Several trends are converging to make SSL (solid-state lighting) of all kinds an attractive opportunity. There is worldwide interest in finding new SSL technologies that are more energy efficient, for example. This has already led to the creation of a healthy market for ILEDs (inorganic light-emitting diodes), especially high-brightness LEDs (HB-LEDs) for signals, signs, and automotive lighting. And there is a fair amount of ongoing investment from private corporations in ILEDs with the hope that they will expand their market further into general illumination markets. There is also considerable willingness by governments all over the world to spend taxpayers' money on LED lighting in the belief that they are energy saving and environmentally friendly.

This interest in ILEDs coupled with the success of ILEDs in the marketplace have encouraged both technology developers and materials firms to look at other SSL solutions that might either be complementary to ILEDs or an improvement on them. Organic LED (OLED) lighting is on the verge of providing an excellent complementary technology today, with the promise of improving on ILEDs in the future in particular applications suited to the OLED's particular talents. (It also provides an interesting diversification for OLED display firms that have been frustrated by the twists and turns of the OLED display market.)

OLED lighting and ILED lighting obviously use very different materials, a fact that is important in the manufacturing arena. OLEDs also have the potential to be manufactured by low-cost printing techniques, which promise lower manufacturing costs. Perhaps more importantly, the ILED lamp is, of course, a small point source of light, while an OLED lamp is a planar sheet of light. The two therefore shine in different market niches. OLED lighting can (in theory, anyway) be scaled up into very large area lighting devices, for example, a capability that can only be matched by configuring many discrete ILEDs into an array and/or incorporating light diffusion subsystems.

Open Questions, Challenges and Solutions

It's easy to make a case for printed and OLED devices in the lighting market but, as always, the devil is in the details

- OLED lighting may be able to offer remarkable things such as flexible lamps, but no one yet knows where the demand lies for that capability and where the perceived value will justify the additional cost.
The potential for low-cost printing and even R2R (roll to roll) manufacturing processes opens up exciting possibilities for price points that would greatly accelerate the adoption of OLED lighting. But so far, nobody has yet proven out their materials set and manufacturing processes in a real-world high-volume environment.

The biggest challenge of all for OLED and printed lighting is likely to be in general-purpose lighting. To what degree will consumers be willing to pay for relatively expensive OLED lights (when they become available) when incandescent and fluorescent lights are so inexpensive? Will the extra efficiency and the ability to create novel kinds of lighting be enough to open up substantial general illumination for organic lighting?

There are no clear answers to such questions yet. In part, this is because OLED display and lighting technologies are at such an early stage of their lives. Although OLED displays have already been shipping for almost ten years, their manufacturing operations are many generations behind LCD fabs. The largest OLED display yet fielded is only 11 inches in diagonal, and most of the devices on the streets are in the 2- to 3-inch realm.

OLED lighting is an even more recent phenomenon. Its capabilities in brightness, efficiency and lifetime have reached the “good enough stage” and OLED-based lighting products are in the works. Now at the beginning of OLED lamp evolution, it’s clear that early stage capabilities won’t necessarily reflect the competitive picture years down the road. Which particular material sets, structures, architectures, manufacturing regimens, etc. hold the greatest long term potential is a completely open question.

Yet, OLED lighting progress continues at a pace. Just one year ago, the state of the art in efficiency for OLED lamps was roughly in the 10 to 30 lm/W range. In this relatively short span of time, the efficiency has progressed to the 45 to 75 lm/W level, and 100 lm/W is being promised within a two-year time frame. The U.S. Department of Energy (DOE) has a technology roadmap that points to possible ratings of up to 150 lm/W for OLED lighting in the long run.

OLED lighting has also been able to piggyback on the substantial development work being conducted for OLED displays-in terms of materials, manufacturing and other aspects-and it will continue to do so. It will, for example, benefit as display manufacturers begin pushing to larger size devices in the next several years to challenge AM LCDs and small PDPs in television applications. Display makers will also be pushing towards larger substrates in order to multiply the resulting number of displays provided per substrate. Manufacturing equipment developed
for large-substrate displays will clearly benefit OLED lighting manufacturing, where large area coverage is the main objective.

Although work on OLED materials continues to improve efficiency, for example, extend life, etc.—much of the work during the past year has shifted to the manufacturing realm. To cite just a few examples:

- DuPont and Dainippon Printing have formed a strategic alliance to bring high-speed nozzle printing systems to market for small-molecule OLED displays.

- Fraunhofer-Gesellschaft is now operating a pilot line for OLED lighting and solar panels, with a second pilot line for flexible devices now being installed.

- GE Global Research and GE Consumer & Industrial successfully demonstrated "the world's first roll-to-roll manufactured OLED lighting devices" in March, 2008, the culmination of a four-year, $13 million research collaboration among GE Global Research, Energy Conversion Devices, Inc., and the U.S. Commerce Departments National Institute of Standards and Technology.

Lighting of the Future

OLED lighting will find easier intrusion points where the application exploits its nature as an area, not a point, source of light. Point-source ILEDs may always be a better solution for car headlights, for example, and area-source OLEDs for general illumination, although this is not a hard and fast rule. At the SID 2007 conference, for example, Novaled demonstrated a Mercedes Benz with OLED headlights.

But where (and when) will OLEDs start making an impact on the evolving SSL market? It's generally believed that at a brightness level of 1,000 nits, efficiency of at least 30 lm/W and effective lifetime in the tens of thousands of hours, white OLEDs will have achieved a "compelling" set of specifications for general purpose lighting applications.

For more modest application requirements, such as those of keypad backlighting, OLEDs can already deliver the goods and should have a role to play if the cost savings of printable lamps pan out as expected. For more demanding applications, such as those of LCD backlighting, OLEDs still have some way to go in performance, but their potential cost savings will make them very attractive when they get there.

The general consensus is that "flat-panel lighting" is likely to emulate flat-panel displays by starting out with products of modest capabilities (backlighting for cell phones and
consumer electronics, for example), then evolving performance over time to capture more demanding applications. But these more demanding applications—even according to the more sober firms that have been in the lighting industry a long time—could involve some fascinating new opportunities. By combining color with shape, organic LEDs could create a new way of decorating and personalizing people's surroundings with light, for example.

It's easy to conceptualize an OLED lamp, flush against the ceiling, replacing a fluorescent fixture or, indeed, replacing a passive ceiling tile with a tile that glows. The vision of large, low-cost R2R-manufactured OLED lamps enabling walls of light is beginning to intrigue some of the biggest lighting firms, firms that have the money to spend to make it happen. Beyond conventional applications, some researchers at General Electric Global Research are thinking about lighted curtains and lighted wallpaper.

Alternatives to OLED Technologies

It is not just ILEDs, incandescent bulbs and fluorescent lights that present competition for OLEDs. There are some other technologies (including some printable technologies) that present competition to OLED lighting in certain applications.

**EL:** In backlights for keypads and instrument panels, for example, thick-film electroluminescent (EL) lamps are the technology to beat. EL is likely to thrive where the higher brightness potential of OLEDs is not required and where efficiency is not a major issue. As it persists and even spreads out in the market, it will continue to illustrate the benefits of printable, flexible lamps and fertilize the field for OLEDs.

**Field Emission:** The appeal of carbon nanotubes (CNTs) for lighting (or displays) is multifold. They provide a very rugged, damage-resistant structure. CNT lighting may also prove printable and thus promise a low cost manufacturing regimen. CNT lighting is also transparent. For very large (tens of stories) side-of-the-building applications, the advantage of a transparent sign is that it doesn't block office windows. Transparency adds value to real estate, enabling both windows and advertising to be deployed in the same physical space. Applied Nanotech, which holds important IP on has noted one licensee's use of a 1 x 1-foot lighting module to create a 10 x 2-foot emissive sign.

*For additional information on this report please visit [www.nanomarkets.net](http://www.nanomarkets.net) or contact us at sales@nanomarkets.net or (804) 360-2967.*