ink is injected onto a continuous roll of material, to print a simple layered device structure onto a flexible, transparent cathode material—poly(terephthalate) coated with ZnO-on-indium-tin-oxide. An active layer of a conjugated polymer (superyellow) and electrolyte (KCF_3SO_3) was first spread to a (dried) thickness of 1 μm, before coating with a similar thickness of poly(ethylenedioxythiophene): poly(styrenesulfonate) to serve as an anode. Despite the relatively thick and rough nature of the resulting layered LEC, they could achieve a brightness of 150 cd m^{-2} at 10 V.

When a voltage is applied to the device, the mobile electrolyte ions in a LEC form electric double layers at the anode and cathode that promote hole and electron injection into the active layer, respectively. This leads to both *p*- and *n*- doping of the polymer film until the two regions meet, allowing charges to recombine and emit light, even in thick films such as these. The time dependence of this doping process makes turn-on time an important property, measured at 2 s at a current density of 770 A m^{-2} for these devices.

LECs share with OLEDs a need to be kept free from oxygen and water vapor during operation, so resistance to ambient conditions was effectively conferred to the developed device by drying at high temperature and encapsulating it inside adhesive barrier layers. Given that these steps could also be carried out in a continuous process, the researchers see their research as a first step toward cheap roll-to-roll printing of large areas of light-emitting "paper" and said that optimization of the active material may lead to rapid improvements in its performance.

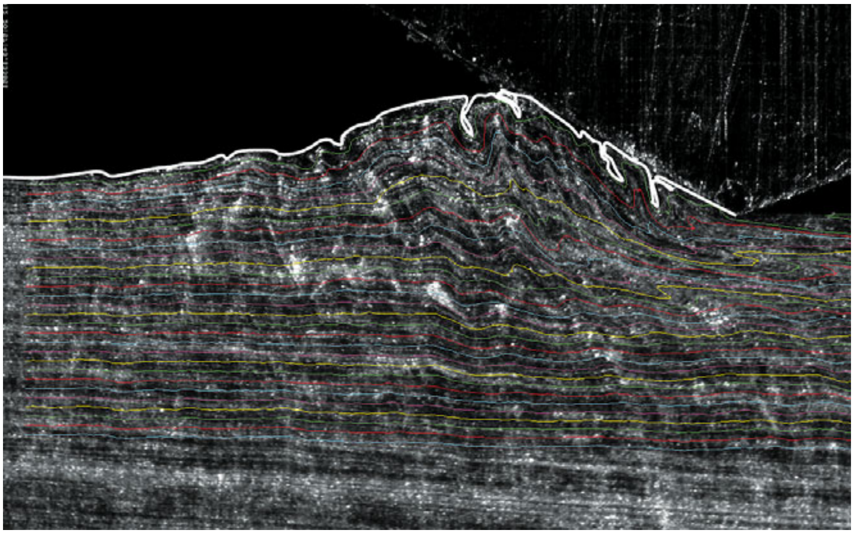
Tobias Lockwood

Sliding metals show fluidlike behavior at the mesoscale

Researchers have discovered a swirling, fluidlike behavior in a solid piece of metal sliding over another, providing insights into the mechanisms of wear and generation of machined surfaces that could help improve the durability of metal parts. Numerous mechanical parts, from bearings to engine pistons, undergo such sliding.

"We see phenomena normally associated with fluids, not solids," said Srinivasan Chandrasekar, a Purdue University professor of industrial engineering who is working with postdoctoral research associates Narayan Sundaram and Yang Guo.

As reported in the September 7 issue of *Physical Review Letters* (10.1103/PhysRevLett.109.106001), the researchers observed what happens when a wedge-shaped piece of steel slides over a flat piece of copper. It was the first time researchers had directly imaged how sliding metals behave at the mesoscale.



This frame from a high-speed camera sequence reveals fluidlike behavior in a solid piece of metal sliding over another (300 μm). The white line is the manually identified surface and superimposed colored lines are streak lines produced from velocity measurements. *Purdue University School of Industrial Engineering image/N. Sundaram and Y. Guo.*

The observations—using a microscope and high-speed camera—show how tiny bumps form in front of the steel piece, followed by the swirling vortex-like movement and then the creation of shallow cracks. The folding and cracking were most pronounced when the steel piece was held at a sharp angle to the copper surface.

The researchers hypothesize that the folding and cracking are due in part to a phenomenon similar to "necking," which happens as a piece of metal is stretched.

The findings were surprising because the experiment was conducted at room temperature and the sliding conditions did not generate enough heat to soften the metal.

"It has been known that little pieces of metal peel off from sliding surfaces," Chandrasekar said. "The conventional view is that this requires many cycles of rubbing, but what we are saying is that when you have surface folding you don't need too many cycles for these cracks to form. This can happen very quickly, accelerating wear."

Metal surfaces that have smaller grains may be less susceptible to the folding and crack formation.

"We need to explore what role grain size plays," Chandrasekar said. "We think there should be some grain size below which this folding mechanism might be less active. We need to explore why—under what conditions—solid metals behave like fluids." □

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