temperature flux of magnesium is three to 10 times greater than the high-temperature flux," de Villiers says. She concludes that far more chemical processing takes place in the warm rock within 2 to 10 kilometers of the central ridge axis than at the ridge axis itself.

The report has elicited a mix of caution and guarded enthusiasm. "That's a very high precision she's claiming for an element [magnesium] that is very hard to measure with a mass spectrometer," says chemical oceanographer John Edmond of the Massachusetts Institute of Technology. "I would be cautious." Mottl agrees that more profiles need to be analyzed by a number of groups, but he feels de Villiers and Nelson "have found something very important." He adds that much of the water in their plume could be coming from even cooler springs, farther from the ridge axis, than de Villiers thinks. "I certainly wouldn't rule out that she's got a substantial input from the [ridge] flank," he says.

If de Villiers and Nelson's technique for tracing plumes of chemically altered seawater to their source pans out, he says, "it will probably be the best way to get the hydrothermal flux" of salts coming off the midocean ridges. The final answer about how the sea gets its salt should be satisfying, if not as spectacular as it once seemed.

–RICHARD A. KERR

DISPLAYS

Switchable Reflections Make Electronic Ink

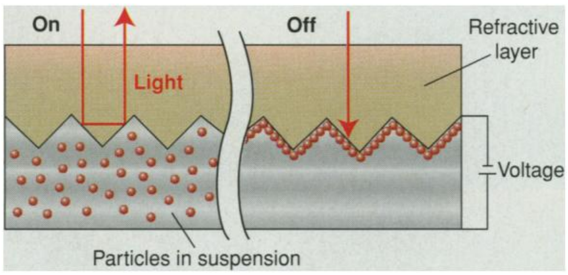
An electronic version of paper and print would combine the optical principle used in reflective signs with a scheme for squelching the reflections at will

Despite the fantastic array of technologies now put to use to display information, the old-fashioned printed word shows little sign of fading away—people just love the comforting look of black ink on white paper. Display researchers have come up with a host of schemes to mimic that partnership in a rewritable medium, many relying on small particles of dark pigment moved around in a liquid suspension by electric fields. So far, most of these electronic ink technologies lack the right mixture of properties, such as low cost, high contrast, and fast rewrite speed. But Lorne Whitehead, a physicist at the University of British Columbia (UBC) in Vancouver, and his colleagues have devised a new electronic display principle that they believe may have the speed and contrast to take some of the shine off ink and paper.

Their technique forms black characters on a white background by switching on and off the reflection of light from a screen. It combines a century-old optical principle called total internal reflection (TIR)—the same principle that makes stop signs bright—and a technique for turning off TIR at will. "The science involved is delightfully simple," says physicist George Beer of the University of Victoria in British Columbia. "The principle has been shown to work." He cautions, however, that the team has not yet shown how to build a working display screen. "The missing ingredient is the technological details."

TIR takes place when light that has penetrated glass—or some other material that bends light sharply—reaches a boundary with a less refractive material, such as air. If the light strikes the interface at a shallow angle, none of it escapes, and it is all reflected back into the glass. TIR is the principle that keeps beams of light careering down fiber optic cables. Whitehead had been trying to improve light guides, but about 2 years ago he wondered if the same phenomenon could be harnessed in a display. "If you can make a surface look white because of TIR and then stop [the TIR] where you want words to form," he says, "it will look like a black-on-white display."

At a meeting of the Canadian Association of Physicists in New Brunswick last month, Whitehead's colleague Andrzej Kotlicki and his student Michele Mossman showed how they would turn that idea into a display screen. They demonstrated a white, flexible sheet made of minute interconnected polycarbonate prisms. The sheet looks bright because, like the reflective coating on a stop sign, it bounces light off the internal interfaces at the correct angle for TIR, eventually directing the light back out toward a viewer.



Blackout. Reflection from the back of a transparent layer is switched off when a voltage coats it with absorbing particles.

To achieve an "ink" effect, the researchers exploited the fact that, because of light's fuzzy wavelike nature, some of the waveform extends about 1 micrometer beyond the surface where the light is being internally reflected. This leaked light is known as an evanescent wave. "To stop TIR, all you have to do is stick an absorbing material into the evanescent wave," says Whitehead. The researchers provided the absorbing material by backing the reflective sheet with a thin layer of fluorinated hydrocarbon liquid in which charged particles were suspended. Using electric fields, they could maneuver the charged particles into the evanescent wave region behind the reflecting sheet to switch off the TIR.

Other schemes for producing electronic ink also use electric fields to move charged particles in a fluid, but those particles must move laterally by about 10 or 20 micrometers to achieve a good contrast between black and white. In the UBC scheme, the particles have to move only about a micrometer toward the screen to switch off TIR. "It is a very sensitive way to switch light," says Whitehead. "You can move an absorbing material a very short distance and get a dramatic change in absorption."

That could mean a faster response and lower power needs than other electronic ink schemes, Mossman says. So far, the group has switched TIR on and off in just a single patch of screen. But they are now planning a prototype display consisting of many pixels, controlled with circuitry like that of the liquid crystal displays in palm-top computers.

The challenge is easier for larger scale displays that need not change as quickly, such as highway signs, and the group is working on several ways to move an absorbing material in and out of the evanescent wave for efficient, low-power displays. One uses air pressure to push an absorbing silicone gel against the walls of the miniature zinc sulfide prisms. Group member Robin Coope is working with the company 3M to commercialize this technology, and the researchers have already shipped a prototype sign for testing.

Physicist Edward Sternin of Brock University in Ontario says that he is eager to watch the group's progress: "It is always exciting to see the application of an old physics principle that has immediate and direct applications to technology."

–MEHER ANTIA

Meher Antia is a writer in Vancouver, Canada.

SOURCE: WHITEHEAD ET AL.