Our Featured Division

Luminescence and Display Materials Division

The Luminescence and Display Materials Division

by David J. Lockwood

Luminescence can be broadly defined as the generation of light in excess of that radiated by thermal means. Since ancient times, human interest in and a long fascination with phosphorescence or luminescence originated from the mysterious fact that an apparently invisible power source could somehow produce observable light. Today, the phenomenon is generally well understood and the commercial applications of luminescence are ubiquitous, with light emitting materials being widely deployed in common commodities such as lamps, television screens, and computer and cell phone displays.

Luminescent technologies are usually categorized by the method of excitation (the "invisible power source"). These classifications include excitation by light (photoluminescence or PL), by electrons in a vacuum (cathodoluminescence or CL), by electrons in a solid (electroluminescence or EL), by chemical change (chemiluminescence), by sound waves (soniluminescence), by heat (thermoluminescence or TL), and by X-rays. Photoluminescent phosphors are used, for example, in fluorescent lamps while cathodoluminescent materials are employed in high-voltage television and computer display tubes. In electroluminescence, the application of an electric field across a phosphor or semiconductor diode contained within a suitable film structure results in the conversion of electrical energy directly to light: This technology allows the production of high-brightness flat displays or laser light sources. X-ray applications involving luminescent materials include, for example, image converters for medical diagnostic purposes.

Within The Electrochemical Society, the Luminescence and Display Materials (L&DM) Division provides a forum for research and development work on the physics and chemistry of light generation and the industrial technology of light-emitting devices. Similar to other Divisions, our bylaws state that the purpose of the L&DM Division is to encourage communica-

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tion, publication, research, and education in the science and technology of luminescence and display materials, as well as to advance the purposes of the Society in general. This is a broad mandate and thus a variety of physical processes and materials plus numerous applications are included in the Division's range of interests. Such interests have varied widely over the years, starting right from the beginning of the Society.[1–3]

As early as 1903, W. J. Hammer described, in the *Transactions of the American Elecrochemical Society*, a number of methods of producing light. He mentioned an Edison "X-ray lamp," which was an early version of the present cathode ray tube. Different phosphors such as $CaWO_4$, ZnS and $ZnSiO_3$ were bombarded by an electron beam and produced light. Various organic and inorganic luminescent materials were shown to emit light of different colors. In 1905, E. Weintraub discussed in the *Transactions*, the conductivity of metallic vapors and the resulting luminescence, and C. Baskerville reported in 1906 on the use of ultraviolet (UV) excitation for studying the fluorescence of thousands of minerals and compounds.

In the early 1900s, Thomas Edison and E. L. Nichols decided that "unless someone discovers a means of making luminescent bodies that are vastly brighter than the best known now, luminescence may be excluded altogether as a factor in artificial lighting." However, in the mid-1930s a small group of innovative engineers at the General Electric Company (GE) coated linear incandescent lamp tubes with a ground-up mineral phosphor (willemite), evacuated the tubes, dosed them with a small amount of mercury, filled them with a few torr of argon gas, and sealed the ends with electrodes. Thus, in 1933, GE introduced the first commercial mercury fluorescent lamps.

In the 1930s a Section of the new Electronics Division of The Electrochemical Society was formed for those interested in luminescence. This was the time when the systematic search for and development of synthetic phosphors began, spurred on by the invention of the fluorescent lamp and the later need for new phosphors for radar screens. Not surprisingly, in the 1930s and 1940s, the Luminescence Section was possibly the most active Section in the Electronics Division, although it was still small compared to the more traditional Divisions of the Society.

From about 1948 on,[1,3] luminescence papers appeared frequently in the *Journal of The Electrochemical Society*. In 1949, for example, 26 papers dealing with different aspects of luminescence appeared. These included significant papers by K. H. Butler, who characterized the zinc berylium silicate phosphors that made white fluorescent lamps possible; F. A. Kroeger and J. E. Hellingman, who described the zinc sulfide phosphors activated with silver and copper that are still used today in color television and display tubes; and H. A. Jenkins, A. H. McKeag, and P. W. Randby, who presented a definitive characterization of the alkaline earth halophosphate phosphors that became the standard white emitting phosphors for fluorescent lamps.

These series of papers also set the scope of the Luminescence Section: the discovery of new phosphors, their synthesis and characterization, their excitation mechanisms, their emitted wavelengths with different activators, their efficiency, and their applications. The physics and chemistry of luminescent materials and their applications became, and still is, the core subject area covered by the Luminescence-Section/L&DM Division symposia.

The first ECS symposium dedicated to luminescence was organized by M. E. Fogel and was held in 1945 at a regional meeting of the Metropolitan New York Section. (There were no general Society meetings that year, because of the Second World War.) Eight papers were presented by some of the most prominent names in the history of luminescence. Fluorescent lighting was the big topic in those days, with five of the papers dealing directly with that subject. The fact that companies such as RCA, GE, Sylvania, and Westinghouse contributed significant papers established the Society as a forum in which established scientists in luminescence found it valuable to present their results to their peers in other companies.

The second symposium on luminescence was held at the 1947 spring meeting held in Louisville, Kentucky. The contributing authors were A. E. Hardy, H. C. Froelich, K. H. Butler, and A. Bramley. Bramley's paper was the first published discussion of aluminized phosphor screens. The first participation by a university professor was in 1948, when R. Ward of the Polytechnic Institute of Brooklyn presented a paper on the infrared sensitive phosphors of doubly-activated alkaline earth sulfides and selenides. The energy stored by the phosphor as a result of UV excitation is released upon subsequent infrared stimulation. The emission spectrum is governed by one of the activators, while the infrared excitation spectrum is governed by the other impurity. The effect is called photo or optically stimulated luminescence. This paper was the first published in the *Journal* on energy storage and retrieval by infrared radiation, although the subject itself dates from the 1890s.

These first symposia have been followed by many others over the years and between 1952 and 1998 almost 2300 papers in total have been presented in L&DM Division (or predecessor) sponsored symposia at Society meetings. Society symposia form an even more important venue today for the exchange of information among luminescence aficionados.

In the 1950s and 1960s, with the invention of the transistor and the silicon chip, the Electronics Division grew rapidly while the Luminescence Section remained roughly constant in size. At this time its symposia and published papers dealt mainly with improvements in phosphors, such as the halophosphates and television phosphors, and their manufacture.

In the 1970s, when it was generally believed that phosphors were about as efficient as they could possibly be, J. Verstegen, D. Radielovic, and L. E. Vrenken announced in the *Journal* a new set of rare-earth activated aluminate compounds. These improved both the color rendition and efficiency of fluorescent lamps and made compact fluorescent lamps possible. Also, with greatly improved X-ray phosphors, X-ray storage devices and scintillation counters for computer-aided tomography became a reality.

In 1982 the Luminescence Section emerged from the Electronics Division and became the Luminescence and Display Materials Group. The L&DM Group consisted mostly of people working on luminescence in the industries that had sprung up to produce phosphors for lamps, displays, and X-ray equipment. The Group activities continued in areas dealing with the physics and chemistry of phosphors and began to expand into other areas including sensors, imaging, non-linear optics, photonics, and excitonics. Symposia on luminescent related topics were co-organized with other Society Divisions.

In 1991 the L&DM Group applied for Division status within the Society, which was granted and resulted in the formation of the Luminescence and Display Materials Division in 1993. At this time the Division was holding successful symposia in the areas of the physics and chemistry of luminescent materials and various luminescence applications. Luminescence was undergoing another renaissance with renewed interest in colored electroluminescent displays, other types of flat panel displays, X-ray phosphors, high definition and projection display phosphors, and the rare-earth fluorescent lamp phosphors.

Currently, the Division is in a healthy state and serves the international community well as a forum for papers in luminescence and related fields. The field of luminescence is very active both in industry and in universities and it is on the verge of still another major revolution with the arrival of high efficiency blue and ultraviolet gallium nitride light emitting diodes (LEDs) and lasers. These LEDs, which directly convert electrical energy into light, can surpass the efficiency of fluorescent lamps and be used to make displays or lamps lasting much longer than current devices. The Division now serves as a forum for papers not only on these and other LEDs and laser diodes but also on cold cathode displays and the luminescent properties of structures exhibiting quantum confinement effects (*e.g.*, semiconductor nanostructures). It has become more intemational in scope in recent years, since a good deal of work in luminescence is now being done in Japan and Europe. The Society has shown a unique strength right from its beginnings 100 years ago as a meeting place for industry, government, and academia, where physicists, chemists, and engineers interested in both the fundamentals and applications of electrochemical and solid-state science/technology can exchange views and information. All these important attributes of our Society are reflected within the operations of the L&DM Division.

In 2002, to mark the centennial year of The Electrochemical Society, the L&DM Division established its Centennial Outstanding Achievement Award. This Award will be presented at fall meetings of the Society in even-numbered years to Active Society Members who have made noteworthy scientific contributions and enhanced the scientific stature of the Society by the publication of significant papers in the Society journals and through presentations at Society meetings.

The interests and work of the Division have been reviewed twice before in *Interface*.[4,5] Here we highlight exciting new developments in different areas of luminescence technology that will have an impact on our every day lives. The first article by L. Shea-Rohwer (Sandia National Laboratories and Division Vice-Chair) and A. M. Srivastava (GE) reviews the latest solid-state lighting technology based on UV-light-emitting semiconductor diodes. In the next article, A. Duggal (GE) and co-workers outline the development and operation of organic light emitting diodes and their applications in flat panel display technology. Phosphor technology, although an old field, is being advanced continually through extensive research in industrial laboratories. Recent advances in the fundamentals and applications of this technology are reviewed by C. Ronda (Philips) and A. M. Srivastava (GE), who are our most recent Division Chairs. In the last article, N. Koshida (Tokyo University of Agriculture and Technology) and co-workers describe the latest advance in field emission display technologies, where the use of nanoscale crystalline silicon cold cathodes is about to revolutionize flat panel display design.

The L&DM Division hopes that these articles will not only inform you about the broad range of interests and potential for future development in the luminescence field but also inspire you to take an active interest in this field and in the affairs of the Division. ■

References

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About the Author

***David Lockwood** is a Principal Research Officer at the National Research Council of Canada in Ottawa, Ontario. He is currently Chair of the Luminescence and Display Materials Division. He may be reached by e-mail at: david.lockwood@nrc.ca.*