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The Solid State Lighting Initiative: An Industry/DOE Collaborative Effort

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The Solid State Lighting Initiative: An Industry/DOE Collaborative Effort

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A new era of technology is emerging in lighting. It is being propelled by the dramatic improvements in performance of solid state light sources. These sources offer an entirely new array of design aspects not achievable with current light sources. At the same time, their performance characteristics continue to improve and are expected to eclipse those of the most common light sources within the near future.

High efficiency is one of these performance attributes motivating the Department of Energy (DOE) to work with the manufacturers of this new technology to create a program plan sufficiently comprehensive to support an industry-driven Solid State Lighting Initiative before Congress. The purpose of the initiative is to educate Congress about the potential of this technology to reduce the electric lighting load within the United States and, consequently, to realize the associated environmental benefits. The initiative will solicit congressional support to accelerate the development of solid state technology through investment in the research and development necessary to overcome the technical barriers that currently limit the products to niche markets.

While there are multiple technologies being developed as solid state light sources, the two technologies which hold the most promise for application to general illumination are Light Emitting Diodes (LEDs) and Organic Light Emitting Diodes (OLEDs). The form of these sources can be quite different from current sources, allowing exciting new design uses for the products. Being diffuse sources, OLEDs are much lower in intensity per unit area than LEDs. The manufacturing process for OLEDs lends itself to shapes that can be formed to different geometries, making possible luminous panels or flexible luminous materials. Conversely, LEDs are very intense point sources which can be integrated into a small space to create an intense source or used separately for less focused applications. Both OLED and LED sources are expected to be thinner than other comparable sources; this thinness offers additional design opportunities.

OLEDs and LEDs have other performance attributes that will enhance the operation and maintenance of the lighting system within a building, and will thus increase the desirability of these sources to the end user. For example, these solid state sources have the potential of being easily dimmed without changing color, altering product life, or decreasing source efficacy. In addition, the source life is not affected by on/off cycling. Although the sources will require a power transformer, it is likely that, through standardization, only a few different types would be required; the dream of a "universal" ballast may be close to realization. Finally, the sources contain no mercury, and thus pose no environmental hazard in disposal at the end of life.

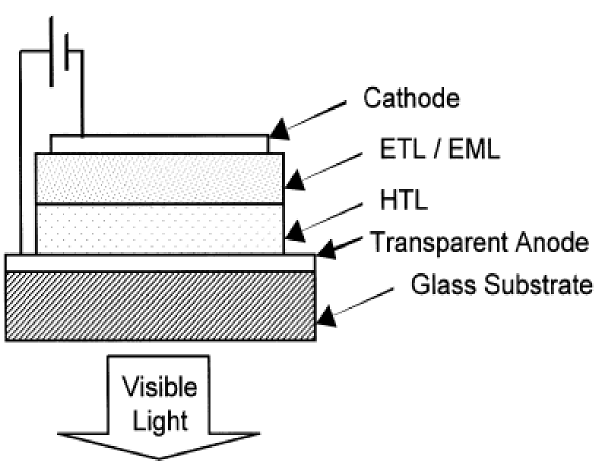

Figure 1. Structural elements of an OLED.

Since both OLEDs and LEDs are diodes they have a similar functional construction. The elements of an OLED are pictured in Figure 1.

Diodes are direct current devices, passing current in one direction from the cathode to the anode. Consequently, these devices require a transformer to convert alternating current to direct current and to maintain the power quality of the electric supply. The diode operates when a sufficient voltage applied across the device results in electrons being injected into the N or electron transport layer (ETL) and holes being injected into the P or hole transport layer (HTL). The applied electric field drives the electrons and holes across the device in opposite directions until they combine at the interface of the PN or ETL-HTL junction. The energy released by this recombination results in the excitation of an atom or molecule, which subsequently radiates. Different chemical compositions at the PN junction are chosen to give the desired spectral emission characteristics. Diodes that radiate in the UV, visible, or infrared portion of the spectrum are available.

Diodes can be very efficient light sources. With the proper selection of materials little energy is lost in the injection and transport of electrons and holes to the PN junction. The diodes are designed to effectively convert the recombination energy of the hole and electron into radiated energy, resulting in the efficient conversion of electric power into visible light. The light generated within the device must then be effectively extracted to achieve an overall efficient light source. Both the Department of Energy and the manufacturers of solid state light sources foresee a significant opportunity to improve lighting efficiency through the application of this emerging technology to general illumination.

Figure 2 illustrates the efficiency of a number of light sources for converting the supplied electrical energy to visible radiation.

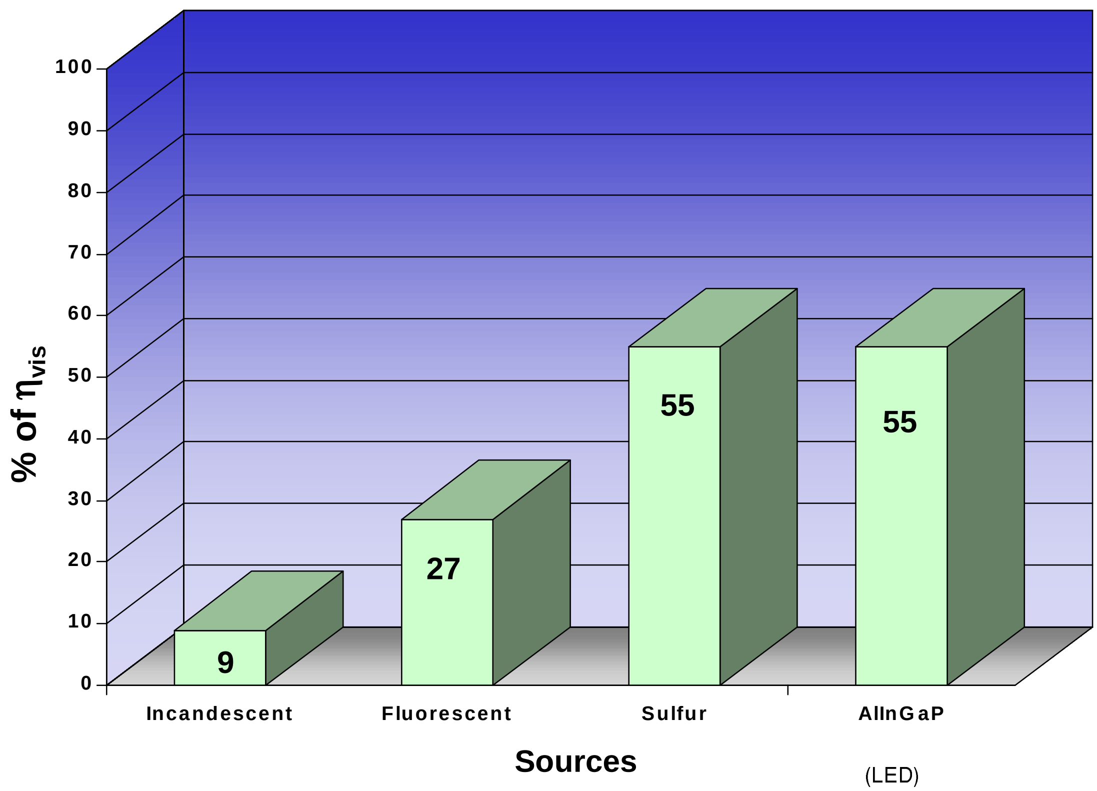

Figure 2. Conversion Efficiency of Light Sources

The incandescent source has the lowest efficiency. Being a black body radiator, a major portion of the radiation, or emitted energy, appears in the infrared region of the spectrum. Discharge sources, like fluorescent and high intensity discharge lamps, radiate principally within the visible portion of the spectrum and have a higher efficiency. However there are loss mechanisms in the electrodes and within the discharge itself. Fluorescent lamps have additional losses in the conversion of the ultraviolet radiation of the discharge to visible radiation by the phosphor.

The promise of solid state sources is exemplified by the recent development of a high efficiency (AlInGaP) red and amber LED by LumiLeds. These devices are capable of converting over 90% of the energy within the device to visible radiation at the PN junction. The efficiency of this process is defined as the internal quantum efficiency. The manufacturer has shaped the geometry of the chip to increase the extraction efficiency and to further enhance performance by surrounding the die with a higher-refractive index epoxy to achieve an external quantum efficiency of 55% for the red (approximately 650 nanometers) LED. This equals that of the most efficient discharge lamp, the sulfur lamp, as shown in Figure 2. The remarkable feature of the device is that the potential exists for significant enhancements in performance by improvement of the extraction efficiencies. Hence, it is not unrealistic to expect the efficacy of solid state sources to achieve 150 to 200 lumens per watt in the coming decades.

Display and signal lighting applications currently dominate the market for solid state sources. Presently, most LEDs in production are not high performance devices; this allows a lower production cost and market price. This fact is understandable, since traditional applications of LEDs may not have justified the added expense of using high efficiency devices. However, the recent application of LEDs for full-color, large-area, flat panel displays, such as the NASDAQ sign in Times Square, and for replacements for filtered incandescent sources in various automotive and traffic lights marks the beginning of a market trend to new applications using more efficient devices. Similarly, the main market interest in OLEDs is presently in the display industry, specifically for full-color flat panel display applications. OLED displays are being developed for use with home entertainment and computer equipment, instrument panels, and handheld communication devices. Because the cumulative size of the markets for these display and signal devices greatly exceeds that of lighting, research and development within the industry is focusing on improving product performance to the meet needs of this market.

Solid state light sources have the potential to fundamentally change the nature of lighting use in the building sector, with large potential savings to ratepayers and associated reductions in environmental impacts. However, the core technologies are being developed for use in special niche applications (*e.g.* auto taillights, displays), which do not have the same performance objectives necessary for products used in general illumination. Realizing this missed opportunity, the industry has turned to the Department of Energy, specifically to the DOE Office of Building Technology, State and Community Programs (BTS), for leadership in supporting a program plan to develop a Solid State Lighting Initiative.

The goal of the initiative is to accelerate the development of high-efficiency solid-state light sources for application to general illumination. Achieving this goal will require an infusion of both private and public resources into research and development of the technology over the next five years. DOE, in collaboration with the industry, has developed a five-step program plan to create the necessary elements to support the initiative’s premises. An outline of the program plan with its five elements is shown in Figure 3. A discussion of the different elements will follow.

The first activity to be completed in the program plan was “The Lighting Industry’s Performance Requirements for Solid State Lighting”. This activity was designed to involve a broad range of individuals from across the lighting industry to insure that the technology roadmap elements are truly targeted to their interests, since many of the manufacturers developing solid state light sources know little about the traditional lighting industry. The final product of the activity is a set of performance requirements specifically addressing the application and market needs for solid state light sources in their application to general illumination. These product performance criteria will serve as performance guidelines in the development of the respective technology roadmaps.

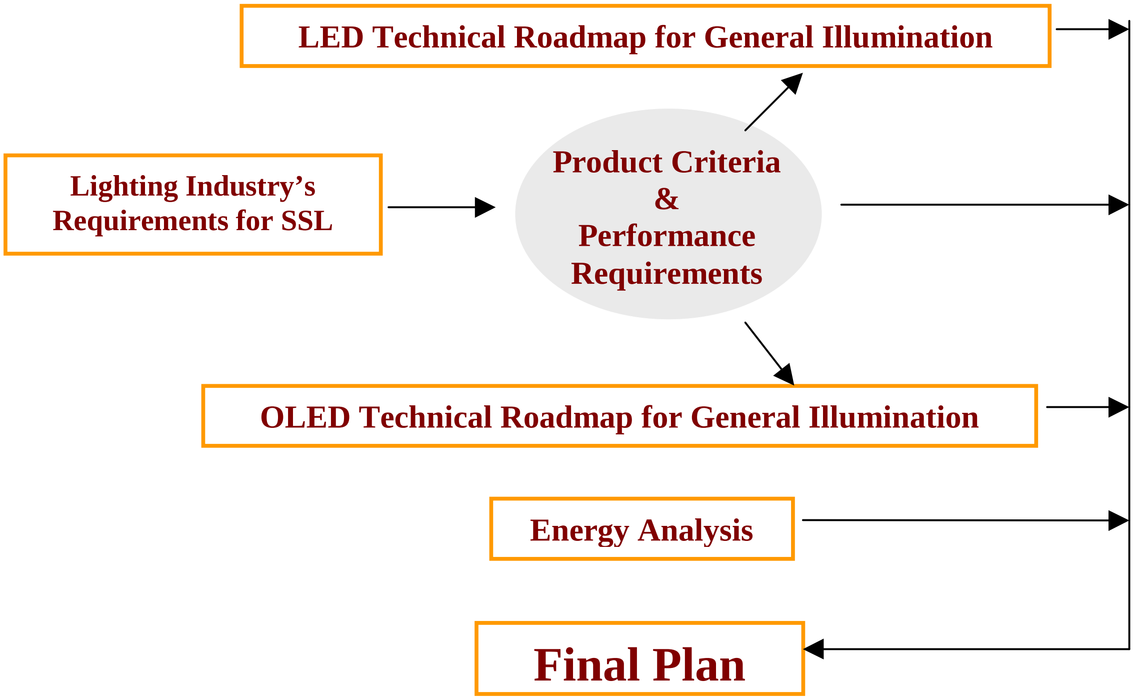

Figure 3. Program plan for solid state lighting.

During Lightfair, a group of industry representatives met to determine the necessary performance requirements. The results of this meeting and subsequent analysis of the data gathered after the meeting will be the subject of a follow-up article in a forthcoming issue of Architectural Lighting.

The next two activities in the program plan are the generation of the LED and OLED Technical Roadmaps. Different technical roadmaps are necessary for each, because the research, process development, and manufacturing of LEDs and OLEDs is unique to each technology. An industry consortium for each technology was established, and a common coordinating agency, the Optoelectronics Industry Development Association (OIDA), was selected by the two consortiums. OIDA will organize the two technical roadmaps and issue reports of the conclusions of the two meetings. The OIDA reports will therefore represent a consensus of which technical activities the industry feels are the most important to pursue.

Sandia National Laboratory will host the LED technical roadmap meeting at the end of October 2000, and Lawrence Berkeley National Laboratory will host the OLED technical roadmap meeting at the end of November 2000. The participants in these technical roadmap meetings will be different from those in the previous Lighting Industry's Requirements for Solid State Light Sources meeting. Participants will be selected for their technical expertise and individuals have been invited from industry, academic and government research facilities.

The LED and OLED roadmaps will address the technical barriers that currently limit the use of solid state sources for general illumination, the possible avenues of research that will overcome these barriers, and the resources required to support this research. The plan will identify research activities and goals achievable within a period of five years. Industry's investment in related research over the same time period will be identified, demonstrating the commitment by the industry to this common goal. The roadmaps will also address the organizational issues associated with such a large effort.

The fourth activity will be a thorough energy analysis to document the energy savings potential for the respective technologies. The analysis will be performed by Arthur D. Little, Inc., which will utilize an extensive data base to develop an analysis of the energy saving potential as a function of the larger components of the residential, commercial and industrial building sectors.

The fifth element in the document is the Final Program Plan. This plan will be a compilation of the Lighting Industry's Performance Requirements, the OLED and LED Technical Roadmaps, and the Energy Analysis into a single document. The Final Plan will also address the organizational issue of operating a large research program involving the participation of industry, universities, and the National Laboratories, as well as other supporting agencies. A Summary will integrate the conclusion of all four reports into a unified plan for addressing the opportunity to accelerate the development of solid state lighting for general illumination. The Final Plan is expected to be both a working document for use within DOE and a tool to be used externally for developing further support for the Solid State Lighting Initiative within Congress.

Acknowledgment

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