CAREER: Nanoelectronic and Nanophotonic Characterization of Hybrid Hard and Soft Materials

Mark C. Hersam, Northwestern University, DMR-0134706

Intellectual Merit:

Organic light emitting diodes (OLEDs) are widely used in commercial applications such as consumer product displays and emergency response equipment. At Northwestern University, a new strategy for characterizing the electronic and optical performance of operating OLEDs has recently been developed. Atomic force electroluminescence microscopy allows the current flow and light emission in OLEDs and other electroluminescent materials to be spatially mapped down to the nanometer length scale. The figure on the right illustrates a current map and light emission map concurrently taken on an array of OLED pixels. These images provide detailed information that is used in the optimization of OLED display technologies.

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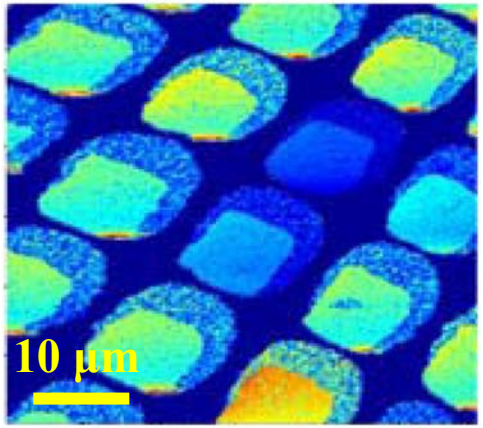
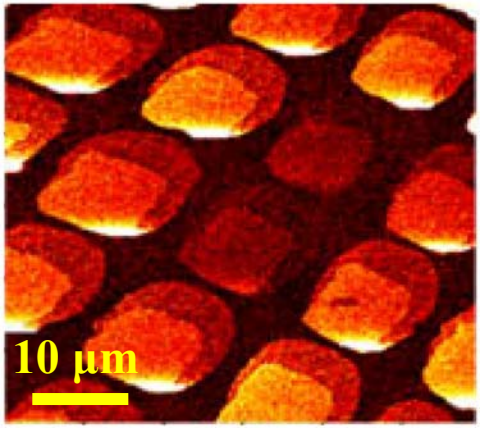
Current Map



Light Emission Map



Intellectual Merit:

This nugget reports the invention of a new strategy for spatially mapping current flow and light emission in organic light emitting diodes (OLEDs) and related electroluminescent materials and devices. The technique, called atomic force electroluminescence microscopy (AFEM), uses a conductive atomic force microscope tip as an electrode that locally injects charge with 10 nm spatial resolution. The resulting current flow can be directly measured while scanning the tip in contact mode. Underneath the sample, collection optics are mounted to gather the emitted light, which is subsequently focused into a photomultiplier tube. In this manner, topography, current flow, and light emission can be concurrently imaged at the nanometer length scale.

The figure shows AFEM data for an array of 8 micron by 8 micron OLED pixels. In this case, the pixels are not uniformly passing current or emitting light, thus illustrating non-uniformities in the underlying organic electroluminescent materials. These images provide real space performance data that are used in the optimization of OLED display technologies. A provisional patent has been filed for AFEM and companies such as Dow Chemical and Kodak have expressed interest in using this tool for quality control purposes.

This work was carried out at Northwestern University and represents an interdisciplinary collaboration with Prof. Tobin Marks of the Chemistry Department. In addition to the provisional patent, this research was recently published in *Applied Physics Letters*: L. S. C. Pingree, M. C. Hersam, M. M. Kern, B. J. Scott, and T. J. Marks, "Spatially resolved electroluminescence of operating organic light-emitting diodes using conductive atomic force microscopy," *Appl. Phys. Lett.*, **85**, 344-346 (2004).

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Broader Impacts:

Seven undergraduate students including three women and two underrepresented minorities contributed to this project while participating in the Research Experience for Undergraduates (REU) program: Steve Akuamoah, Jenny Collins, Samantha Cruz, Leah Edelman, Shaun Elder, John Joo, and Matthew Schmitz.

This research has also been incorporated into the Nanotechnology Materials World Module (MWM). The MWM program creates curricular materials that are subsequently implemented in K-12 classrooms. The figure on the right illustrates the Nanotechnology MWM being used at the annual Boy Scout "Nano Event" held at Northwestern University.

Boy scouts from Troop 309 experience nanoscale science and engineering first hand at the annual Northwestern University Boy Scout "Nano Event."

Broader Impacts:

Seven undergraduates including three women and two underrepresented minorities contributed to this project while participating in NSF funded Research Experience for Undergraduates (REU) programs. Samantha Cruz, Leah Edelman, Shaun Elder, and John Joo were funded through REU Supplement Grants to DMR-0134706, while Steve Akuamoah, Jenny Collins, and Matthew Schmitz were funded through REU programs sponsored by the NSF Nanoscale Science and Engineering Center and NSF Materials Research Science and Engineering Center.

This research has also been incorporated into the Nanotechnology Materials World Module (MWM). The MWM program creates curricular materials that are subsequently implemented in K-12 classrooms. The Nanotechnology MWM has reached gamma stage testing in local high schools and will be published in final form in the near future. As part of the testing, the Nanotechnology MWM was used by boy scouts from Troop 309 at the annual Boy Scout "Nano Event" that was held at Northwestern University on March 13, 2004. A photograph from that event is shown in the figure.