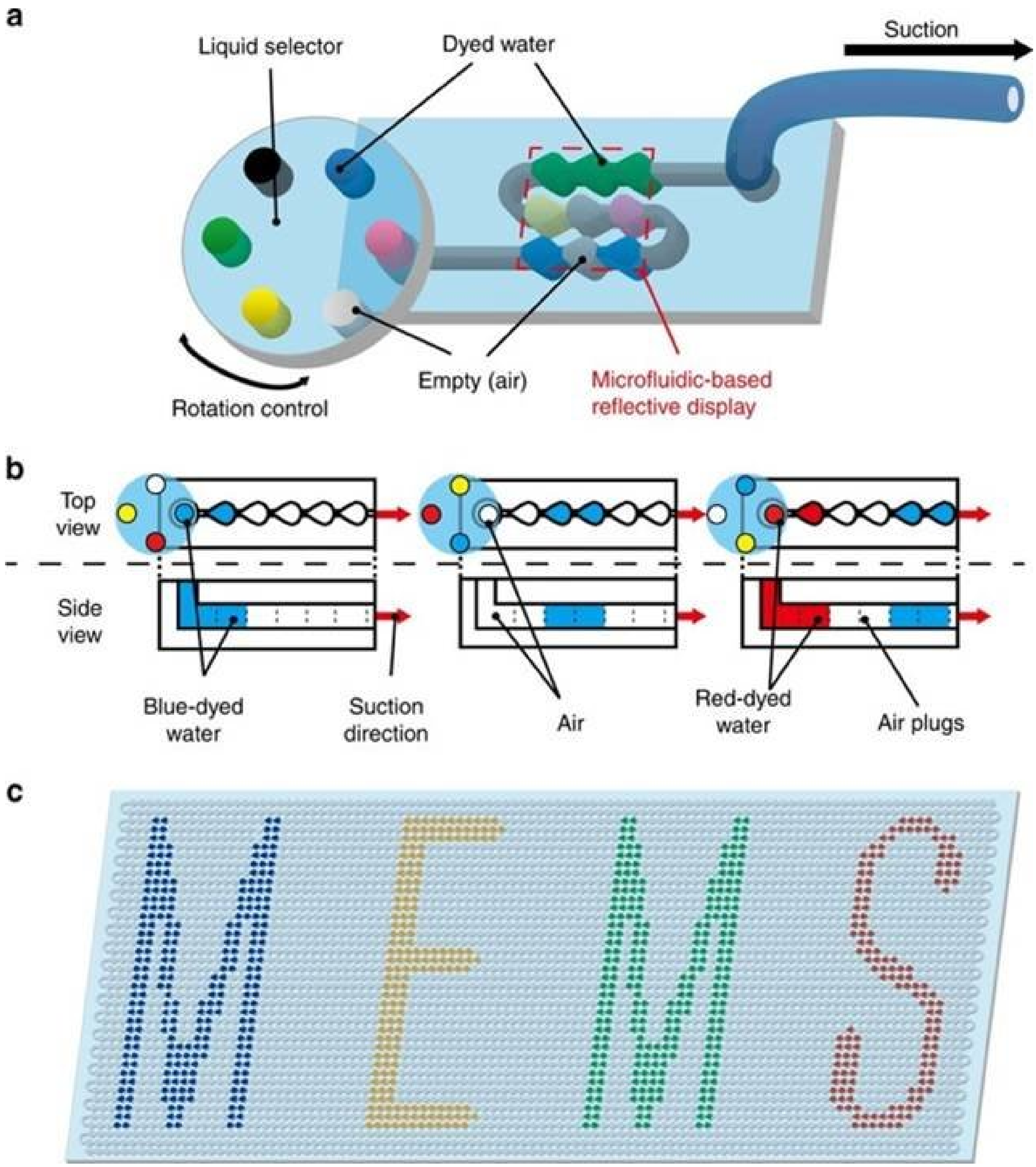
Flexible color displays with microfluidics

August 16 2018, by Thamarasee Jeewandara

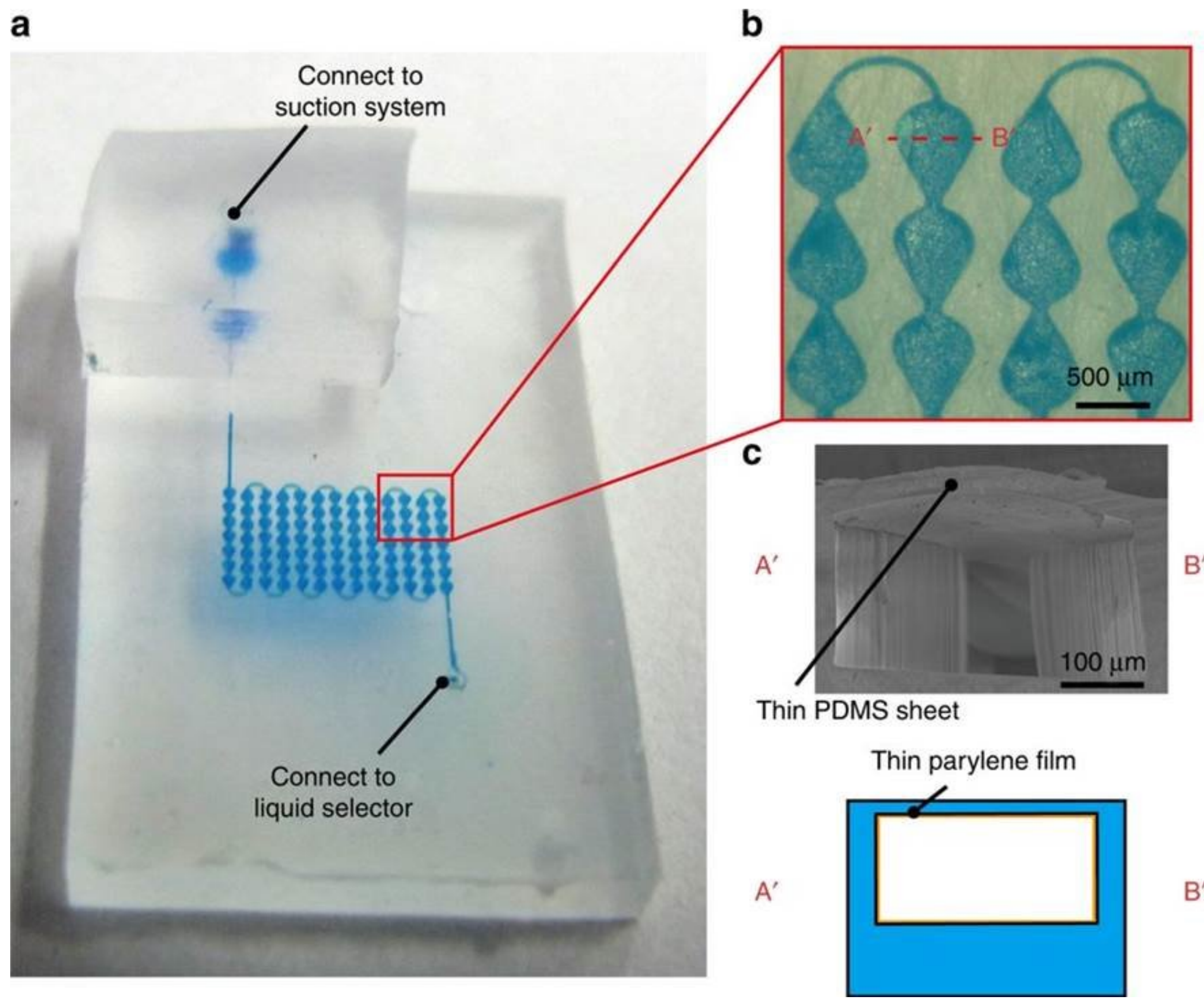


The schematic principles of device design and fabrication: The proposed microfluidic device made of polydimethylsiloxane (PDMS) polymer, using standard photolithography fabrication techniques to form pixel-patterned microchannels. The pressure inside the microfluidic device was regulated with a computer-controlled valve system composed of a solenoid valve, vacuum pump and air regulator. The switch control was programmed by MATLAB and gauge pressure controlled by the in-built regulator. Credit: *Microsystems and Nanoengineering*, doi: 10.1038/s41378-018-0018-1

A new study published on *Microsystems and Nanoengineering* by Kazuhiro Kobayashi and Hiroaki Onoe details the development of a flexible and reflective multicolor display system that does not require continued energy supply for color retention. The idea aims to find futuristic applications with sustainable color displays and replace existing electronic display signs currently used for multicolor messages and images. While the concept originates from electronic paper or flexible electronics that look like print on paper (developed for smart wear), the proposed method simply relies on sequentially introduced colored water droplets and air pockets in a microfluidic device precisely fabricated on a flexible polymer to maintain stable bitmap images without energy consumption.

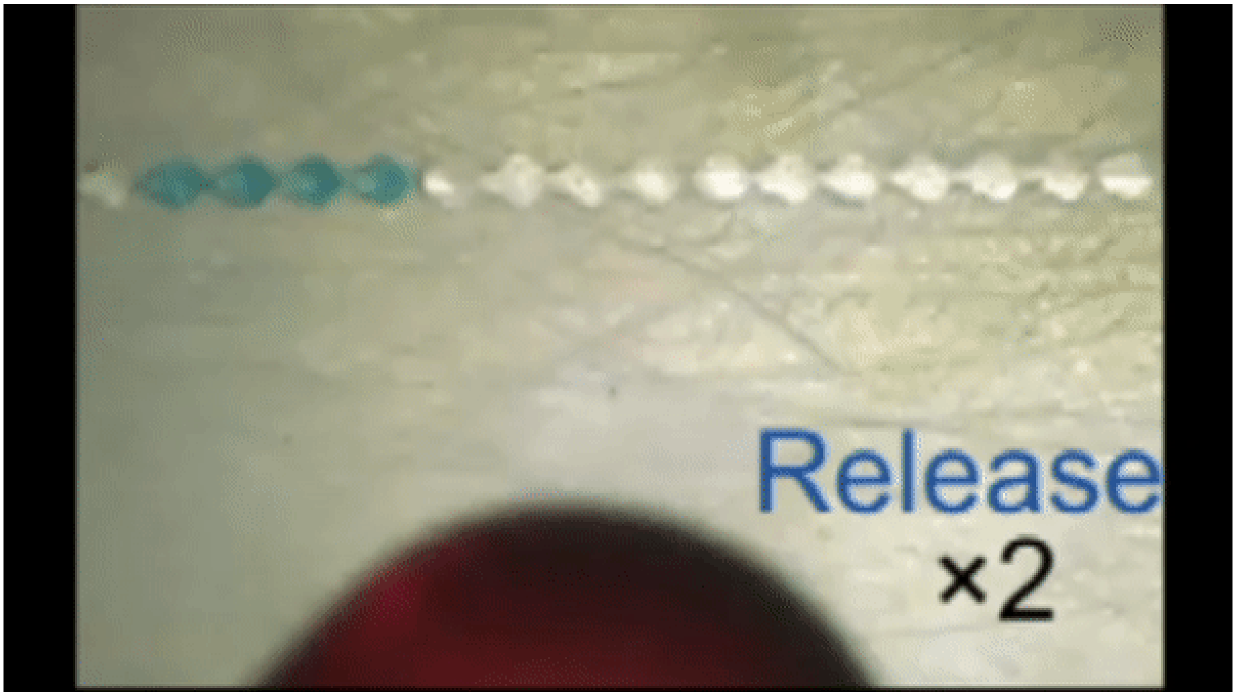
The method also deviates from existing techniques of liquid crystals or organic light emitting diodes (OLEDs), which consume energy at the level of the light-emitting pixel. The technique houses a microfluidic water droplet train as a flexible, reflective display. The working principle of the system is based on a rotary liquid selector with suction-based negative pressure to drive the droplets in the intended direction and form a predetermined sign.

Microchannels of the proposed device were fabricated with the flexible polymer, polydimethylsiloxane (PDMS), a material with properties that include transparency under visible light and permeability to air. The authors used soft lithography and bonding techniques to create PDMS-PDMS microchannels with pixel patterns ranging from 400-800 µm in diameter and 50-200 µm in height. In the device architecture, the patterns were connected via linear channels of 100-200 µm in width. Since the material is permeable to air and gas soluble, a thin Parylene layer (500 nm thick) was deposited within the microchannels to prevent the leakage and evaporation of air and water.



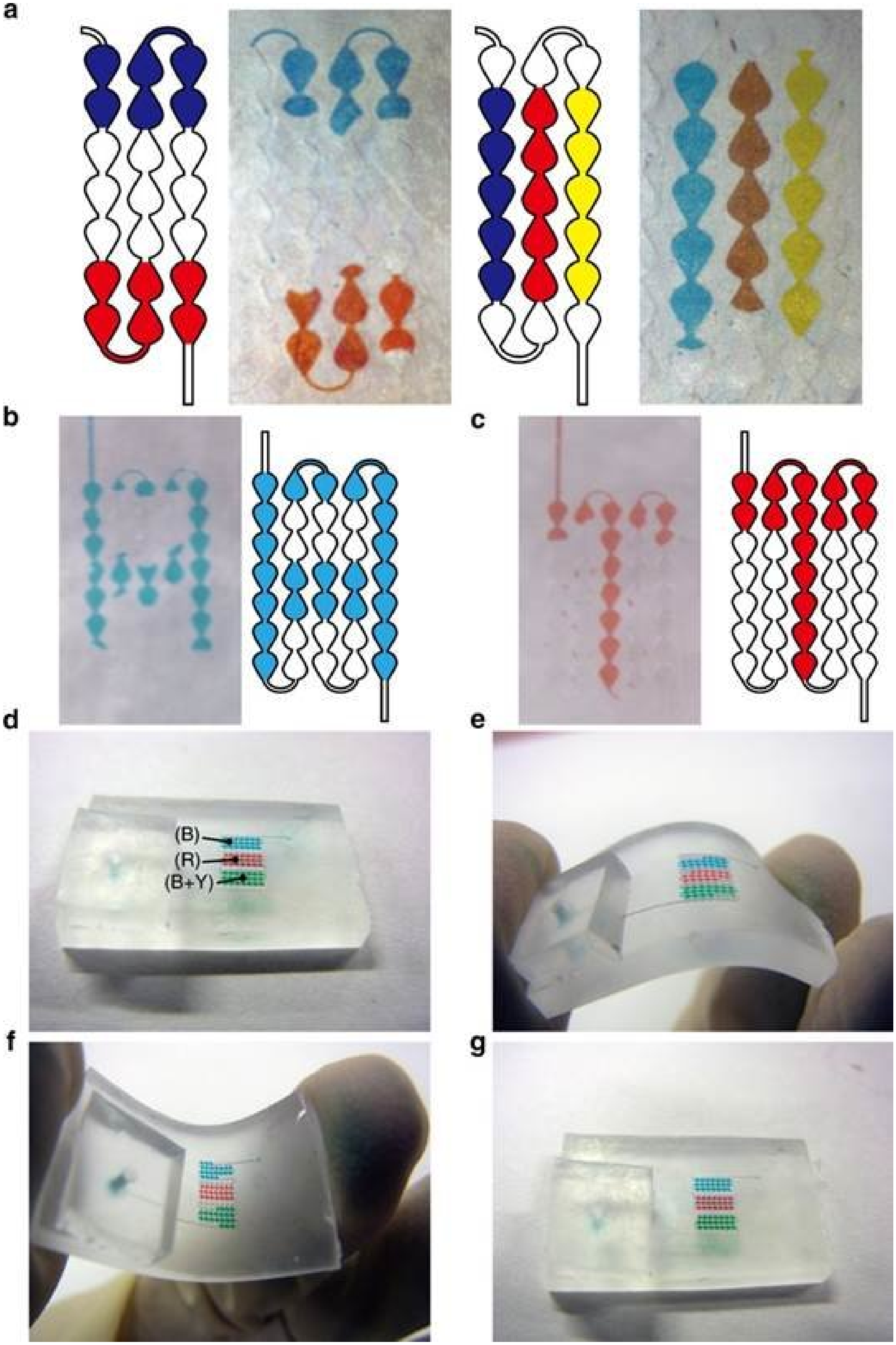
The fabricated device for color display a) Meandering microchannels with a 7x13 pixels (25 dpi) display. Inlet and outlet ports were connected to the liquid selector and suction system, b) microscopic images of the tear-drop shaped pixels that constitute the microchannels, the white dots on each pixel were caused by visible light illuminated on the device surface, c) cross-sectional view of the microchannel, a thin parylene film was deposited within the microchannel to prevent air leakage. Credit: *Microsystems and Nanoengineering*, doi: 10.1038/s41378-018-0018-1

To fabricate an optimized pixel size, the authors devised a relationship between the microchannel geometry and water loss in order to maintain a specific volume of dyed water as droplets advanced in the device. The device design and optimization included measurements of the minimal differential pressure required to drive dyed water droplets through the microchannels. The pressure within the microfluidic device suction system was controlled with a computer-aided valve system, and the switch control was programmed using MATLAB. In addition, the capacity for color switching and droplet control was assessed at the level of the single pixel for optimized image display. The relationship between droplet position and the time of negative pressure applied was optimized to indicate that the device could be controlled at the level of the single pixel.



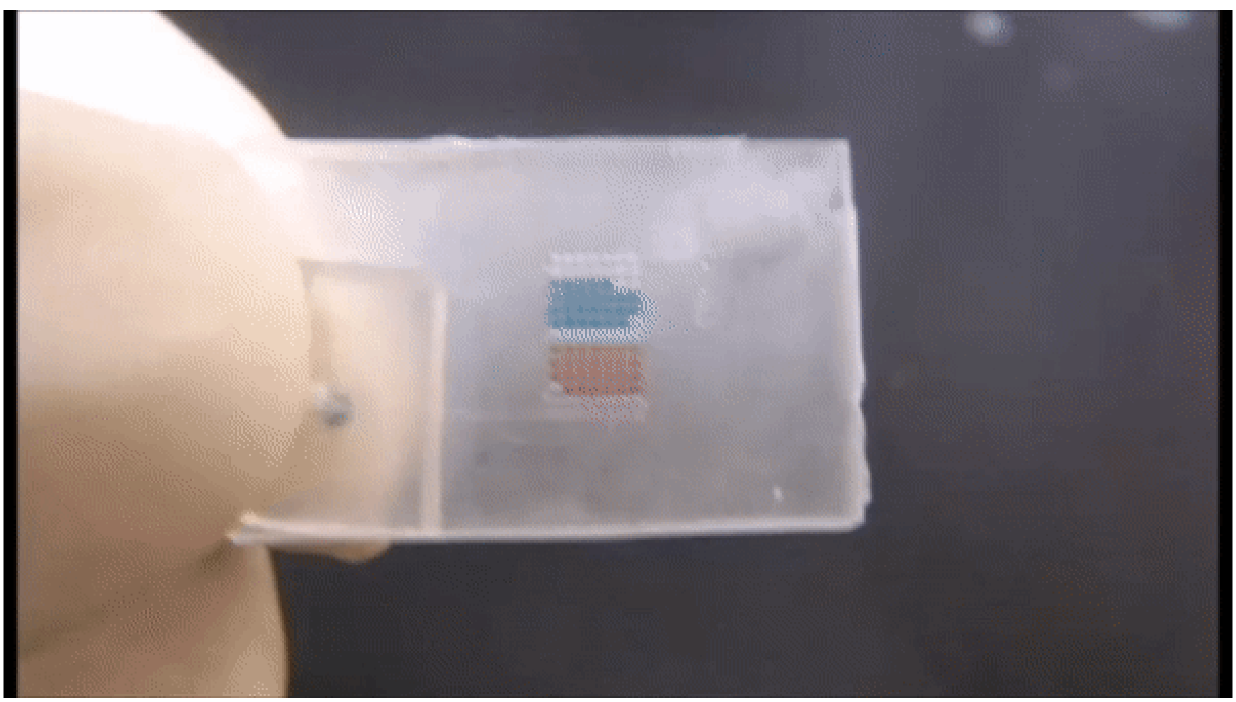
Observing the relationship between the droplet position and the timing of negative pressure applied to control the position of droplets at the level of the single-pixel. Credit: Microsystems and Nanoengineering, doi: 10.1038/s41378-018-0018-1

In the study, a range of images were created in this way in zig-zag microchannels as proof of principle to test the proposed concept of flexible multicolor reflective displays. Color retention was enabled by stopping the suction system, during which the orientation of the display remained intact without energy supply.


a
b
c
d
e
f
g
(B)
(R)
(B+Y)

The proof-of-principle of a three-color dot matrix a) multicolored stripe patterns (vertically and horizontally aligned) displayed on microchannels, b-c) the bitmap characters 'A' and 'T' visualized on the microfluidic-based reflective display, d-g) testing the flexibility of the display to indicate maintenance of the original framework for multicolored display retention. Credit: *Microsystems and Nanoengineering*, doi: 10.1038/s41378-018-0018-1

Experimental results validated that the system could display multicolored reflective images and retain them without energy consumption as theorized. The images were durable while maintaining their position after pliable twisting, to indicate flexibility and recovery of the original multicolored framework. The scientists predict that such flexible and energy-less display systems may find innovative applications on robot skins, clothes and accessories in daily life in the future.



Observing the flexibility, recovery and retention of the multicolored display within its original dimensions on microchannels of flexible PDMS. Credit: *Microsystems and Nanoengineering*, doi: 10.1038/s41378-018-0018-1

More information: Kazuhiro Kobayashi et al. Microfluidic-based flexible reflective multicolor display, *Microsystems & Nanoengineering* (2018). DOI: 10.1038/s41378-018-0018-1

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