TECHNOLOGY

New Electron Emitters May Slim Down Computer Displays

EINDHOVEN, THE NETHERLANDS–Computers seem to become more sophisticated by the minute, but behind every desktop computer screen sits a bulky descendant of the first electronic devices ever made, the so-called Braun and Crookes tubes of the 19th century. Like those first vacuum tubes, modern-day cathode ray tubes (CRTs) contain electron guns, which fire beams of electrons across a vacuum at a phosphor screen that lights up in response.

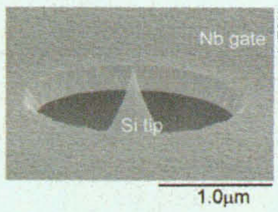
CRTs work extremely well, but for laptop computers and applications such as future avionics displays, those chunky screens just won't do; a more slender, lightweight screen is needed. One solution takes the form of today's flat-screen laptops, which avoid electron beams altogether and rely on glowing liquid-crystal displays (LCDs) instead. Until recently, this technology seemed the way to the future for displays on everything from laptops to car dashboards to copiers and cameras. But LCDs, in which liquid-crystal cells transmit more or less light from a background source depending on the electric field, are poorly suited to some applications, such as those requiring very large screens. So some researchers are exploring a different route: in effect, shrinking the CRT into a flat package. They are experimenting with very small electron-emitting devices, called field emitters, which can be fabricated with current nanotechnology methods—and may give LCDs a run for their money.

The promise of electron-emission research was evident when 200 scientists gathered here from 1 to 4 July at the First International Vacuum Electron Sources Conference. Field-emitter displays (FEDs) still have some drawbacks—they often require high voltages and provide a fluctuating current that causes the display to flicker, for example—but new materials, fabrication methods, and strategies for improving their behavior are brightening the prospects for flat-panel CRTs. Indeed, at least one company hopes to have them on the assembly line in about a year. Meanwhile, other researchers are uncovering new applications for field emitters in microscopy, and still others are trying to slim down the traditional CRT. Thanks to "strong pressure from the display community," research on these devices is flourishing, says Peter Duine of Philips Research Laboratories in Eindhoven.

The oldest and still the most ubiquitous vacuum electron sources are the thermionic cathodes, which use heat to cause electrons to flow from a filament or tube. But these devices typically build up too much heat for use in a flat-panel screen. In contrast, field emitters (also called cold cathodes) rely on an electric field to pull out the electrons, much as a strong field can create an electric spark.

Electric sparks generally occur at sharp edges because that is where electric fields are strongest. Most field emitters take advantage of this fact by employing arrays of nanotips, small cones of metal, silicon, or diamond that emit a stream of electrons into a vacuum. In prototype flat-panel displays these arrays are as big as the screen itself, and up to 3000 nanotips fire electrons at a single pixel.

Some materials emit electrons more readily than others, and a flurry of research is seeking the best ones. Many researchers see diamond, which emits electrons even more readily than many metals, as the front-runner, and at the meeting, scientists reported improvements on diamond's already glittering performance. For example, Michael Geis of the Massachusetts Institute of Technology's Lincoln Laboratories in Boston coaxed electrons from diamond grit, a form of diamond which has many sharp edges, at a field strength of only 5 volts—"probably a theoretical minimum," he says. That low voltage allows the emitter to be directly connected to the controlling semiconductor electronics, which simplifies the assembly.



Not only does diamond readily surrender electrons, says Geis, but "in some cases the electrons seem to become very energetic, much higher than you expect." Apparently, electrons can propagate inside diamond as if it were a vacuum, explains Paul Cutler of Pennsylvania State University: "Electrons in diamond exhibit ballistic properties: They gain energy from the [electric] field and can be emitted with nearly all the energy that the field imparts on them," he says. This opens the way to an entire new field, vacuum microelectronics, in which diamond serves as a form of solid-state vacuum.

Making screens skinny. A trimmed-down conventional CRT (*above*) is one route to a flat-panel display; another uses an array of nanotips like the one coupled to a gated transistor (*top right*).

In fact, diamond doesn't even need to be shaped into a nanotip to serve as a cold cathode, because diamond films, which are easier to manufacture, also display excellent emission properties. That is because a diamond "film" may really be composed of sharp points at the nanometer scale, says Henry Gray of the Naval Research Laboratory in Washington. "Even the very flat diamonds appear to be extremely small sharp structures," he says.

Although research on diamond is furthest along, other materials can also deliver precise electron beams. Last year, Walter de Heer from the École Polytechnique Fédérale de Lausanne reported coaxing graphite, in the form of tiny tubes called nanotubes, to emit electrons (*Science*, 17 November 1995, p. 1119). At the meeting, he announced a fivefold increase in the emission intensity, which means that nanotubes may emit enough electrons to drive phosphor screens. "Now we are competitive with the diamond films," he says.

Other materials can also be turned into field emitters if they can be made into a sufficiently sharp tip. Vu Thien Binh of the University of Lyon, for example, reported an ingenious method for crafting a nanotip only one atom wide by using an electric field to pull a heated, viscous material such as tungsten into a point. Binh showed that such tiny tips can emit a low-energy beam of electrons of 200 electron volts. The feat could benefit electron microscopes, which typically use beams with an order of magnitude more energy, and so break the carbon-hydrogen bonds of biological molecules. Binh's "gentler" electron beam may offer a new method for studying such molecules. Already, he and colleagues have observed a polymer superstructure and the structure of RNA with their new nanotip.

Of course, like all technologies, field emitters have their drawbacks. For one, the current that nanotips emit often fluctuates by up to 50%, because the tip is constantly bombarded with atoms from residual gas in the vacuum. The result is that flat-panel CRTs are prone to uneven illumination of the screen. One way to control the current is to use the nanotip as the "drain" in a particular kind of transistor (called a MOSFET transistor), as reported at the meeting by Junji Itoh of the Electro-Technical Laboratory in Tsukuba, Japan. By controlling the voltage in the transistor, researchers can control the rate at which electrons flow out of the nanotip. In Itoh's device, emission fluctuated by only a few percent, a solution that could make the field-emitter arrays more readily usable.

So far no flat-panel displays on the market actually use field-emitter arrays, but Robert Pressley from Candescent Technologies (formerly Silicon Video Corp.) in San Jose, California, says that his company expects to manufacture such displays in about a year. "We are now at the stage of putting the assembly line together," he says. They hope that their design, in which several thousand molybdenum nanotips illuminate each pixel on command, will be a competitor for the high-end LCD market.

Meanwhile, researchers haven't forgotten the traditional CRTs, reporting sizable increases in electron emission in thermionic cathodes, for example. And at the meeting, a Philips Research Laboratories team unveiled a fully working prototype of a flat-panel display that is basically an adaptation of a conventional CRT. Rather than emitting electrons from many single points adjacent to the screen, as the nanotip-based FEDs do, this device relies on a linear array of common thermionic cathodes mounted in the bottom of a flat tube less than 1 centimeter thick, with a phosphor screen on one side and supporting struts in the middle.

These internal pillars keep the flat sides of the vacuum vessel apart and also guide the electrons to the screen, says team leader Gerard van Gorkom. When an electron hits a strut, the strut responds by emitting exactly one secondary electron. The emitted electrons thus "follow" the path laid out by the struts, so researchers can precisely direct the electrons to the screen. "It is very nice technology," says Pressley. "To me it is amazing that no one stumbled on that before," agrees Brad Pate of Washington State University. "If the price is right, this is a real winner."

But apparently, not everyone thinks so: In April, Philips decided to discontinue development of the device because it had no partners in the project. "We do not exclude the possibility that others will take up this project," says van Gorkom, who hopes that Philips might one day restart the project. But even if Philips backs away from this device, the flurry of results seems likely to help computer screens of the future shed their portly profiles in favor of a trim silhouette.

–Alexander Hellemans

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MEETING BRIEFS

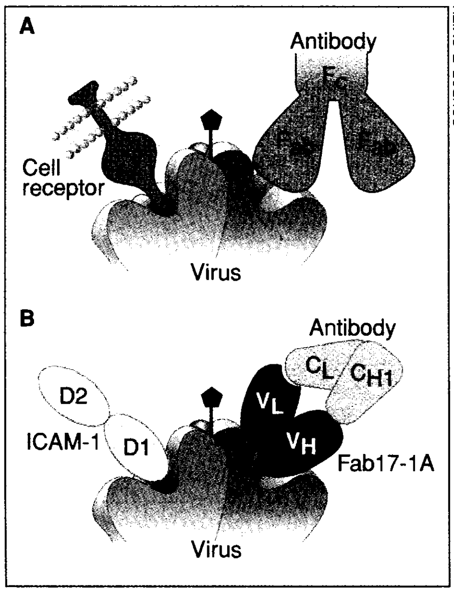
Crystallographers Pinpoint What Goes Where

SEATTLE—In structural biology, as in real estate, location is key. And by tracking x-rays or other high-energy sources as they scatter off crystallized biomolecules, crystallographers can pinpoint locations of structures that perform crucial biological functions. At the International Union of Crystallography XVII Congress and General Assembly, held 8 to 17 August, researchers using the technique reported insights into the evasiveness of viruses and the failure of AIDS drugs, among other topics.

Cold Virus Betrays Potential Achilles' Heel

Science still has no cure for the common cold. Fortunately, the immune system has its own remedies. New findings presented at the meeting reveal one immune strategy, showing that antibodies, immune proteins that attack invaders, can directly block features on rhinoviruses, the cold-causing culprits. The conclusion overturns previous assumptions about antibody behavior, and may serve as a model for anti-cold remedies that could supplement the natural defenses.

Researchers have long known that the surfaces of many viruses are pocked with tiny crevices, which help them infect cells by latching onto complementary-shaped protrusions on the cell surfaces. Researchers also believed, however, that the crevices play a secondary role as well, helping viruses evade immune detection. If antibodies plugged up these crevices, they could not only keep the virus from binding to the cell, they could mark the virus for later destruction by the immune system's heavy artillery. But crystal structures of the surfaces of viruses suggested that the crevices in rhinovirus are so small that antibodies' bulky heads wouldn't be able to wedge their way in. Instead, researchers believed, the antibodies simply try to smother the crevices by lying on top of them. But viruses, being slippery beasts, could presumably counter this by altering amino acids on their outer coat, causing the antibodies to lose their grip.



SOURCE: T. SMITH

A better fit. (A) Older theories held that antibodies lay atop the cold virus; (B) the new view shows that they plug into viral crevices.

Yet after crystallizing rhinovirus particles with antibodies bound to them and bombarding them with x-rays, Purdue University crystallographer Thomas Smith and his colleagues came up with a different picture. Their map of the complex showed that part of the head groups from rhinovirus antibodies do, in fact, fit snugly in the viral crevices. The implication, Smith says, is that crevices' shapes evolved solely to boost a virus's ability to invade its victim's cells, not to avoid antibody interference.

"It's a very important finding," says molecular biologist Ian Wilson of the Scripps Research Institute in La Jolla, California, for it points researchers toward designer drugs that might be able to affect the crevice interior, limiting the ability of the virus to bind to target cells.

A Better Handle on AZT?

AZT has never amounted to the AIDS wonder drug that many had hoped it would be. At the meeting, a group from the Max Planck Institute for Molecular Physiology in Dortmund, Germany, reported a clue to the compound's shortcomings: AZT's molecular structure may make a poor "fit" with the cellular enzyme needed to transform it into an active, antiviral form.

AZT, or azidothymidine, stops viruses like HIV from replicating by preventing them from using the nucleotide thymidine to translate the RNA in their genome into DNA inside the cells they invade. The drug's structure