Cutting edge: Thin, lightweight, foldable thermochromic displays on paper

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In this issue of *Lab on a Chip*, Siegel *et al.* present a novel method for electronic control of displays on paper substrates. The authors micropatterned electrically conductive wires on one side of the paper, and coated thermochromic ink on the other side. This combination of materials allows a clever operation: as current flows through the wires to achieve localized resistive heating, dye in the surrounding area turns from opaque to translucent (due presumably to evaporation of the co-solvent to favor the ring-closed state of the dye) to reveal messages and pictures pre-printed on the underlying paper.

This method presents two novel twists for the lab-on-a-chip community: paper as a substrate for micropatterning of electrodes, and the problem of data reporting.

Use of paper as a substrate in lab-on-a-chip systems has been gaining attention. Paper and membranes are well-established substrates for diagnostics, as shown in the lateral flow assay, the most commercially popular format for point-of-care tests. As such, research on improving the performance of paper-based diagnostics (for example, *via* improved detection) has been intense both at diagnostics companies and within academic groups (a recent effort being the Sentinel Bioactive Paper Network in Canada). Recently, the Whitesides group at Harvard University has integrated microfabrication techniques with paper, to move the capabilities of paper-based assays closer to what can be achieved with integrated lab-on-a-chip systems. In terms of technical innovation, Siegel *et al.* add to this toolbox of paper-based microfabrication techniques by demonstrating a simple method for micropatterning electrodes on paper. Their method, which uses stencils as masks, and evaporation or sputtering to deposit metal or carbon on the substrate, can achieve localized heating in the paper capable of about 200 μm resolution.

In electronically controlled displays, Siegel *et al.* have chosen an inspired initial application. For diagnostics tests, clear display of results is an important attribute; it is also often overlooked, especially in resource-limited settings. For example, the lateral flow test that detects β-hCG to indicate pregnancy – one of the first diagnostic tests to be introduced to consumers – has recently been re-introduced to display an unambiguous digital result, in order to reduce error in user interpretation of intensities of bands (*i.e.* the Clearblue® Easy Digital Pregnancy test by Inverness Medical Innovations). The variety of display applications shown in Siegel *et al.* can potentially enhance such adaptations. This study also shows how lab-on-a-chip methods can be engineered to compete with display technologies. For example, the demonstration of flexible and foldable displays matches the capabilities of electronic ink (currently used in the Kindle book reader from Amazon), but with low cost of materials and low toxicity as advantages for disposable displays.

Several issues should be addressed for this method to be truly useful as a display of diagnostic results in developing countries. (1) Cost. Since the manufacturing process is complex compared with lateral flow assays, it may increase the overall cost of goods of a disposable diagnostic test and limit mass production capabilities. (2) Complexity. An electronic circuit has to be built for the assay detection module to interface with the driving electronic circuit for the display. This requirement establishes a minimum level of complexity in the instrumentation; how an integrated assay (in which the display element is embedded inside the disposable substrate rather than reusable instrument) will be driven by a battery is not yet established. (3) Competition. Since electronic control is used, this method will compete with other electronically controlled – but also low-cost and simple – display methods (*e.g.*, LEDs & LCDs).

Nevertheless, the technology presented by Siegel *et al.* is promising and abound with opportunities. For example, Xerox photo paper was used in this study, but in future, paper and membranes with a range of porosities, wicking speed, and mechanical properties can be tested. (Especially interesting for display applications may be glass microfiber and polycarbonate membranes from Whatman that can turn transparent.) A variety of new functions and applications can be expected from lab-on-paper systems, as this study shows how a novel manufacturing method (micropatterning of electrodes on paper) can extend lab-on-a-chip research into new ground (data reporting and display).

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References