Bright future for electronic paper

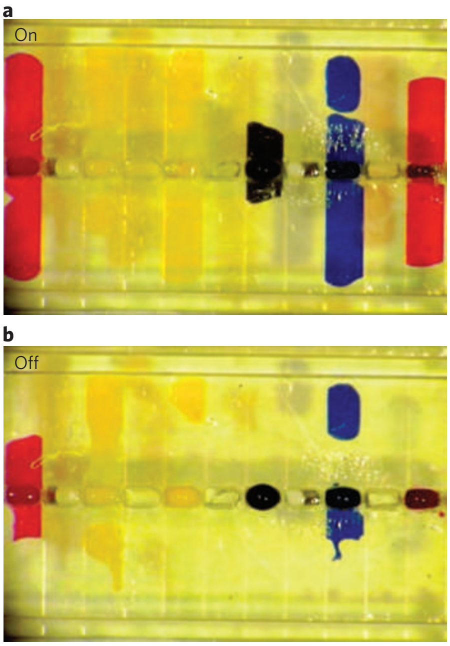
A prototype display technology that electromechanically transports colourful aqueous dispersed pigments over the surface of mirror-like pixels is a promising new approach to making electronic paper with high reflectivity and contrast. *Nature Photonics* spoke to Jason Heikenfeld to learn more.

Where did the idea of making an electrofluidic display come from?

I started electrowetting display work in late 2003 and have been involved in several academic–corporate projects in the area. This has included collaborations with Prime View International (PVI) and the Industrial Technology Research Institute (ITRI), both in Taiwan, and with Sun Chemical, Motorola and Polymer Vision. Sun Chemical is one of the world-leading providers of pigments, so it should be no surprise that Russ Schwartz of Sun Chemical and I were exploring ways to use Sun Chemical pigments in electrowetting displays. Our basic pixel switching concept was realized while I was reading some papers on the role of Young–Laplace pressure in electrowetting lab-on-chip devices. Our first attempt can be seen in our published work on arrayed electrowetting microwells. Our second attempt (see photo) was drastically different in structure and closer to that which we report in this issue. I vividly remember viewing this device in the lab with our post-doc Dr Bo Sun. The device was crude, but both Russ and I were absolutely struck by the brilliant coloration exhibited by the device. This device had paper-like colour that was unlike anything we had previously seen in electrowetting or electrophoretic displays. As we do with all our new discoveries, we next spent a few months theoretically refining the device design, and mapping out manufacturability and performance metrics. Only after that did we begin intense research and development of the electrofluidic display platform.

How exactly does an electrofluidic display operate?

The long-term goal of reflective displays is to mimic the appearance of pigment on paper. This means more than just bright colour: the reflection also has to be diffuse like paper rather than specular like a mirror. One could argue that the ultimate reflective display would simply place the best colorants used by the printing industry directly beneath the front viewing substrate of a display. In our electrofluidic display pixels we place an aqueous pigment dispersion inside a tiny reservoir. The reservoir comprises ~5–10% of the viewable pixel area and therefore the pigment is substantially hidden from view in the pixel's off state. We then use voltage to electromechanically pull the pigment out of the reservoir and spread it as a film directly behind the viewing substrate. As a result, the display takes on a colour and brightness similar to that of conventional pigments printed on paper. When we remove the voltage, Young–Laplace pressure (surface tension) causes the pigment dispersion to recoil rapidly back into the reservoir.



The early days: image of a switched pigment pixel in its on and off states from one of the team's earlier designs.

What are the benefits of your scheme over competing electronic-paper and reflective display technologies?

First, our displays have the potential for a much higher contrast ratio and brightness. In simple terms our displays will look more like real paper than current e-paper. We believe that consumers will place a great deal of value on this benefit. Low power consumption, rollable functionality and video capabilities are all desirable features for e-paper but ultimately what consumers want is a bright display with saturated full colour, which is not currently available. Another key advantage of this technology is that it is much easier to offer a wide array of colour because we already have a high-performance colour set just like that in your inkjet printer, so we can mix these colours and deliver any desired colour at no additional cost. A third advantage is that there is no colour mixing within each pixel. For electrophoretic displays like the Amazon Kindle [an e-book platform] one colorant must be electrically segregated from another, but this separation is not complete and there is always colour mixing which adversely affects shade. This is not to imply that electrophoretic displays are not a brilliant invention, but they are not perfect. In summary, our new displays are a major step forward in realizing true paper-like reflective displays. Our newer embodiments further reduce manufacturing complexity, and we estimate for simple applications that it should be possible to hit an ultimate cost point of less than US$10 per square foot.

Tell me about your future plans?

Now that we have published these first-generation devices we have two major ongoing activities. First, we are exploring some interesting alternative designs of an electrofluidic pixel. As part of this work we are collaborating with Dr Rajesh Naik of the Materials and Manufacturing Directorate at the Air Force Research Laboratory on designing bioinspired devices that mimic the dynamic coloration seen in cephalopods. Second, we have just launched a new company named γ-Dynamics to off-load and accelerate commercial development. This company includes John Rudolph and Ken Dean as founding members, both of whom are well known in the displays industry. This commercialization effort also includes a partnership with PolymerVision for creating full-colour rollable displays.

INTERVIEW BY OLIVER GRAYDON

Jason Heikenfeld and his co-workers have a paper on their electrofluidic display research on page 292 of this issue.