THOMAS R. ANTHONY

1941–2017

Elected in 1990

"For outstanding application of diffusion phenomenology to the development and fabrication of materials and devices."

BY RICHARD ALBEN, SLADE CARGILL, AND FRANS SPAEPEN

THOMAS RICHARD ANTHONY, a prominent materials researcher at the General Electric Research & Development Center (now GE Global Research) for more than 36 years, died December 12, 2017, at the age of 76. Throughout his career, he demonstrated the importance of fundamental scientific understanding to the development of new processes and products.

Tom was born in Pittsburgh in 1941. His father Harry was a professor at the Carnegie Institute of Technology, and his mother Evelyn was a secretary. He attended Shady Hill Academy, where he excelled in both academics and wrestling. He graduated in 1962 from the University of Florida with a BS in physics and mathematics and was accepted to the graduate program of the Division of Engineering and Applied Physics (DEAP) at Harvard, where he earned an MS and PhD in applied physics.

At the time, David Turnbull had just joined the DEAP faculty after 15 illustrious years at the GE Research Laboratory, where he laid the foundations of current understanding of the kinetics of phase transformations in condensed matter. He was delighted to take Tom as a student and suggested that he work on an intriguing aspect of solid-state diffusion.

In his GE days, Turnbull had explained the remarkably fast diffusion of copper atoms in germanium by demonstrating that they could move interstitially between the host atoms in the open covalent structure. Similar observations were made for the silicon host, and there were indications that the same would hold even for metallic group IV hosts, such as tin and lead.

In his thesis work, Tom demonstrated fast diffusion of a range of noble metals (copper, silver, gold) in several polyvalent metallic hosts (lead, tin, indium, thallium, cadmium), and helped develop the understanding that interstitial motion was possible here because of the relatively small size of the host atom ion cores in a large sea of valence electrons. His research laid the groundwork for many years of work on fast diffusion in Turnbull's group.

In graduate school Tom had toyed with the idea of becoming an astronaut. In the end, he decided that the military-style regimentation of such a career was not for him. Instead, he joined GE Research & Development and, with his wife Angela, whom he had met at Harvard, moved to Schenectady, New York.

Throughout his long career at GE, Tom's approach to research remained firmly rooted in the fundamental materials science he had learned from his mentor: think deeply about the problem at the atomic level, create a clean physical model, and design simple experiments to test that model.

His early work, with Harvey Cline, was a comprehensive study of the thermomigration of liquid droplets through solid crystals. When such a droplet is placed in a temperature gradient, the solubility of the matrix atoms in the liquid is greater at the hot end than at the cold one: the atoms at the hot end dissolve into the droplet, diffuse down its length, and plate out at the cold end. As a result, the droplet moves up the gradient through the crystal.

The Anthony-Cline team explored this phenomenon for a variety of systems, such as brine in salts and liquid metals in semiconductors. Their work was an exemplary combination of experimental design, critical observation, careful measurement, and elegant modeling based on fundamental thermodynamics and kinetics. They came to understand in detail the morphologies of the droplets, the rate-controlling factors, and the effects of crystal defects and how to deal with them.

The metal-semiconductor work had practical implications for electronic device processing. By sending a p-dopant, such as aluminum, through n-doped silicon, it became possible to create a long, narrow columnar p-n junction throughout a thick wafer. They used this to create, for example, deep-diode arrays for radiation detectors that combined the high resolution of thin shallow-junction detectors with the high sensitivity of thick shallow-junction detectors. Their work resulted in multiple patents and a business that was sold to AT&T in 1979 for almost $10 million.

During the latter part of his career, Tom worked on the synthesis of diamond. GE had a longstanding interest in this material, going back to its pioneering of high-pressure, high-temperature synthesis in the 1950s. Since then there had been progress elsewhere in the low-pressure synthesis of diamonds by chemical vapor deposition (CVD) from carbonaceous vapors, and in 1984 Tom was asked to head up an effort in this area at GE. In characteristic fashion, he delved deeply into the atomistics of carbon incorporation on a growing diamond surface. He developed a comprehensive understanding of the importance of atomic hydrogen and was the first to appreciate its role in the establishment of a minimum in the temperature-dependence of carbon solubility in the gas phase, which turns out to be the optimum substrate temperature.

One of the signature results of that effort was the production of isotopically pure ^{12}C and ^{13}C gem-quality diamonds, which have record-high thermal conductivity and can be used, for example, to make the most damage-resistant high-power laser windows. The synthesis technique consists of making a CVD diamond deposit from isotopically enriched methane, crushing it, and using the powder as the feed material in seeded high-pressure, high-temperature growth. The CVD diamond work resulted in numerous patents as well as several new businesses.

At the end of his career, Tom held 168 patents, one of the highest in the history of GE. In 1978 he became a GE Coolidge fellow, the company's highest research distinction. In addition to his election to the NAE, he received 25 major honors, among them top awards from the professional societies; he was the inaugural Turnbull Lecturer of the Materials Research Society (1992), and received the McGroddy New Materials Prize from the American Physical Society (1999) and the Thornton Award of the American Vacuum Society (1992). He was very much in demand as a speaker and as a teacher of short courses on diamond synthesis.

After he retired in 2004, Tom had time to cultivate his many other interests, from nutrition and exercise to investing and technology. For the last decade of his life, he ate a plant-based diet and became a long-distance cyclist. He contributed to the design of an elliptical bicycle developed by an Australian company, leading to his last patent, issued in 2017. He was also an active musician who played the piano, violin, classical guitar, and even the bagpipes.

Tom leaves his wife Angela, daughter Wendy, and son Jason, all in Saratoga Springs, NY. He will be remembered for his intellectual brilliance, for his tenacity and discipline, and for his unwavering focus on the importance of fundamental science to the success of industrial research.