled at New York University, but he was really spending most of his time deep inside the New York Public Library, searching for anything he could find about optical physics, especially about polarization. According to Land's biographer, Victor McElheny of the Massachusetts Institute of Technology (MIT), USA, the young dropout was walking down a New York street when he realized that reducing headlight glare would be a fine use of cheap polarizers—if only he could invent them. McElheny wrote that the headlight-glare problem was Land's "energizing principle" that gave him the "moral energy" to spend two decades searching for a solution.



Silver iodide replicas of (disoriented) herapathite needles in the J polarizer. (Electron micrography by C. E. Hall, MIT, 1949.)
J. Opt. Soc. Am. **41**(12), 957-963 (1951)

The way Land envisioned the glare-reducing system, an automobile's headlights would be covered with polarizers with their axes tilted about 45 degrees from the horizontal, and its windshield would contain similarly oriented polarizing material. "If you now consider two such cars, and if you imagine that one is turned around so that it faces the other, you see that the headlight polarizers of the approaching car are 'crossed' with the one before the driver's eyes," Land wrote many years later. The polarization of the windshield would block the glare from the oncoming vehicle, but the driver would still be able to see the rest of the roadway.

To make the system work, Land would need thin polarizing sheets wide enough to cover both the headlight lenses and the windshields. He could find no law of physics that would forbid the creation of a large, flat, inexpensive sheet of polarizing material. But no one had yet devised a recipe for one, either.

Herapath's crystals

Digging through the literature, Land discovered the work of William Bird Herapath (1820-1868), an English surgeon who had found an artificial polarizer of limited use. One of his students had added iodine to the urine of a dog that had been fed quinine and created some strange green crystals. Herapath played with the crystals under a microscope, noticed that they were dichroic, and spent the next decade trying to grow these crystals large enough to be used as a polarizer in a microscope. However, they were much too fragile and brittle for the task.

By the 1920s, scientists had not figured out a way to enlarge these crystals, now called herapathite, or to make them stick to something useful. An Austrian scientist had tried growing herapathite on a vertical glass plate, but the process took months.

At first, while working nights in secrecy in a Columbia University science laboratory, Land tried to repeat Herapath's attempts to grow large, thin crystals of the substance, iodosulphate of quinine. Faced with the same failure, Land decided to go in the opposite direction and figure out how to make submicroscopic crystals that he could somehow align and fix into position, resulting in a large polarizer.

In 1928, Land borrowed $5,000 from his father, who believed in his son's work but worried that the big companies would take it away from him. The younger Land used the money to hire an organic chemist, Dr. Joseph Friedman, and the pair worked in the senior Land's summer home on Long Island on various types of lacquers that could fix microcrystals in place. Land kept a ball mill running for a full month to grind herapathite crystals, mixed with nitrocellulose lacquer, to a fine enough size.

One day in the fall of 1928, a Columbia University professor let Land use a large electromagnet in the school's physics laboratory. The young inventor poured the suspension of herapathite crystals into a glass cylinder "about a half-inch in diameter and a quarter-inch in length," as he described it years later. Brownian motion oriented the particles randomly, so that the fluid appeared uniformly reddish black.

Next, Land turned on the electromagnet, which produced a field of about 10,000 gauss, and placed the glass cell into the field. He later recalled that "slowly and somewhat sluggishly the cell became lighter and quite transparent; when we examined the transmitted light with a Nicol prism, it went

from white to black as the prism was turned." Land called the confirmation of his hypothesis "the most exciting single event in my life."

Improving the new polarizer

To make his first solid thin-sheet polarizer, Land poured the herapathite suspension into a test tube and dipped a plastic sheet into the liquid. While the test tube was sitting in the magnetic field, he pulled the sheet out, leaving a coating of dispersed crystals on the sheet. He let the sheet dry while still in the magnetic field, thus preserving its polarizing capability.

A chalkboard in the laboratory proclaimed Land's underlying concern: "Every night 50 people will die from highway glare."

Land hypothesized that the herapathite crystals were about 1 μm long and a "small fraction of a micron in diameter," he wrote years later. However, he had no way to see the crystals until the late 1940s, when someone at MIT treated a sheet of Land's J polarizer with silver nitrite to replace the herapathite with silver iodide, which could be imaged with an electron microscope. Land found that the needles were indeed the size he had suspected.

Of course, to be a financial success, Land required a method for creating large amounts of polarizer rapidly. Fortunately, Land was operating in an era when industrial laboratories were pouring time and money into large-scale manufacturing methods for the latest synthetic materials, such as rayon, cellophane, nylon and neoprene.

Through much trial and error, Land wound up abandoning the use of electrostatic and magnetic fields for aligning the tiny crystals. Instead, he and his colleagues developed a viscous colloidal dispersion of the herapathite needles in cellulose acetate, which they extruded through long narrow slits to align the needles and form sheets. This product became known as the J polarizer. (Later, according to McElheny, a newspaper article would attribute this idea to Land's playing around with a sheet of rubber and a pencil.)

Now that Land had a potential product, he had to protect his intellectual property. Through his old camp leader Cap Girden, Land found Julius Silver and Donald Brown, two attorneys who would shepherd his patent and financial dealings for decades. Brown's firm filed Land's first U.S. patent application on 26 April 1929 and wrote him a letter of introduction to C.E. Kenneth Mees, director of the Kodak Research Laboratories.

During his research-and-development years, Land envisioned other uses for synthetic polarizers besides controlling automobile headlights. He imagined how sheet polarizers could be used to watch three-dimensional movies, and for a

OSA Centennial Timeline 1926-35

www.osa.org/100

OSA HISTORY

1928
OSA's First Medal is Endowed in Honor of Frederic Ives

1930
OSA Membership Hits 600

POLITICAL/ SOCIAL

1926
A Flight over the North Pole

1927
Metropolis Premiers; Lindbergh Crosses the Atlantic

SCIENCE/ ENGINEERING

1926
Schrödinger Publishes New Quantum Theory

1927
Heisenberg's Uncertainty Principle; Raman Scattering Observed

time in early 1928, he and a technician, Ernest Calabro, tried to build a Kerr cell out of semi-metallic mirrors for a different industry barely entering infancy: television. The headlight glare problem, however, remained uppermost in Land's mind.

The Land-Wheelwright Laboratories

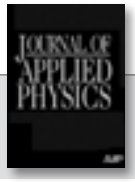
With his first patent proceeding through examinations and many of his technical problems solved, Land re-entered Harvard in the fall of 1929. By then, McElheny notes, most of his classmates had advanced to their senior year. Instead of throwing himself into a typical undergraduate lifestyle, though, Land married his sweetheart and lab assistant, Helen "Terre" Maisen, and they moved into an apartment near the campus.

Land continued to work on commercializing his polarizing technology. One of his physics instructors, John McCloud, possibly aided by a graduate student named George Wheelwright III, gave the undergraduate his own laboratory in Harvard's physics building. Wheelwright was Land's electricity and magnetism instructor, and the two became friends.

Land came to realize that some of the more prominent Harvard physicists, including department head Theodore Lyman and future Nobel laureate Percy Bridgman, did not quite understand what the enterprising undergraduate was doing in the lab. So on 8 February 1932, Land became the first Harvard undergraduate to address the weekly physics colloquium. While Land fielded a host of questions from faculty members, Wheelwright overheard some snide remarks from his classmates. Shortly thereafter, the pair decided to strike out on their own and go into business together.

By 1939, Polaroid was producing glasses, ski goggles, 3-D glasses, and dark-adapter goggles for the U.S. Army and U.S. Navy.
Polaroid Archives / Opt. Photon. News **7**(10)

In its first year, the Land-Wheelwright Laboratories moved three times, ultimately settling into a basement not far from the Boston Public Library. Land faced continuing challenges in his efforts to convert his polarizing films from laboratory experiments to reliably manufactured products. With his characteristic perseverance and capacity for total immersion in a problem, the young inventor threw himself into the slow migration to the extrusion method of



1931
American Institute of Physics is Formed

1932
OSA is Formally Incorporated

1933
Reviving the Colorimetry Committee

1929
Onset of Great Depression

1931
Japan Invades Manchuria

1933
Hitler Sworn in as German Chancellor

1929
Expansion of Universe Discovered

1932
First Image Transmitted Through Fiber

1934
Hale Telescope Mirror Poured

Source: (top row, from left) Wikimedia, OSA Historical Archives, Wikimedia, OSA Historical Archives, iStock / NASA; (center row) Wikimedia; (bottom row, from left) Wikimedia, iStock, NASA, iStock, Wikimedia

Even after instant photography brought him worldwide fame, Land remained fascinated with light polarization and his theory of vision.
J.J. Scarpetti

producing continuous sheets of film. According to author Christopher Bonanos, a chalkboard in the laboratory proclaimed Land's underlying concern: "Every night 50 people will die from highway glare."

In July 1933, Land received his first patent for his practical polarizing sheet. The automotive industry had done little on its own to reduce headlight glare, and several other scientists and tinkerers were pursuing their own ways to fix the problem. Indeed, the Westinghouse Electric Company's research director, Lewis Warrington Chubb, had tried to patent the notion of anti-glare polarizers for headlights, but he had not created a practical material for the task. Chubb and a couple of other rival-turned-partner inventors had contacts within the automotive and glassmaking industries, but Land now had the power of patent law behind him.

The arc of Land's life—from college dropout to American industrial icon—ultimately became the model for later dropouts such as Steve Jobs and Bill Gates.

As detailed in McElheny's biography, during the mid-1930s Land and his rivals were constantly negotiating with potential company partners that stood to profit from adding polarizers to automobiles. The Chubb alliance had grandiose plans that never materialized.

Birth of a household name

At some point, Land and Wheelwright realized that their sheet polarizers needed a proper product name. While discussing it with Land in 1934, Smith College art history professor Clarence Kennedy proposed "Epibolipol," evoking the Greek-derived biological term "epiboly," describing the spreading out of cells into thin sheets within vertebrate embryos. Fortunately for Land's future marketing teams, Kennedy also offered an alternate suggestion: taking "polar-" from "polarization" and "-oid," as in "spheroid" and "ovoid." Now Land had a striking brand name for his products: Polaroid.

Kodak—which, decades later, would lose a major patent lawsuit to Land and Polaroid—was the Land-Wheelwright Laboratories' first big customer. At the end of 1934, Land and Wheelwright shipped off their first batch of products to the Rochester, N.Y., company for $5,000—good money during the Great Depression. Kodak used the Polaroid material to make polarizing photographic filters.

Likewise, in 1935 the American Optical Company licensed Land-Wheelwright's polarizers to make sunglasses. In a display of marketing acumen, Land won over the American Optical executives by renting a Boston hotel suite, setting a goldfish tank in front of a large window, and demonstrating how polarizers could cut the blinding glare and allow people to see the fish. He had to rush to figure out how to laminate polarizing material to curved lenses, but he managed to do it in time for the "Polaroid Day Glasses" to go on sale in December 1936. Between the Kodak filters and the American Optical sunglasses, polarizers had made the leap from the laboratory to widespread public use.

Other large companies realized the value of Land's polarizing technology and tried hard to acquire the plucky little Boston laboratory; Kodak invited Land and Wheelwright to move their operation to Rochester. However, Land fought fiercely to maintain his financial and scientific independence.

In 1935, Land sent samples of his polarizers to the author of his favorite book: R.W. Wood, who served as president of the American Physical Society that year. The Johns Hopkins University professor wrote back that he had studied the polarizers thoroughly and encouraged the younger man to continue his research.

Legacy of the polarizers

Land, always a private man, ordered that his letters and papers be burned after his death. Fortunately for posterity, he described his early work on sheet polarizers in detail in several scholarly articles, including a paper published in the *Journal of the Optical Society of America* (JOSA) in December 1951 (the source of Land's direct quotes in this article). He wrapped up the JOSA article with a description of the glareless headlight system that he hoped would become a universal automotive feature.

That dream of Land's never came true, because all of the U.S. automobile manufacturers hesitated to buy into the idea. No company wanted to be the first to take the step of adding the technology to their cars, so the system never got off the ground. However, Land continued to pursue studies of glare and traffic for decades after his invention of the sheet polarizers.

Land's business, which he renamed Polaroid Corp. in 1937, went on to develop the Vectograph, a 3-D viewing method incorporating polarizing eyewear. During World War II, Polaroid provided the U.S. armed forces with the viewing equipment for stereoscopic aerial reconnaissance photographs, plus variable-density goggles and plastic optics.

Thus, Polaroid was already well established when Land dreamed up the idea for instant photography in the 1940s. Once again, he took a technology that had existed for more than a century, reshuffled its essential elements to fit inside a camera, and created not just a new product, but a whole new market for that product. Without the financial capital and the entrepreneurial know-how finely honed during Land's development of sheet polarizers, his instant camera might have remained a distant dream.

The arc of Land's life—from college dropout to American industrial icon—ultimately became the model for later dropouts such as Steve Jobs and Bill Gates to wreak massive, disruptive changes on the computer industry. Jobs, especially, idolized the Polaroid founder during the 1970s and consciously shaped both his career trajectory and his company's well-branded product ecosystem along similar lines to Land's.

Modern smartphones are indirect beneficiaries of Land's early work in thin-film polarization.

iStock

Land once stated his belief that, in the era of instant photography, a camera would become something that people would use all day, every day. In today's digital world, of course, people rely on super-miniaturized integrated circuitry, not chemistry and paper, to capture their images. Ironically, thin-film polarization enables the brilliant liquid crystal displays on modern smartphones. Land, who died in 1991, would have been pleased to see how hundreds of millions of people are using a distant descendant of his first product all day, every day. OPN

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