Phosphors

Certain solid materials can absorb energy from x-rays, ultraviolet light, or high-energy particles, then re-emit the energy as visible light. Such "phosphors" are used in fluorescent lamp bulbs, electroluminescent lamps, and television screens. Without phosphors, I would not be able to see these words as I type them on my computer screen.

Scientists had known for some time that certain minerals were capable of giving off visible light when excited by other forms of radiation. Then, in 1801, Johann Wilhelm Ritter, a physicist in Germany, discovered that some materials luminesce brightly when exposed to light from the invisible spectral region beyond violet; Ritter was thus the first to discover ultraviolet radiation. The term *fluorescence,* first used in 1852, was derived from the mineral fluorospar, which emits a violet light when exposed to ultraviolet radiation.

In 1859 in France, Alexandre Edmond Becquerel described a fluorescent lamp he had produced; more than a century earlier Benjamin Franklin had described the principle on which it was based—that the luminescence of lightning is caused by electric discharge through the atmosphere. In 1860, the Royal Society of London observed an electric discharge lamp that excited rarefied carbon dioxide gas into producing a brilliant white light.

Chemists began to search for practical solid materials to be used as phosphors. The first phosphor synthesized was barium sulfide, but this material had low luminance efficiency and decomposed quickly into hydrogen sulfide and other components when exposed to moist air. By 1866, the first stable phosphor of zinc sulfide was produced by heating zinc oxide in a stream of hydrogen sulfide. In 1870 a preparation of calcium sulfide, called "Balmain's Paint," became the first commercially available phosphor.

In 1887 it was discovered that chemically pure samples of these sulfide phosphors do not fluoresce; only those that contain small impurities of an "activator" metal do. Activators, first studied in 1890 by the physicist Philipp Anton Lenard in Germany, are ions surrounded by host crystal ions, which form luminescing centers for the phosphor's excitation-emission process. A mere trace of the activator must be present, and evenly distributed, or else the luminescing centers will cancel each other out. Activators enhance the light-producing properties by many orders of magnitude and also determine the color of the emitted light. Zinc sulfide, for example, can be activated by copper, silver, or gold, yielding a variety of colors.

If prepared with appropriate activator impurities, other materials, such as certain silicates, borates, phosphates, or metal oxides, can become phosphors. For instance, when activated by magnesium ions, zinc silicate, zinc and cadmium borate, and zinc beryllium silicate become efficient phosphors, emitting in the red to green region. Other phosphors commonly used in fluorescent lamps are tungstates, phosphates, and halophosphates of zinc, calcium, and magnesium.

Fluorescent lamps operate on a simple principle. If the inside of a glass tube is coated with a thin film of phosphor, then filled with a gas through which an electrical discharge is passed, the ultraviolet light from the gas discharge provides energy to make the phosphors shine in visible light. Though this was known from Becquerel's work in 1859, the first widespread use of fluorescent lighting did not occur until almost seventy years later.

Fluorescent lighting was first used for advertising in Europe in 1925, though experiments to apply the principle for practical interior lighting did not take place until a decade later in the United States. These very successful experiments allowed for commercial introduction of low-voltage fluorescent lamps three years later. In 1939 only straight tubular designs of fluorescent lamps were available, and only in 15-, 20-, 30-, and 40-watt sizes. Two decades later, more than 45 sizes and shapes of fluorescent lights were commercially available—straight, curved, and dented, and ranging from 4 to 204 watts.

A similar principle was used in the first "electroluminescent" lamp in 1936, which produced light by the excitation of zinc sulfide phosphors directly from an electric field, rather than from ultraviolet light created by the electric field. Georges Destriau constructed a lamp that sandwiched the phosphor and its activators between two electrically conductive plates, one of which was transparent. Depending on the frequency of the AC electrical current, the light from an electroluminescent lamp can be pink, blue, yellow, or green, while the brightness depends on the voltage. Unfortunately, the luminance of these light sources is low and progress has not been rapid. After two decades of development, researchers can create sources of no more than 10 to 12 lumens.

Many materials—ruby, diamond, crystal phosphors, and certain platinum salts—fluoresce under the impact of accelerated electrons, formerly called "cathode rays." The viewing screen of an oscilloscope constructed in 1897 made use of this "cathodoluminescence."

A monochrome screen is coated with a fine dispersion of two phosphors, usually silver-activated zinc sulfide (blue light) and silver-activated zinc cadmium sulfide (yellow light). This coating is sealed on the back of the curved tube with a film of aluminum thin enough for the bombarding electrons to pass through it; the aluminum coating also provides a mirror surface that reflects light toward the viewer and prevents backward-emitted light from being lost in the interior of the tube. Similar screens are used in radar systems, computers, and electron microscopes.

A color television operates on the same principle, but uses a combination of three colors of light—red, green, and blue. Silver-activated zinc sulfide emits the blue light; magnesium-activated zinc orthosilicate emits green light; europium-activated yttrium vanadate emits red light. In appropriate combinations, dots of these three colors of light can simulate any range of colors.

Crystalline phosphor materials are also used as scintillation counters in investigations of cosmic rays and other elementary particles. In 1980, physicists discovered that alpha particles bombarding solid zinc sulfide or cadmium sulfide produce tiny flashes of light. In a scintillation detector, a large transparent block of phosphor is attached to a photomultiplier tube, so that when a high-energy particle passing through the system causes the phosphor to scintillate, the photons are detected. Scintillation detectors use transparent crystals of organic fluorescent materials such as naphthalene (which was the first used) or anthracene (currently, the most commonly used material). Inorganic phosphors used in scintillation counters include sodium iodide activated with thallium, as well as calcium tungstate and cadmium tungstate.

New phosphor materials and new activating impurities are being developed to provide an even wider range of colors and efficiencies in emitted light. Computer screens, televisions, and scientific instruments make use of this broader palette in our daily lives.

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