Robert L Fleischer

ROBERT L. FLEISCHER

1930–2011

Elected in 1993

"For contributions to the development and diverse applications of high-temperature materials, solid solution hardening, and etched particle track detectors."

BY JAMES D. LIVINGSTON AND ELIZABETH L. FLEISCHER

ROBERT LOUIS FLEISCHER, a leading researcher in materials science and engineering for many years, died March 3, 2011, at age 80 of cardiac amyloidosis, a rare heart disease with no known treatment or cure.

Bob was most notable for the extremely wide range of scientific and engineering fields impacted by his work. He made significant contributions to understanding of the mechanical strength of metals, alloys, and high-temperature materials, but he is most widely known as a pioneer in the study of etched particle tracks in solids. These etched tracks not only served as a new and useful method of detecting nuclear radiation, but found widespread applications in a host of fields, including nuclear physics, cosmic ray physics, dating of minerals and archaeological artifacts, lunar science, radon dosimetry, and filtration.

Bob was born in Columbus, Ohio, on July 8, 1930, the second son of Rosalie Kahn and Leopold Fleischer. He was only nine when his father died, so he was raised mostly by his mother. After graduating from Columbus Academy, he studied engineering and applied physics at Harvard University, receiving his AB in 1952, his AM in 1953, and his PhD in applied physics in 1956. While at Harvard, he met and married Barbara Simons, a love match that lasted throughout his life.

Bob's doctoral research at Harvard was under Bruce Chalmers, a British physical metallurgist who had recently arrived at Harvard and was an expert in the solidification and deformation of metals. Bob's thesis research introduced him to the study of the mechanical properties of metals, a subject that interested him throughout his career.

The plastic deformation of metals and alloys occurs by the motion of linear crystal defects called dislocations, and one source of strengthening in pure metals is the interaction of dislocations with the boundaries between adjacent crystals, commonly called grain boundaries. Bob's thesis involved the growth by directional solidification of aluminum bicrystals, samples that contained only one grain boundary. This approach enabled detailed study of the effect of a single grain boundary on the strength of metals and led to his first published paper.

His first position after Harvard was assistant professor of metallurgy at the Massachusetts Institute of Technology, where he served from 1956 to 1960, when he became a staff physicist at the General Electric Research Laboratory in Schenectady.

GE was his home base for 32 years, during which he also served as a senior research fellow in physics at the California Institute of Technology (1965–1966), adjunct professor of physics and astronomy at Rensselaer Polytechnic Institute (1967–1968), visiting lecturer in geophysics at the University of Western Ontario (1968), visiting scientist at the National Oceanic and Atmospheric Administration and National Center for Atmospheric Research (1973–1974), adjunct professor of mechanical engineering and applied physics at Yale (1984), and adjunct professor in geological sciences at SUNY-Albany (1981–1987).

After retiring from GE in 1992, Bob was a research professor of earth and environmental sciences at Rensselaer until 1997, when he became a research professor of geology at Union College in Schenectady. These appointments in different departments at so many different organizations provide testimony to the wide breadth of his research.

His research at MIT and his first years at GE focused on solution hardening, analyzing the strengthening of alloys by the interaction between dislocations and alloying elements. Differences in size and compressibility between alloying atoms and the dominant atoms of the metal produce localized internal stresses in the crystal lattice that interact with the stress fields of dislocations, interfering with dislocation motion and thus producing hardening. His research gained recognition in the field, and the term "Fleischer hardening" is still used to refer to some of his specific contributions.

In the late 1980s Bob returned for a few years to the study of mechanical properties of materials, this time with a focus on high-temperature properties. The efficiency and total thrust of a jet engine increase with peak temperatures of operation and current limits are set by the thermal constraints on materials. Nickel-based "superalloys" largely derive their high-temperature strength from an intermetallic compound, nickel aluminide (Ni_3Al). A variety of other intermetallic compounds have been considered for high-temperature applications, and Bob's major contribution to this field was to assemble and edit a four-volume compendium on what is known about these compounds and their properties, particularly their mechanical properties at high temperatures. This series, *Intermetallic Compounds* (with Jack Westbrook; Wiley, 2000), became the major source of information about these important and promising materials.

Although Bob's contributions to mechanical properties of materials were significant, he became best known for his work on nuclear tracks in solids, a topic he worked on from 1962 until his death. Two of his colleagues at General Electric, P. Buford Price and Robert M. Walker, had discovered the etching of nuclear tracks in mica in 1961, and invited Bob to join them in this promising new field.

Paths of nuclear particles had much earlier been detected in cloud chambers, where, traveling through supersaturated gas, such as moist air, the particles produce a trail of tiny droplets. Later the bubble chamber was developed, in which nuclear particles traveling through a liquid close to boiling produced lines of bubbles. To these established techniques for nuclear track detection, cloud chambers and bubble chambers, the work of Fleischer, Price, and Walker added etched particle tracks in solids. Their pioneering work, summarized in their coauthored book *Nuclear Tracks in Solids: Principles and Applications* (University of California Press, 1975), generated widespread interest in laboratories around the world, which in turn led to many international conferences on the subject.

Traveling through solids, high-energy nuclear particles produce a wake of displaced atoms that has higher energy than the surrounding material, making the track susceptible to preferential removal by chemical etching. The etched track has the advantage that it is permanent and can be enlarged to become visible in an optical microscope. Bob and his colleagues rapidly found that the ability to etch nuclear tracks in solids was not limited to mica but could be applied to numerous minerals and even to many glasses and plastics. This greatly widened the applicability of the technique.

Bob summarized the many applications of etched nuclear tracks in solids in a popular-science book, *Tracks to Innovation: Nuclear Tracks in Science and Technology* (Springer, 1998). He describes many other uses of etched nuclear tracks in science and technology, including nuclear physics, neutron dosimetry in nuclear technology and radiobiology, even earthquake prediction and the use of filters to remove yeast particles from beer. And in a characteristic Fleischer pun, he wrote that in embarking on a study of etched nuclear tracks, which are essentially linear holes, he and Price and Walker embarked on a "holey" quest.

Etched tracks proved particularly powerful in studies of cosmic rays, which are fast-moving nuclei of extraterrestrial origin. Sheets of plastic detectors were sent aloft in high-altitude balloons, and the varying speed of the nuclei through the plastic led to variations in the length and shape of the etched tracks that produced information on the charge and energy of each nucleus, allowing identification of each. Most cosmic rays observed in these experiments originated outside the solar system, but plastic and glass track detectors sent to the moon with Apollo 16 generated considerable information on particles associated with solar flares. Tracks produced by cosmic rays have also been studied in numerous minerals, meteorites, moon rocks, and glass from a Surveyor moon lander brought back by Apollo 12.

At a NASA meeting in Houston, Bob was fascinated to learn that the space helmets worn by the Apollo astronauts were made of Lexan polycarbonate, which had been established as a well-calibrated detector of cosmic rays. He obtained several helmets from the Apollo 8 and Apollo 12 missions to determine what doses of heavy high-energy particles the astronauts had been exposed to. From the shapes of some of the tracks, it was clear that several of the particles came to rest as they were leaving the helmet, i.e., after traversing the astronaut's head. Reporting these results, he announced that they now had exact quantitative evidence on what was "going through the minds" of the astronauts during their missions. This was a clever play on words, but not all the astronauts appreciated this particular example of Bob Fleischer humor.

Nuclear track etching has also found wide use in fission-track dating. The spontaneous fission of uranium-238 produces etchable fission tracks in many solids, with the density of tracks depending on both the age of the sample (time since it last cooled) and the concentration of uranium. The latter can be determined from slow-neutron irradiation of the sample, which produces fission of uranium-235 and new etchable tracks. This dating technique has been used with a wide variety of minerals and archaeological specimens, including a tool used by early humans.

One of the most widespread practical uses of nuclear track etching is for the detection of radon. Radon (a radioactive daughter of uranium-238) and its own radioactive daughters (which include lead, bismuth, and polonium atoms) produce alpha particles (helium nuclei) whose tracks can be revealed in plastic track detectors. Because these alpha particles can be dangerous to health, radon track detectors are commonly used to determine long-time exposure to radon in homes and elsewhere. Radon detectors had originally been used by Terradex, a spinoff company from GE, in exploration for uranium ores, but this business has declined while their use for health protection has risen.

Radon also produces nuclear tracks in glass, and in one of Bob's final research programs at Union College, he studied the use of common eyeglasses as a measure of long-time radon exposure. Once a family member, talking with him about the various things he had done with his life, asked him when he felt most in his element. "Radon is my element," he said.

Bob continued close collaboration with Walker and Price after they left GE. Their seminal 1960s work on etched particle tracks had a huge impact around the world. Later he worked closely with other GE colleagues, including Howard Hart and Antonio Mogro-Campero, on nuclear tracks. He coauthored papers with as many as 50 GE colleagues and with more than 60 collaborators from elsewhere.

Bob received many awards for his research, including in 1971 the US Atomic Energy Commission's prestigious E.O. Lawrence Award. While most awardees attend such occasions with their wives, Bob was accompanied not only by his wife Barbara but also by 10 others of his extended family. His was a very close family.

Among his many other honors were NASA's Exceptional Scientific Achievement Medal and the American Nuclear Society's Special Award for Distinguished Service in the Advancement of Nuclear Science. He received a Golden Plate Award (1972) from the American Academy of Achievement and was presented with GE's R&D Center's Coolidge Fellowship Award, GE's highest scientific award. He was elected to the NAE and the American Academy of Arts and Sciences and was a fellow of the American Physical Society, American Geophysical Union, American Society of Metals, and Health Physics Society.

In addition to over 350 published papers, Bob had 19 patents and received three IR-100 awards from *Industrial Research Magazine* for his technological contributions. His work led to two spinoff companies, Nuclepore, which utilized etched particle tracks to produce filters, and Terradex, which used etched particle tracks to detect radon.

Turning to Bob's private life, he left daily love notes for his wife Barbara whenever he left for work. He lived a life of love—and humor, teaching his children never to take anything too seriously. Both daughters ended up going into science, not because Bob urged them to but because they observed first-hand how much pleasure he took in his work.

As he described in one of his later writings, Bob's studies "continue to provide new adventures and undiminished intellectual stimulation." At the same time, he maintained a healthy balance in life, always arriving at home for dinner before 6:00. He read widely, biked to work when the weather was good, and swam at lunch when it wasn't.

Among those speaking at Bob's memorial service was his long-time friend Ivar Giaever, Nobel Laureate in physics. He recalled a friendly bet with Bob at a weekend lakeside party. Bob tied himself to a small boat and swam in one direction while Ivar, in the boat, rowed in the other. To Ivar's great surprise, it was quite a battle, and most spectators concluded that Bob had won. Those many lunchtime swims had made him a very strong swimmer.

Bob is survived by his brother Richard, his wife Barbara, daughters Cathy and Elizabeth (Betsy), and grandchildren Allison and Daniel. He will be remembered not only for his many contributions to science and technology, but also for his loving, humor-filled, and warmhearted approach to life.

We are pleased to acknowledge the assistance of Barbara, Cathy, and Bob's colleagues Howard Hart and Buford Price in preparing this memorial.