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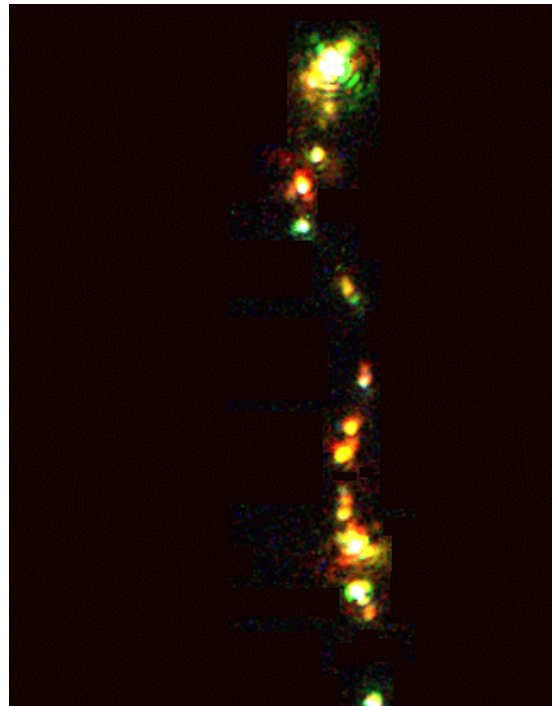
TURN ON THE “NANOLIGHT:” NANOMETER-SCALE LIGHT SOURCE IS FIRST TO SHOW SINGLE-MOLECULE ELECTROLUMINESCENCE

Using photon emissions from individual molecules of silver, researchers at the Georgia Institute of Technology have created what may be the world’s smallest electroluminescent light source.

Believed to be the first demonstration of electroluminescence from individual molecules, the work could lead to new types of nanometer-scale optical interconnects, high-resolution optical microscopy, nanometer scale lithography and other applications that require very small light sources. And because single molecules are known to emit one photon at a time, the technique could ultimately be the basis for high-efficiency quantum information processing and cryptography.

Though the effect was first reported in silver clusters composed of 2-8 atoms, the researchers also demonstrated electroluminescence in similarly prepared copper clusters, suggesting the effect may broadly apply to other metals. Details of the research were reported in the August 6 issue of the *Proceedings of the National Academy of Sciences*.

“This is the first time that anyone has seen electroluminescence from individual



Multicolored electroluminescence from single silver molecules occurs within the electrically discolored region of an activated silver oxide film.

molecules,” said Robert Dickson, assistant professor in Georgia Tech’s School of Chemistry and Biochemistry. “What we have observed involves sub-nanometer scale

sources to which an electric field is applied. These molecules emit very strongly, and are very robust.”

Dickson and collaborators Tae-Hee Lee and Jose Gonzalez began with thin films of silver oxide that are not electroluminescent.

By exposing the film to electrical current of approximately one amp, they “activated” some of the silver oxide molecules, which then appeared within “discolored” regions in the film. When electrodes were attached to the film and an alternating current applied, a thin line of silver clusters began to emit light in colors that varied depending on the size of the clusters. The system operated at room temperature.

“When you zoom in more closely, you can see the emissions coming from single molecules,” said Dickson. “They blink and have dipole emission patterns. You see an incredibly thin line of emissive species close to the middle of the sample.”

Electroluminescence occurs when an electron recombines with a positively charged molecule from which a single electron has been removed to create an electron-hole pair. First, an electron is removed from a molecule, creating a positive charge.

Then, an electron is quickly injected into a different state of the same molecule. Because of the charge differences, the electron is attracted to the hole, and when they recombine, a photon is released.

While normally stimulated by applying direct current (DC), the Georgia Tech group observed a dramatically enhanced response from high frequency alternating current (AC).

While DC voltage produced electroluminescence in the activated silver clusters, Dickson and his colleagues found that high frequency AC voltage – above 150 megahertz -- produced a response as much as 10,000 times greater.

Dickson believes the AC voltage created rapid recombination within single molecules in a very narrow section of a sample, producing the enhanced response. Bulk materials normally cannot respond quickly enough to the alternating current to enhance the electroluminescence to such a large degree.

The AC current was more efficient than DC current at converting electrical current to light because it injects the electron charge at just the right time, minimizing the amount of energy lost

to production of heat. From a practical standpoint, that increases the operating life of the emitting clusters and reduces the amount of current required to produce light, Dickson explained.

“We know that the charge is recombining in the molecules because you can simultaneously measure the electroluminescence and the current, and the peaks are correlated,” he said. “This is an extremely interesting materials system, not only because of the single-molecule electroluminescence, but also because of the resonance we see at relatively high frequencies.”

Though the discovery may have important implications for optoelectronic devices, Dickson’s group is focusing first on understanding the basic process.

“We are concentrating on understanding the very fundamental aspects of this: what the nature of the emission is, how the emission occurs, the different time scales for electron injection, hole injection and recombination,” he said. “We need to know how to better control this before we can begin to use it in nanometer scale devices or as nanometer scale optoelectronic components in circuitry. A lot of engineering will have to be done to make any potential optoelectronic devices both useful and stable.”

The electroluminescence research builds on earlier work done by Dickson and colleagues Lynn Peyser and Amy Vinson that demonstrated optical storage potential of thin-film silver oxide clusters. In that work, reported in the journal *Science* in January 2001, the researchers demonstrated binary optical storage by writing and reading simple images recorded on films of silver oxide nanoparticles activated by light of a specific frequency. That work is continuing, and advances have been made toward potential optical storage systems.

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