of concern," says Steere, who was also a principal investigator on one of the vaccine trials. Indeed, he notes, arthritis did develop in several subjects who received the vaccine, although a number of the controls also became arthritic. "Ongoing surveillance will be important" to detect any problems, he adds.

The path to the current finding began about 10 years ago. Immunologists know that some people are genetically predisposed to autoimmunity because of natural variations in their so-called HLA molecules, which reside on certain immune cells and help determine to which antigens a person responds. And in 1989, the Steere team found that the patients who get persistent Lyme-related arthritis very often carry a particular HLA variant designated *DRB1*0401*. Because that same variant is associated with rheumatoid arthritis, an autoimmune disease, it seemed that Lyme disease arthritis might itself result from an autoimmune attack, possibly triggered by a *B. burgdorferi* antigen that resembles some component of human joint tissue.

So, Steere and his colleagues looked for antigens on the pathogen that *HLA-DRB1*0401* might recognize. And in 1994, they found one that might fit the bill: a *B. burgdorferi* protein called OspA (for outer surface protein A) that was frequently recognized by the T type of immune cells from treatment-resistant patients but recognized only uncommonly by T cells from those whose arthritis responded to treatment. OspA had also become the primary component of the Lyme disease vaccine because it provided a protective antibody response in animals injected with it.

Steere's group then joined forces with immunogeneticist Huber to look for human proteins that might resemble OspA. Using a computer algorithm based on a previous lab analysis of DRB1*0401's peptide-binding abilities, they showed that DRB1*0401 binds to a particular nine–amino acid segment of OspA when it triggers an immune response. Then, the scientists searched a database looking for human proteins that contain the same sequence and might therefore be the target of an autoimmune attack initiated by OspA. They turned up one candidate, a protein called hLFA-1, found on blood and other cells.

When the researchers studied T cells from 11 patients with treatment-resistant Lyme arthritis, they found that nine of them carried T cells that respond strongly to the key sections of both OspA and hLFA-1. T cells taken from controls with other forms of arthritis did not show those responses. These findings suggest, Steere says, that T cells originally triggered to recognize OspA go on to attack the unfortunately similar part of hLFA-1 found on the patients' own cells.

Steere and Huber are quick to admit, however, that the evidence for this scenario is circumstantial. One worry is that they couldn't find hLFA-1–reactive T cells in all 11 patients, although Kotzin says that may just be because T cells from joint fluid can be hard to study. "That they are able to demonstrate such a specific response from these T cells is really remarkable," he adds.

But if that specific response to hLFA-1 causes the arthritis, asks immunologist Kai Wucherpfennig of the Dana-Farber Cancer Institute in Boston, why is the inflammation confined to the joints, while hLFA-1 is found on cells all over the body? One explanation: T cells naturally have hLFA-1 on their surfaces and therefore carry it along when they move into joints to combat *B. burgdorferi* infections. This may exacerbate immune-cell responses to hLFA-1, resulting in a vicious cycle in which the joints become permanently inflamed. Nonetheless, Wucherpfennig wonders whether "there may be other important targets that have not yet been identified."

Researchers might be able to settle these issues if they could recreate treatment-resistant, Lyme-related arthritis in an animal such as the mouse. So far, however, they haven't been successful, perhaps because mice have a different form of LFA-1. "This is an initial observation," says Steere. "Now, one sets forth on the next phase of the journey."

–STEVEN DICKMAN

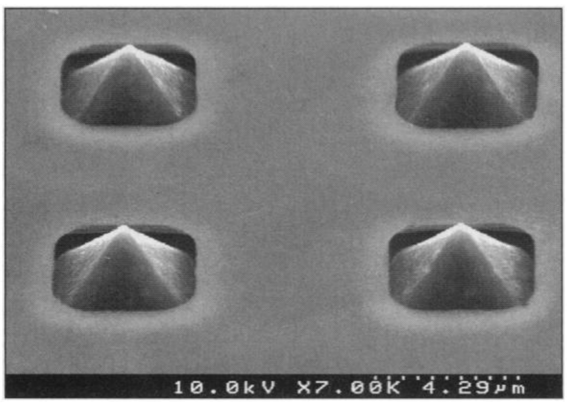
Steven Dickman is a writer in Cambridge, Massachusetts.

TECHNOLOGY

Field Emitters Finding Home in Electronics

New materials promise smaller, more efficient way to deliver electrons to flat-panel displays, cameras, and microscopes

TSUKUBA, JAPAN—The big vacuum tubes and copper wiring that filled the backs of early televisions have long since been replaced by tiny semiconductor chips and printed circuit boards. The one holdout against miniaturization is the cathode ray tube (CRT), which retains all the bulk and inefficiency of 50 years ago. Various flat-panel display technologies have emerged, but none matches the brightness and resolution of the CRT, in which a heated filament spews a stream of electrons that light up phosphors on the image screen. But time may finally be catching up with the CRT.



So long, silicon. These diamond tips (magnified 7000 times) form part of an emitter array developed by researchers at Vanderbilt University.

J. DAVIDSON, W. P. KANG/VANDERBILT UNIV.

A recent meeting here* highlighted advances in a technology that uses an electric field rather than heat to wrest electrons from an emitter material. A key step forward in this technology, called field emission, is the use of more durable materials that promise slimmer, more energy-efficient, and portable displays for personal computers. Perhaps more significantly, researchers are also applying field-emission technology to microscopes, image sensors, and other devices that have traditionally used electron guns, like those in CRTs, as electron sources. New uses for field emitters "have been popping up like mushrooms," says Chris Holland, a field-emission specialist at SRI International in Menlo Park, California. That activity, he says, is a good indication of how quickly the field is maturing.

Field emission is not a new idea, either. But the pointlike cathodes—traditionally made of silicon or tungsten—have tended to break down quickly in the powerful electric fields. Researchers have long had their eye on diamond film as a cathode material, but it has proven tough to fabricate into the sharply pointed shapes needed for electron emission.

* The Second International Vacuum Electron Sources Conference, Tsukuba, Japan, 7–10 July.

That obstacle also has hindered efforts to add an extra terminal, or gate, to the diamond cathodes—a drain as well as a cathode and anode—that allows for more precise control of the flow of electrons. At the meeting, however, two research groups have reported success in fabricating three-terminal, or gated, diamond arrays. In a display, for example, a gated array would mean faster, more precise switching on and off of pixels.

One team, at Vanderbilt University in Nashville, Tennessee, started with a pyramidal mold for the deposition of diamond film. They added terminals and backing, using conventional semiconductor fabrication techniques. Finally, the mold material was etched away. The result was a uniform pattern of diamond pyramids in a three-terminal configuration. Electrical engineer Jim Davidson says the array "could significantly outperform silicon devices in speed, power [consumption], and reliability" once some practical problems are solved. Among these is a tendency to get reverse current flow between the gate and the tip, which limits the three-terminal performance.

Wolfgang Mueller of Research 2000 Inc., a start-up company in Westlake, Ohio, described tests on an approach that dodges the problem of fashioning an array of diamond points. Starting with a silicon substrate, he adds a grid of an insulating material topped by a second conductive layer laid down in wide lines. The wells between the grid lines then get a sprinkling of diamond crystals. Passing a current from the substrate through the diamond crystals to the top conductive layer induces field emission in the diamond that should send streams of electrons to an anode above the semiconductor sandwich. This would be an extremely simple and easy way to fabricate a three-terminal array. However, Mueller and his team have yet to add the anode and make precise measurements of emission currents. "It is very recent work," he explains.

While researchers are still struggling with diamond emitters, a group led by Yahachi Saito, an associate professor of electrical and electronic engineering at Japan's Mie University, is staking its efforts on carbon nanotubes as field emitters. The team mounted a wafer of multiwalled carbon nanotubes on a substrate and treated the surface with an etch to remove carbon debris and expose the tips of the nanotubes. Then, they put this cathode in a thumb-sized vacuum tube with an aluminum film anode and a phosphor screen. This CRT lighting element emits a bright light that remains stable for 10,000 hours, promising to bring the brightness and resolution of the CRT to flat-panel displays. Ise Electronics Corp., which is collaborating on the work, has already adapted the device for use in a rudimentary flat-panel display.

But Saito says there are still formidable challenges to commercializing the technology. Scaling up the production of the device is one hurdle, as is making large quantities of the nanotubes themselves, now created by passing an arc discharge between graphite electrodes in a helium environment. "We've succeeded with an experimental device, but it's not clear yet if we can successfully commercialize it," Saito says.

A team at Delft University of Technology and Philips Research Laboratories in the Netherlands is studying carbon nanotubes as a possible electron source for electron microscopes. The big advantage of carbon nanotubes in that environment would be their ability to emit electrons in an extremely narrow energy range. "The more monochromatic the source is, the better electron lenses can be used to focus the beam," says physicist Martijn Fransen. A single, multiwalled carbon nanotube produced an energy spread of just 0.11 electron volts, compared with a spread of 0.6 to 0.3 eV from the best electron sources currently being used. "The difference doesn't seem like much, but it's quite important to get [the value] lower," he says. The biggest challenge, according to Fransen, is reducing the variability in emission characteristics among nanotube samples.

Indeed, field-emission researchers are now thinking far beyond flat-panel displays, which inspired the early work on the technology. Other groups reported attempts to use them in image sensors, mass spectrometers, and even in a surge absorber for high-speed computer communication lines, in which the surge of energy is diverted to emit electrons. But much more work is needed before emitters can deliver on their promises. "The easy experiments have been done," says Ian Milson, a researcher at EEV Limited, a British company considering ways to commercialize field-emission technologies. "The problems left are the difficult ones."

–DENNIS NORMILE

ECOLOGY

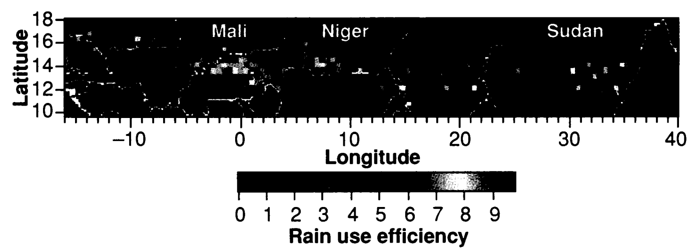
The Sahara Is Not Marching Southward

From a satellite perch, the supposed steady encroachment of desert into Africa's Sahel appears instead to stem from climate variation

Twenty-five years ago, the Sahel—the narrow band of barely habitable semiarid land stretching across Africa at the southern edge of the Sahara—was thought to be on the verge of disappearing. Images beamed around the world showed deep drought, starving millions, and land stripped of vegetation by man and beast as human activity turned the land into permanent desert. Sub-Saharan Africa became the embodiment of "desertification," the human-driven, irreversible expansion of the world's deserts. Thought to be gobbling up tens or even hundreds of thousands of square kilometers of arable land every year, desertification provoked an outpouring of aid and an international treaty.

For the past decade, however, scientists armed with ecological studies have been fighting the idea that such desertification is wide-spread or largely human induced. Now, they have satellite images to bolster their argument that much of what has been called desertification was instead the reflection of natural ups and downs of rainfall.

"We're not trying to say desertification is not happening," says climatologist Sharon Nicholson of Florida State University in Tallahassee, lead author of one of two recently published satellite studies. "We're saying the scenario of the Sahara sands marching southward at the hands of humans is wrong." The studies show that natural climate variation has shifted the desert's edge, with no net effect on the amount of vegetation. Although people may be degrading the drylands of the Sahel, mainly by changing the mix of plants, they aren't expanding the desert.



Two views of the Sahel. Broad satellite views show no change in the amount of green plant produced per unit of rainfall, but humans can change the mix of tree, shrub, and grass.

SOURCE: 1998 BLACKWELL SCIENCE LTD., *GLOBAL CHANGE BIOLOGY* 4, 359-374   C. O. CECIL / VISUALS