How eInk Puts Words on Your eReader

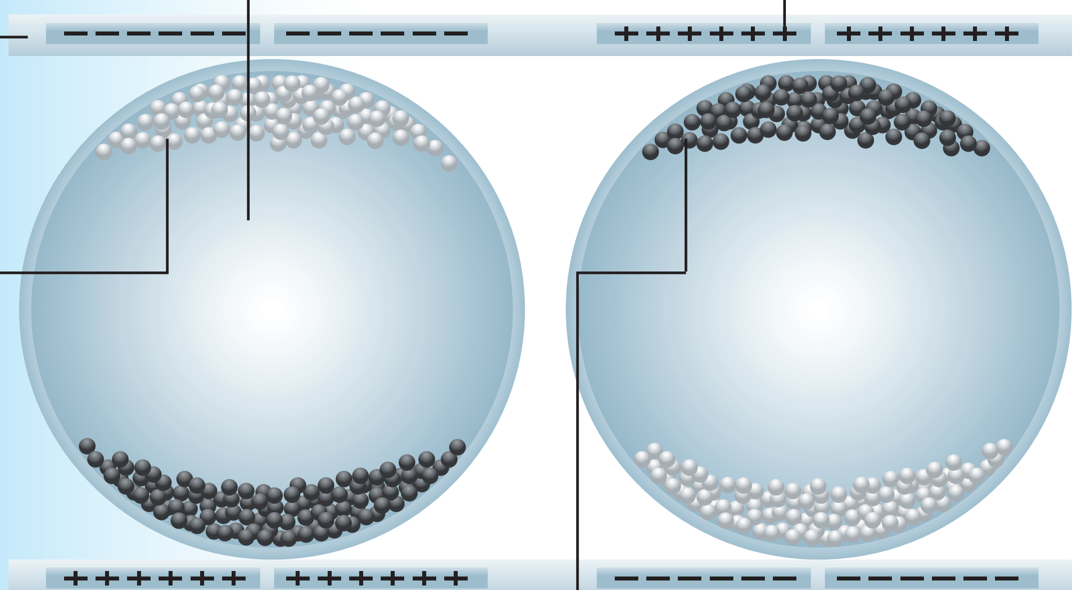
THE MOST SURPRISING thing about a mobile device, such as the Kindle, comes when you turn it off. The screen doesn't go dark. The screen continues to display an image. Sure, the image doesn't move or change, but what keeps it going without running the battery down to zero?

It's called electronic ink. An **electronic paper display (EDP)** looks much like a traditional sheet of paper—thin and flexible. But instead of the mashed wood pulp that goes into ordinary paper, a sheet of electronic paper, about twice the thickness of common paper, is made up of two sheets of thin film that sandwich millions of **microcapsules** containing electronic ink.

1 The forerunner in the industry, E Ink Corp., uses an **electrophoretic frontplane,** a sort of e-paper sandwich filled with a layer of microcapsules that are 100 microns wide, roughly the diameter of a human hair. A square inch of electronic paper contains 100,000 of these microcapsules.

2 Each of the capsules contains a clear liquid polymer. Suspended in the fluid are tiny white and black particles, made of several silicone dioxide-coated layers, beginning with a white or black titanium dioxide pigment. The outer layer is a carbon-based, hair-like surface. The hairs stop the particles from sticking together and hold a positive electrical charge on the white particles and a negative charge on the black ones. These charges allow the particles to be herded through the microcapsules' liquid center.

3 The e-paper's bottom layer uses a **TFT (thin-film transistor), active-matrix** technology also found in the screens of laptops. The organic–carbon-based–transistors are printed directly on the film along with circuits leading to a microprocessor. The processor sends signals to those transistors, causing each to have either a positive or negative charge.



4 On a blank sheet of electronic paper, a processor has sent a positive charge to all of the microcapsules. Because similarly charged materials repel each other, the positively charged white particles move away from the bottom layer to the top surface of the paper, creating a sheet that is completely white.

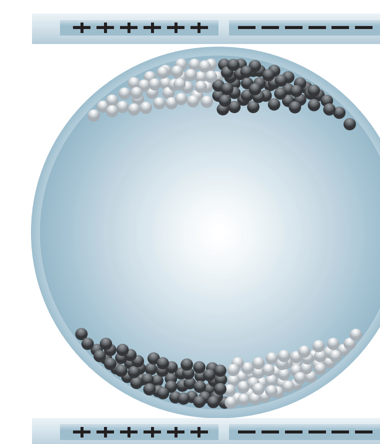
5 To create dark text or images on the paper, the processor reads the text or images from up to hundreds of books stored in memory chips, and sends signals to the transistors in patterns that correspond to the shape of text or images from the book. These signals give those transistors negative charges that pull the white particles down from the top surface of the paper and push the positively charged black particles up to take the place of the white bits.

E-paper Versus Laptops

Significantly, the signals to the transistors last only microseconds, but the electrical charges remain after the signals have ended. This is why images remain on Kindles and other readers after they are turned off. In fact, like real paper, the Kindle needs a light shining on the front of the paper for anything to be visible to the reader. The brighter the light, the easier it is to read. Laptops, in comparison, are harder to read in bright light. These differences are also why readers' batteries last so long between charges compared to laptop displays.

How Black and White Produce Shades of Gray

1 It would appear that each dot making up electronic ink is either all on or all off. And yet these readers are capable of displaying finely detailed images, such as this one from a first-generation Kindle.



2 Detail and shading are partially a product of the fact that there are more transistors in the bottom film than there are micro pigment capsules. The processor sends opposite signals to transistors placed next to each other so that one transistor forces black particles to the top while the other transistor forces white to the top, with the combination creating gray.

3 The other way e-paper creates shading and detail lies in the fact that each pixel, usually created by two microcapsules, is extremely small. In this photo, shot through a microscope, the red circles identify black dots outside the lettering and the white dots in the black letters. These are defective microcapsules, or capsules stuck in the wrong positions, which give you an idea of the size of the capsules. When you see how many of them go into creating ordinary text, it's easy to imagine how combinations of tiny white, black, and gray microcaps can be mixed to create subtle images. (Also, notice the green circles around gray dots used for anti-aliasing the jaggies.)