Micro-cavity arrays: Lighting the way to the future

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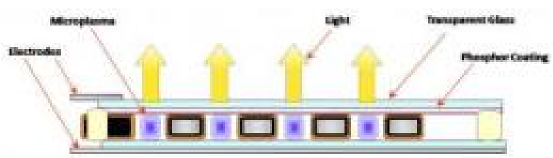

A research team funded by the Air Force Office of Scientific Research has pioneered the use of micro-plasmas in a revolutionary approach to illumination. Just as in a fluorescent light, a micro-cavity array is energized by an applied voltage. By successfully confining that plasma in parallel rows of micro-cavities within thin sheet materials, Drs. Gary Eden and Sung-Jin Park of the University of Illinois, Urbana-Champaign, ultimately arrived at various implementations of micro-plasma arrays, which result in inexpensive, wafer-thin, and very flexible sheets of light. Credit: Courtesy of Eden Park Illumination

It was not too long ago that basic science lectures began with the three forms of matter: gases, liquids and solids—and somewhere along the line plasmas were occasionally added to the list. But to be precise, a plasma is an ionized gas; thus, a subset of the big three. But this subset has coexisted with the other forms since the Big Bang and actually makes up 99 percent of the universe. It is found in our Sun and all the other stars, and in more down to earth applications: in neon signs, Plasma TVs, Cathode Ray Tubes, and the ubiquitous fluorescent light.

It is now also found in a new form of lighting. A research team funded by the Air Force Office of Scientific Research has pioneered the use of micro-plasmas in a revolutionary approach to illumination, and Drs. Gary Eden and Sung-Jin Park of the University of Illinois, Urbana-Champaign, have founded Eden Park Illumination, Inc. to bring this new lighting technology to the world.

As is the case with many basic research endeavors, Dr. Eden did not set out to make a better light bulb—it was a query from two graduate students that showed the way. Dr. Eden explains: "In 1996 the students approached me with, literally, a block of silicon, and they said, 'do you mind if we drill a small hole in this and try to produce a plasma inside the hole?' In short order they produced a plasma inside a hole with a diameter of about 400 microns, a crude forerunner of the current micro-cavity array lighting system."

What made this fortuitous discovery interesting to Dr. Eden was the issue of space and pressure. A fundamental rule for stable, steady state plasmas is pressure times diameter scaling, the smaller the plasma dimensions, the higher the pressure can be. The very high pressures that can thus be obtained in micro-plasmas give rise to unique lighting and other properties. It is at this point that the "eureka" lightbulb (or in this case—microplasma array (MCA)—literally turned on.

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The key to these light arrays are the micro-cavities which are formed within the flexible sheets. In one of the most important implementations, the one being developed by Eden Park Illumination, a sheet of aluminum foil is placed in an anodizing bath. By controlling the bath parameters, its temperature, and the time of anodizing, large arrays of micro-cavities can be formed with near optimum shape and with automatically placed interconnecting aluminum electrodes. The largest array thus far contains a quarter million luminous micro-cavities. Thin laminated films on the surface of the wafer contain the electrical power interconnects which feed the individual cavities. When A/C power is supplied through the almost invisible grid, the array bursts to life.

Many gases can be used to make the micro-plasma arrays. In Eden Park's commercialization processes, rare gases produce ultraviolet light, and specialty phosphors convert the UV into visible light, as in fluorescent lamps.

The largest arrays currently being produced are six inches square. These can be conveniently tiled together, in different colors if desired, to make larger arrays, and if desired, much larger arrays can be made, limited only by the size of the anodizing bath. Conveniently, aluminum foil is used, with a thickness of 125 microns (5/1000ths of an inch). The cavities are then sealed in very thin sheets of glass resulting in an array that is one to two millimeters thick.

The Eden Park plasma arrays are ruggedized to a certain extent and have an ultimate thickness of about four millimeters, leaving you with a wafer that weighs less than 200 grams.

But is this a revolutionary advance? The advantages compared to contemporary lighting technologies are quite impressive: the first thing to note is that the array is flat—a major contributor to efficiency. All one has to do is compare the six inch by six inch (by four millimeter thick) size of a micro-cavity array to a standard fluorescent office light. The fluorescent light tube—which derives its light from a mercury plasma—has a stated efficiency of about 75 to 80 lumens per watt, but much of this is lost due to its 360 degree design. By comparison, the utilization efficiency of the MCA is over 90 percent; as such, a 35 lumen per watt array has the same output as its much larger fluorescent cousin.

A further advantage: the MCA does not contain mercury—an environmental advantage. In addition, the array is fully dimmable while fluorescent lighting is not.

Color is also a factor. The Color Rendering Index (CRI), by which the varying representation of color is brought forth with different lighting systems, is also a plus. On the CRI scale the sun is a perfect 100—the yardstick by which all lighting is measured. With a CRI of over 80, the MCA approaches sunlight quality.

What also makes this light unique is that from the beginning it was designed to be fully recyclable—the plastic, glass, and aluminum contents are not only easily repurposed, but it takes very little energy to do so.

How long do these arrays last? The specification for currents arrays is currently 20,000 hours before failure.

But what about a comparison with LEDs? While the efficiency of the MCA does not quite measure up to that of LEDs, there is a positive side, that being a huge difference in thermal dissipation. MCAs generate far less heat and therefore do not require an aluminum heat sink as LEDs do, thus, MCAs not only run much cooler, but are much lighter as well.

With so many advantages, there must be a downside. Well, yes and no.

Let's consider cost: Even though all the MCA materials are inexpensive, current rate of production has not yet made the cost competitive with current lighting options. But there is light at the end of the tunnel: Congress has mandated that incandescent lights be phased out beginning in 2014; this opens up the field to a much wider acceptance of MCA technology and its application.

Micro-plasma arrays have applications in general and specialized lighting. They can be prepared to light up as a single broad light source or can be individually addressed for display type applications. Special applications might include aircraft cockpit lighting and displays due to less weight, size and heat, as well as the flexibility to conform to cramped interior spaces. Tanks and other combat vehicles would offer an ideal application for the same reasons—not to mention the absence of mercury—a hazard given the rough operating environment. Car interiors could become a customized light show unto themselves. Interior lighting for homes and offices could be transformed given the flexibility of the technology. Even the lowly refrigerator light could be in line for an upgrade.

Another surprising capability of micro-cavity plasmas is their inherent characteristic of an enormous amount of power being delivered per unit volume at high pressure, while they remain perfectly stable and benign. What does this mean in practical terms? It is a technology not only well suited for light production, but is ideal for "on-chip" special chemistries. Also by utilizing the linear micro-channel design, as employed in an MCA lighting panel, one can place a large number of parallel receptors within a small area to perform a variety of sensory activities, depending on the chemical composition within the cavities.

One such capability is the generation of ozone (O_3) for water purification. Early tests demonstrate a high degree of uniform ozone producing discharges comparable to the best values currently available by commercial means. This portends a huge advantage with regard to water purification efforts in community systems when compared to the use of chlorine with its inherent environmental drawbacks —the ozone process is completely benign, as it shortly reverts back to its native oxygen (O2) state. Microplasma ozone generation also has important potential for producing small, portable ozone water purification systems, impossible now because of the inefficiency of existing technology.

Micro-cavity arrays have much to offer—the future just has to catch up.

Provided by Air Force Office of Scientific Research