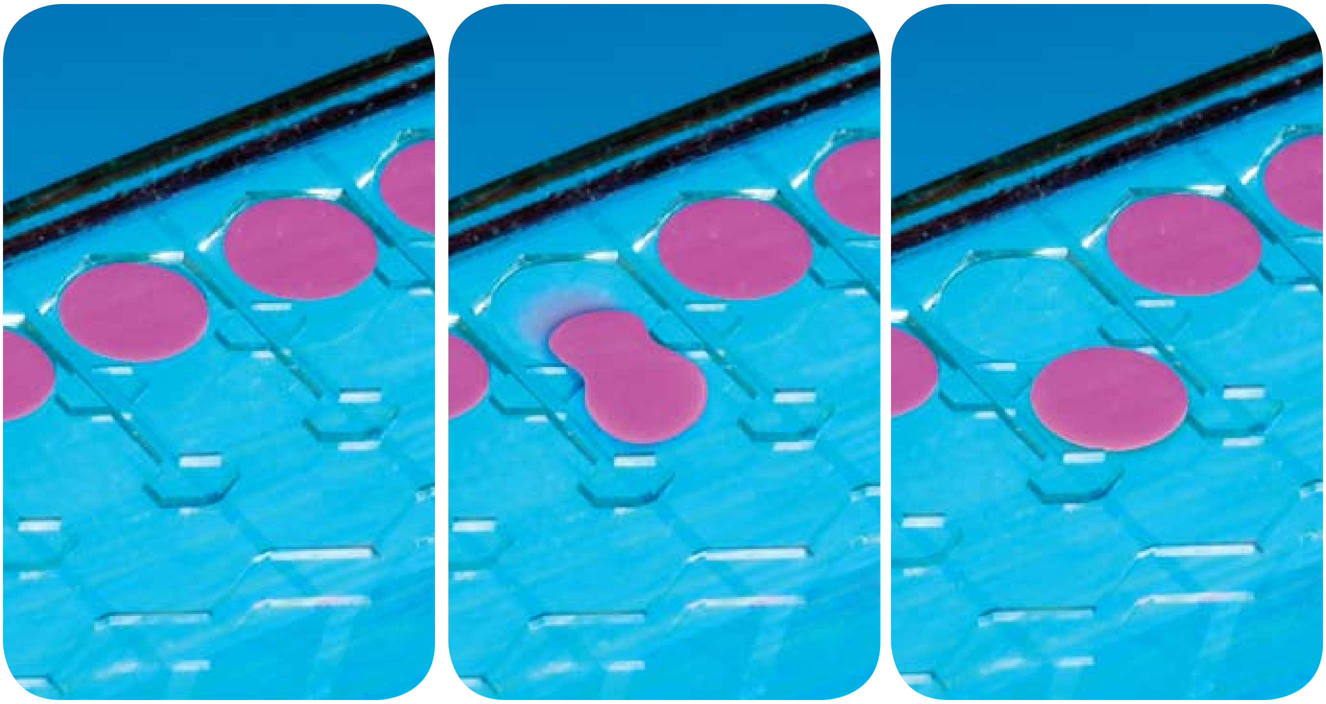
DROPLETS and PIXELS



Sequence shows how electrowetting moves a droplet from one chamber to another. The middle image shows the droplet on the move after voltage applied. In both the left and right images, the droplet maintains its position without voltage. In a display implementation, one side would be masked, so that the colored droplet alternately appears and disappears from the pixel.

Microfluidic technology enables high reflectivity and bistability.

by richard babyak

The seemingly simple act of moving a miniscule droplet of dye from one reservoir to another in order to change pixel status lies behind a novel display technology developed by advanced display technologies (adt) Deutschland GmbH, Bad Soden, Germany, in conjunction with Bartels Mikrotechnik GmbH, Dortmund, Germany, and Pforzheim University, Pforzheim, Germany. The droplets are shuttled back and forth using the principle of electrowetting, an approach that enables the creation of a passive matrix display that is highly reflective, bistable, scalable, and can be produced on flexible substrates.

The principle of electrowetting involves the application of a voltage to change the surface tension of a droplet on a hydrophobic substrate. Without the voltage, the droplet remains contracted, like a bead of water on a freshly waxed car. When the voltage is applied, the droplet relaxes and spreads out. The effect is the same as adding a surfactant, only here it is accomplished electrically instead of chemically, and is reversible by removing the voltage.

There are different ways of employing the electrowetting effect. Liquavista, Eindhoven, the Netherlands, developed a display technology where a fixed droplet alternately relaxes to cover a pixel cell and then contracts into a corner of the cell. (See "Color Coordinated," Appliance Design, November 2007, page 28.)

The adt method employs electrowetting to move the droplet from one cell to another. The cells are filled with a clear oil, so there are no voids, just one liquid (dye) moving and displacing the other liquid (clear oil). With this approach, one cell is open and visible, while the other is masked and not visible. In other words, the droplet alternately emerges from or retreats to its hiding place, thus leaving the visible pixel either colored or clear. When the cell is clear, light passes through and is reflected off a white backplane. The concept can be implemented one of two ways, with the two cells adjacent to each

Electrowetting is used to move droplets in and out of 2 mm pixels in a 5 x 7 monochrome array that is passively driven.

other or stacked. In the first, the droplet moves sideways; in the second, it moves between an upper and lower location.

The dyed droplet is electrically engaged by means of a common electrode covering both cells and two separate control electrodes beneath the cells. The two separate control electrodes permit a phasing of the voltage application that coaxes the droplet from one cell to the other. Once the droplet has moved into a new cell, it will stay there after the voltage is removed. This is what makes the display bistable, meaning that it only draws power when pixels change; the display does not require power to maintain static information. The power-saving aspect of a bistable display benefits portable applications that rely on battery power.

Grayscale representation can be achieved one of two ways. One is to keep the pixels in a binary on/off mode and achieve grayscale by spatial dithering, varying the ratio of light-to-dark pixels in a pattern. An alternate approach involves partially filling the visible cell with the dye in varying increments using a technique that can define the volume of the droplet being moved.

A full color version of the display can be created by stacking three layers containing cyan, magenta, and yellow dyes, respectively, which produces color by subtractive color mixing. (Stacking magenta and yellow to display red, cyan plus yellow for green, magenta plus cyan for blue, and stacking all three to produce black.)

The available pixel sizes for an adt electrowetting display are on the larger side, currently ranging from 0.3 mm to 10 mm. The displays can be driven by commercially available ICs, but an ASIC is planned for the future. Driving voltages vary from 10 V to 80 V, depending on droplet size and

In a simple indicator implementation, electrowetting moves the colored dye in and out of the visible area under a lens, serving as an LED alternative.

desired switching speed.

The switching speed varies by voltage and droplet size. Smaller droplet sizes can have switching times of 300 ms and lower, with the best time achieved so far being 100 ms. Droplets at the larger end of the scale can switch between 300 ms and 800 ms.

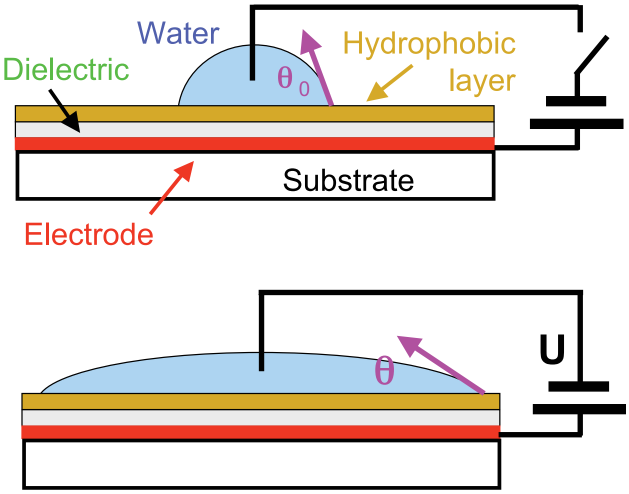
Adt says that the displays are readable in sunlight and provide a paper like quality, with a 10:1 contrast ratio, reflective light transmission of >85 percent, and white reflectance of 77 percent. It also says the CMY version of the display can produce a wide color gamut similar to that of a color printer.

The displays can operate within a temperature range of -40 DegC to >100 DegC and their manufacturing process allows them to be produce on flexible substrates. The passive matrix driving scheme avoids the cost of thin-film-transistors.

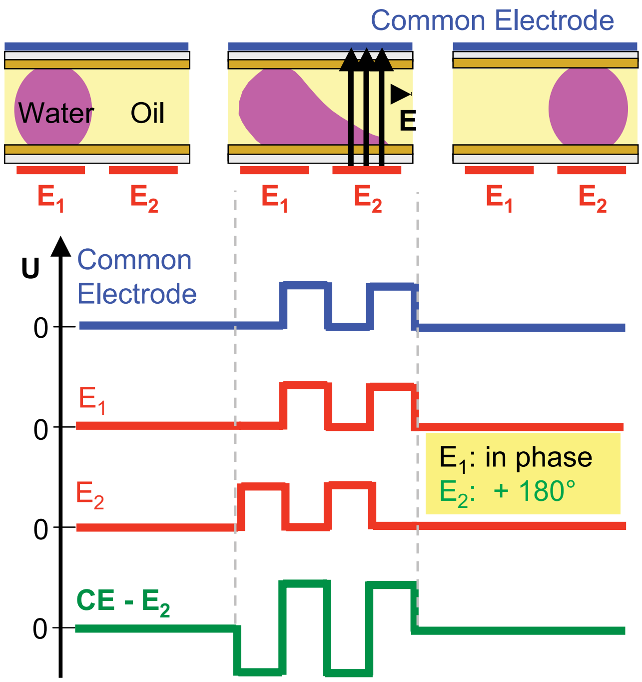
According to adt, the technology is broadly scalable, from the perspectives of both size and content complexity. Displays can be sized small enough for smart cards and watches, and large enough for signage and billboards. The technology can be used for low-content applications such as 8-segment displays or simple on/off status indication, but can also be employed for high-resolution displays in PDAs and document viewers. The company says it expects strong interest from home appliance makers because the technology can produce a "true white" display to match a white appliance. ■

For more information, take the taxi at *www.appliancedesign.com/taxi* or visit: *www.adt-gmbh.com*

The ability to attain a "true white" will make the technology attractive to appliance makers, according to adt.



The electrowetting effect can be described as the change of contact angle of a fluid resulting from the application of an electric field. In the lower drawing, the water droplet has wetted out in response to the applied voltage.



This sequence illustrates how the applied voltage draws the droplet to the alternate position.