More Energy Efficient and 'Smart': Solid State Lighting Potential Grows

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"Smart" solid-state light sources now being developed not only have the potential to provide significant energy savings, but also offer new opportunities for applications that go well beyond the lighting provided by conventional incandescent and fluorescent sources, according to E. Fred Schubert and Jong Kyu Kim of Rensselaer Polytechnic Institute.
In an article published May 27, 2005 in the journal *Science*, the authors describe research currently under way to transform lighting into "smart" lighting, with benefits expected in such diverse fields as medicine, transportation, communications, imaging, and agriculture.

The ability to control basic light properties — including spectral power distribution, polarization, and color temperature — will allow "smart" light sources to adjust to specific environments and requirements and to undertake entirely new functions that are not possible with incandescent or fluorescent lighting.

For example, "smart" solid-state light sources have the potential to adjust human circadian rhythms to match changing work schedules, to allow an automobile to imperceptibly communicate with the car behind it, or to economically grow out-of-season strawberries in northern climates, according to Professors Schubert and Kim.

Solid-state lighting sources such as light-emitting diodes (LEDs) already offer energy savings and environmental benefits compared to traditional incandescent or fluorescent lamps, say Schubert, the Wellfleet Senior Constellation Professor of the Future Chips Constellation at Rensselaer, and Kim, a post-doctoral fellow. Fundamental principles of physics place far greater limits on the efficiency of incandescent and fluorescent lights than on solid-state lights. In theory, solid-state devices with perfect materials and designs would require only 3 watts to generate the light obtained from a 60-watt incandescent bulb.

Solid-state sources potentially could cut in half the 22 percent of electricity now consumed by lighting. Traffic lights using LEDs, for example, use only one-tenth the power of signals using incandescent lamps. Further development of solid-state sources to replace traditional lighting will reduce energy consumption and dependency on oil and decrease emissions of greenhouse gases, acid-rain-causing sulphur dioxide, and mercury.

However, it is the possibility of controlling such basic properties of solid-state lighting as spectral content, emission pattern, polarization, color temperature, and intensity that gives these light sources the ability to provide entirely new functions. For example:

-- Recent research shows that ganglion cells in the human eye, which are believed to be involved in the human circadian or wake-sleep rhythm, are most receptive to the light in the blue spectral range that is experienced midday under clear skies. According to a basic physics definition, this light has a high color temperature, while evening light has a far lower color temperature. Lighting that offers the ability to adjust color temperature could benefit human health, mood, and productivity.
-- The ability to rapidly modulate LED-based light

sources gives these lights the potential to sense and broadcast information by blinking far too rapidly for the human eye to perceive. Auto brake lights, for example, could communicate an emergency braking maneuver to a following car.
-- The ability to control the spectral composition, polarization, and color temperature of light used in microscopy could greatly improve the clarity of images, enabling real-time identification, counting, and sorting of biological cells for research and medical applications.
-- Controlling the spectral composition of grow lights would offer an energy-efficient method to grow fruits and vegetables out of season or in climates where they don't usually flourish.

To achieve these benefits, according to Schubert and Kim, improvements are needed in materials, device design and fabrication, and packaging of solid-state components into lamps and luminaires. Researchers must learn, for example, how to grow ultraviolet, green, yellow-green, and yellow emitters with improved internal quantum efficiencies.

To efficiently extract light from the LED chip and package, new methods are needed such as the omni-directional reflectors recently developed by a team led by Schubert. Several strategies are being pursued to increase the power per package, including scaling up the chip area, scaling up the current density, and increasing the maximum allowable operating temperature.

Scaling is particularly interesting, as it is reminiscent of the successful scaling in silicon technology that for decades has shrunk computers while increasing their power, say Schubert and Kim. The scaling up of LED chip size and current density will substantially reduce costs, bringing LEDs into offices, homes, and, perhaps, even dining room chandeliers, the authors say. In addition, low-cost availability of solid-state lighting devices will contribute to the development of a wide variety of totally new smart lighting functions.

Source: Rensselaer Polytechnic Institute