GALENA: THE FIRST SEMICONDUCTOR

Galena [lead sulfide, PbS] is mineral with unusual collector interest. It is valued mainly for its beautifully formed cubic or modified-cubic crystals, metallic luster, lead-gray color, high specific gravity of 7.4-7.6, and perfect, three-directional cleavage. Galena has added interest because it has always been the primary ore of lead. Yet another point, one not often remembered in our modern age of solid-state electronics, is that galena was the world's first semiconductor.

A favorite science project for youngsters through the 1950s was building crystal-radio sets. All that was needed was a basic interest in science, a readily available schematic diagram, some copper wires, and a cheap, carbon-particle earphone. The key component, which scientific-supply houses sold for a dime, was a crystal of galena. This tiny, cubic galena crystal had the seemingly magical ability to modify complex electrical microcurrents and act as a semiconductor to isolate the particular wave component that carried the audio portion of broadcast radio waves.

Semiconductors—solid materials with levels of electrical conductivity tht ranged between those of conductive metals like copper and nonconductive insulators like glass—were first studied in the 1830s. The mystery surrounding semiconductors began to unravel in 1874 when German physicist Ferdinand Braun (1850-1918) observed that electrical resistance in metal-sulfide crystals varied with the direction of current flow. Concentrating on galena, Braun found that the current modification was greatest when one of the connecting electrodes was a pointed wire. By discovering the so-called "point-contact electrical-rectifier effect," Braun had also invented the first crude semiconducting device.

But Braun's discovery had no practical application until the early 1900s, when American scientist Greenleaf Whittier Pickard (1877-1956) learned that semiconducting galena crystals could detect radio signals amid electrical currents—knowledge that led directly to the development of the first radio receivers, fittingly known as "crystal sets." These simple devices consisted of a wire aerial, a tuning circuit composed of two concentrically positioned wire coils, an earphone, and a "detector." The detector was a cubic crystal of galena measuring about one-quarter inch on a side. Detection of the usable audio portion of the microcurrent was accomplished by touching a thin, flexible copper wire, fittingly called a "cat's whisker," across a face of the galena crystal until the audible signal was loudest.

The beauty and magic of the crystal set was its material simplicity. It could be built for pennies and required no outside electrical power. Its power—less than one-thousandth of a watt—came from the microcurrent that the electromagnetic energy of the broadcast radio wave induced in the aerial. During the 1920s and especially during the subsequent Depression years, millions of people built and used crystal sets, tuning into countless "free" hours of music, news, and entertainment, all made possible by that tiny cubic crystal of galena.

Science was then only beginning to understand what really happens when electrical current passes through galena crystals. Galena and most other metal sulfides form anisotropic crystals—crystals that exhibit different values of conductivity along different crystal axes. Broadcast radio waves induce alternating current, which is a complex current that flows back and forth in a circuit from which separating an audio component is difficult. But a galena crystal rectifies this alternating current by allowing it to pass in only one direction, in effect converting it to direct current. The crystal's directionality also separates the current into its specific wave characteristics which, in current induced from a broadcast radio wave, includes the audio component.

Galena's chemistry and crystal-lattice structure is the key to its ability to rectify alternating current. The galena lattice consists of a repetitive sequence of lead and sulfur atoms. Theoretically, a pure galena crystal consisting only of lead and sulfur would just function as a weak electrical conductor. But galena is never pure and contains traces of other elements such as silver, copper, and zinc. These impurities create either an excess or a deficiency of free electrons in regular places throughout the crystal lattice. These points act as electron "traps" that permit a dominant electron motion in one direction only.

Knowledge derived from the study of the electrical properties of galena has resulted in the discovery of such semiconducting materials as germanium, gallium, and silicon, and the development of such modern semiconducting devices as solid-state and light-emitting diodes, transistors, diacs, and triacs, all of which are essential to everything from computers to cell phones. And it all started in crystal radio sets with those tiny cubic crystals of galena.

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Steve has worked with the Mineral of the Month Club since 2002. As a former hardrock miner, he has mined Colorado molybdenum, Alaska gold, Arizona copper, and Wyoming uranium. Eight of his ten books deal with topics of minerals, mineral collecting, mining, and gemstones. He has written more than 1,000 articles and is a contributing editor and science columnist with *Rock & Gem* magazine. His work has also appeared in *The Mineralogical Record* and *Lapidary Journal*. He is a former member of the board of directors of the National Mining Hall of Fame & Museum