High-Quality, Energy-Efficient and Affordable Light Source using Cathodoluminescent Phosphors

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ABSTRACT A new light-source technology for residential general lighting is described. The technique uses electrons in a flood emission to excite cathodoluminescent phosphors to produce an efficient output which emulates a 3200K incandescent light. The lamp is in manufacturing and promises to be an affordable, bright, high-quality alternative option to other energy-efficient light-source technologies.

TEXT Cathodoluminescent (CL) phosphors as the source of emissive radiation in sources for general lighting have been proposed for several years using multiple formats. Recently, the field-emission "light tile" has been viewed as a specific viable technology [1]. Although there already exist, available on the market, other energy-efficient technologies, such as compact fluorescent (CFL), and solid-state lighting using nitride semiconductors and down-converted photoluminescent phosphor (LED), and others, there remains significant room for performance improvement and user acceptance. The general lighting arena, especially in the context of residential use, has numerous requirements besides energy efficiency, notably high total flux, high-quality spectral content, reasonable heat dissipation, low cost, low glare, dimmability, and environmental friendliness and sustainability. No single technology has met all these requirements yet. We present here a new, emerging general-lighting technology which is meeting these constraints.

Figure 1 shows the basic concept of the light source [2], [3]. This is shown in the format of a ordinary R-30 source for use in standard residential dimmable downlight luminaires; however, the concept is applicable to A-19 and other popular formats as well. A vacuum envelope, pumped using a getter, contains a cathode which (using simple electron optics) emits a "flood" of electrons, uniformly accelerated toward the inner surface of the envelope upon which the CL phosphors are applied. The electron optics restrict the electrons to the phosphor layer which has a reflective layer, similar to ordinary CRT screen [4], thereby assuring that the phosphor's radiative emission is confined to the direction associated with the needs of the (in this case) downlight source. Outside the vacuum envelope, in the base of the source, is housed the electronics associated with the acceleration of the electrons. Although this power supply has a high-voltage output, the total electron current is maintained such that the power density at the phosphor is low (a typical target value for good efficacy is $150 mW/cm^2$ [1]), and the total lamp power is efficient. The CL phosphor lamp is manufactured and marketed exclusively by Vu1 Corporation [5], defining the technology as Electron Simulated Luminescence, ESL™. For the remainder of this presentation, this name will be used.

For the R-30 application, the target specifications are 500 lumens, 3200K, CRI $\geq$ 90, R9 $\geq$ 85, 19 Watts, 10,000-hour lifetime, and maximum operational temperature of 120°C with full dimmability and operation in any configuration within a downlight luminaire. An important feature, for high color quality, is that the emissive output emulates natural light closely [6]. It has been long noted that CL phosphors are suitable for such requirements [7]. Figure 2 compares the spectra of CFL and LED lamps with the incandescent "standard" which end-users are familiar and comfortable with. Also shown is the spectrum of the produced ESL™ lamp (the luminosity function is superimposed, showing the visible spectrum covered.) The CL phosphors are a mixture, balanced to give the desired emission, and to age without significant chromatic shift over the 10,000-hour lifetime. The result emulates the incandescent output closely.

The materials used in this light source are inexpensive, promising an alternative to other technologies which is affordable: in volume, the price is slightly more expensive than the current incandescent R-30 product. However, the source is three-times as efficient and lasts five times as long as the incandescent it replaces. The emissive surface is low-glare and highly uniform. In a downlight fixture, untrained viewers cannot distinguish the source from the incandescent lamp it replaces. The materials used are also environmentally-friendly and sustainable. There is no requirement for hazardous mercury, nor for limited-resource Indium or Gallium. There are scant quantities of Eu in the red phosphor; however, there are emerging red phosphors which may become available to replace even this minute inclusion.

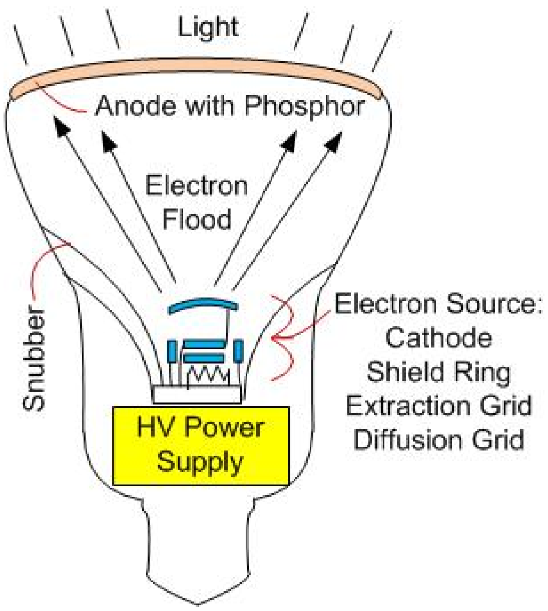

Figure 1. Conceptual depiction of the ESL™ configuration

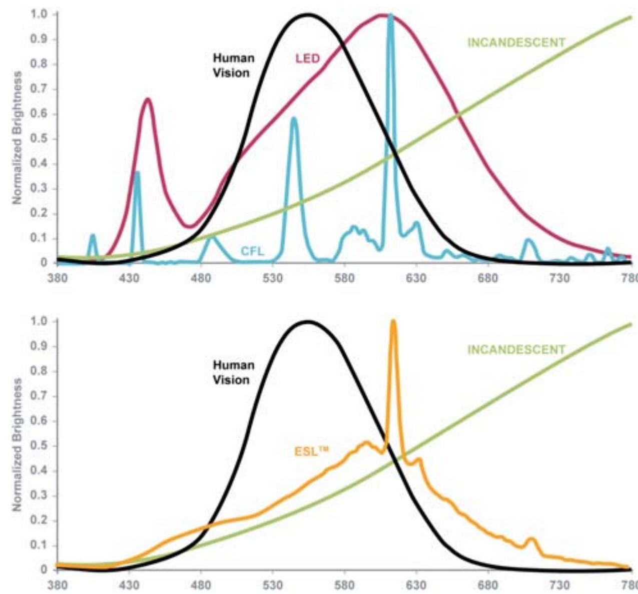

Figure 2. Comparative spectra of LED, CFL, incandescent and ESL™ lamps. The luminosity function, $\upsilon(\lambda)$, is included

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