Bright White Light Coaxed from Unexpected Source

December 18 2008

'Doped' zinc oxide 'phosphor' converts ultraviolet to visible white light. Image: John Foreman

(PhysOrg.com) -- Duke University and United States Army scientists have found that a cheap and nontoxic sunburn and diaper rash preventative can be made to produce brilliant light best suited to the human eye.

Duke adjunct physics professor Henry Everitt, chemistry professor Jie Liu and their graduate student John Foreman have discovered that adding sulfur to ultra-fine powders of commonplace zinc oxide at about

1,000 degrees centigrade allows the preparation to convert invisible ultraviolet light into a remarkably bright and natural form of white light.

They are now probing the solid state chemistry and physics of various combinations of those ingredients to deduce an optimal design for a new kind of illumination. Everitt and Liu have applied for a patent on using the preparations as a light source. "Our target would be to help make solid state lighting with better characteristics than current fluorescent ones," said Everitt, who also works with Foreman at the Army's Redstone Arsenal in Huntsville, Ala.

The researchers said they are producing white light centered in the green part of the spectrum by forming the sulfur-doped preparation into a material called a phosphor. The phosphor converts the excited frequencies from an ultraviolet light emitting diode (LED) into glowing white light.

Nanometer-diameter zinc oxide powders are being prepared by Liu's research group, which focuses on the chemistry of nanomaterials. He is Duke's Jerry G. and Patricia Crawford Hubbard Professor of Chemistry. They are then being tested at the Aviation and Missile Research, Development and Engineering Center at Redstone Arsenal by Everitt, an Army senior research scientist, and Foreman, an Army research physicist.

The researchers are also exploring using electricity alone to trigger the visible emissions without need for an ultraviolet light trigger.

The Army has selected the project for priority funding through a competitive In-house Laboratory Independent Research program because of its potential advantages as an energy efficient and safe illumination source.

"One of the objectives is to give soldiers efficient lighting that doesn't run their batteries down," Everitt said. "They need efficiency, brightness, longevity and ruggedness, and this helps with all of those things."

Existing commercial LEDs are already rugged enough to be used in bumper-mounted brake lights, Everitt said.

"They are good enough for decoration and for use in traffic lights, but they don't make good reading lights because they are not of a white color that our eyes use best," Liu said. White LEDs on the market now are costly, short-lived and not truly white, the researchers added.

A compound that can be used on faces or babies' bottoms also has major safety advantages over fluorescent bulbs, which happen to contain toxic mercury. "If a fluorescent bulb gets broken in the course of battle, it exposes soldiers to that mercury in addition to its shattered glass," Everitt said.

"I think the biggest payoff for the general public will ultimately be in future energy crises we're certainly going to face," Everitt added. "If we can have more efficient lighting it will reduce our energy requirements."

Scientists have long known that zinc oxide can itself serve as a solid state ultraviolet light source. They have also known that adding sulfur allows it to emit some white light. But Liu, Everitt and Foreman are investigating how nanostructuring and doping improves its performance.

The introduced sulfur is thought to boost wavelength conversions from ultraviolet to visible wavelengths by serving as an "impurity" that changes the chemistry and physics of the zinc oxide in ways the Duke researchers are still probing.

Most scientists consider such impurities "defects" that interfere with zinc oxide's ability to produce a stronger ultraviolet light, they said. But "we love the defects that other people hate," Everitt said. "That's been the gift of nanostructured doped zinc oxide, emitting what your eye expects white light to look like."

In a report published May 10, 2006, in the research journal *Nano Letters*, Foreman, Everitt, Liu and co-researchers first disclosed they could induce a formulation of zinc oxide shaped into nanowires to absorb light from an ultraviolet laser and re-emit it as a "broadband visible emission of unprecedented brightness." The white light component was more than 1,000 times brighter than the ultraviolet component, they reported.

In a followup report, published July 2, 2007, in the journal *Applied Physics Letters*, the Duke researchers initiated what they expect to be a series of published papers exploring how various alterations affect the white light emissions.

"We've learned something about what makes the white light conversion happen, and what makes it happen so efficiently," Everitt said. The Duke team has already achieved efficiencies as high as 80 percent. But there are still technical issues to resolve tied to the operating temperatures of the phosphors and the power from the underlying ultraviolet LED.

"Our challenge has been getting a foundational understanding so we can understand what is physically possible and how close we are to achieving it," Everitt said.

Zinc oxide would be both a less-toxic and cheaper light source than the combinations used in today's commercial LEDs -- gallium nitride and cerium-doped yttrium oxide, they said. Cerium-doped yttrium oxide is also used in today's mercury-containing fluorescent bulbs, Everitt added.

Liu's lab originally stumbled on to the light emitting potential of sulfur-doped zinc oxide while studying its electronic conductivity. "We just lit it up with an ultraviolet laser and -- whammo -- there was a lot of white light coming out," Everitt said.

Provided by Duke University