the blades really do provide the "early glimmerings" of the modern mental condition, he says, "it would be more comforting if they had spread, instead of popping up and disappearing."

That spread, which does occur in Europe, signals that something dramatic was happening which hasn't been found in Africa, according to J. Desmond Clark of the University of California, Berkeley: a change not just in technology but communication. "There's no doubt that blades go back for a very long time in Africa, and that's very interesting," he says. But the African tradition seems isolated; the appearance of the sophisticated European tool kit within a few thousand years all over the map, in contrast, means that toolmakers must have also developed language. And that cultural advance, he says, is truly revolutionary.

But McBrearty doesn't buy the idea that blade tools and language had to come in a revolutionary package. "You can point to a lot of so-called revolutions that happened over a long period of time," she says. "As an undergrad I was taught that bipedality, the big brain, and tool use all happened at once; now we know bipedality preceded the big brain by 2 million years." Likewise, she believes, language acquisition could have been a stepwise process, with the simpler African blades the product of its early stages.

She and Brooks both note that archaeologists really have no idea about the spread of technology in the African Middle Stone Age because they haven't looked in many places. Brooks notes that the European record is more elaborate because it's been extensively studied for 150 years, beginning with some of the founding fathers of archaeology, such as Edouard Lartet. "One problem with standing on the shoulders of giants," she observes, "is that you don't have that much choice about what direction you're walking in."

The direction McBrearty plans to go is back to Kenya, where she and her colleagues plan to search for more sites and more tools. "You know how textbooks say that early evolution happened in Africa, but the minute there's any behavior that smacks of being sophisticated, suddenly you're in France?" she says. "If I can change the last chapter in those textbooks in my lifetime, I'll be satisfied."

–JoAnn Gutin

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MATERIALS SCIENCE

Nanotubes Show Image-Display Talent

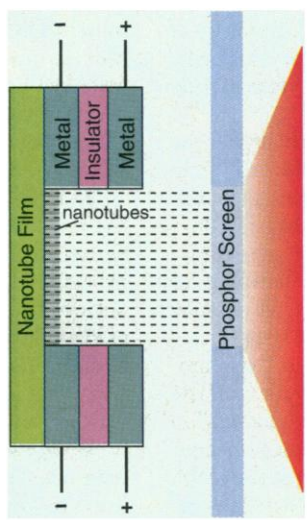
Nanotubes may be good for something after all. Ever since the tiny all-carbon hollow cylinders—less than 15 billionths of a meter in diameter—were discovered in 1991, researchers have published countless papers on their synthesis, properties, and potential for becoming everything from drug carriers to nanowires. But potential is a long way from product, and thus far nanotube wares have remained a distant vision.

On page 1179 of this issue, however, a report from a Switzerland-based research group brings one potential nanotube application within clearer sight: inexpensive, high-quality, flat screen displays. The team—led by physicists Walt de Heer and André Châtelain at the Ecole Polytechnique Fédérale de Lausanne and Daniel Ugarte at the Laboratório Nacional de Luz Síncrotron in Campinas, Brazil—turned an array of vertically aligned nanotubes into tiny but powerful electron emitters, functioning much like the ubiquitous cathode ray tubes (CRTs) in television and desktop computer displays. Simpler to make and much lighter than conventional technology, the nanotubes "could make a big impact on flat screen display technology," says physicist Andrew Rinzler of Rice University in Texas.

That's because they might provide the first good substitute for the large electron guns that create a CRT's color picture by firing a beam of electrons at a display screen coated with color phosphors. These devices are too heavy and bulky for portable laptop computer displays and flat screen TVs. So most popular flat screen displays use liquid crystals and a series of color filters—but they aren't as bright and can't be seen at sharp viewing angles. Experimental displays using thousands of tiny electron emitters, known as field effect devices, have been explored, but these electron emitters are made of silicon wafer and circuitry like computer chips, and thus are relatively expensive and cumbersome to manufacture.

That's where nanotubes come in. Researchers have known for years that nanotubes are good electrical conductors, and their long, narrow shape helps concentrate electric current to a small area, which is essential for efficient electron emission. In order to make a nanotube-based imaging device, however, scientists needed a way to get tens of thousands of nanotubes oriented in precisely the same direction, then induce these arrays to fire electrons at the same time.

De Heer and his colleagues met the first of these requirements earlier this year, when they created an electrically conducting polymer film with tens of thousands of nanotubes sticking up from it, like straws stuck precisely in a foam block (*Science*, 12 May, p. 845). And in the current experiment, the researchers took the next step, by showing that such nanotube arrays could emit enough electrons simultaneously to make a powerful stream.



Display model. A field effect device based on nanotubes would shoot electrons (–) at a phosphor display, triggering light emission.

The step, de Heer admits, was rather straightforward. The researchers first wired a ground electrode to the polymer film containing the nanotubes. On top of the film, they then layered a screenlike grid of a thin insulating sheet of mica, followed by a grid made of copper, a very good conductor. The copper and the ground electrode were then connected to opposite poles of a 200-volt battery, copper to positive and polymer to negative. The 200-volt difference forced electrons into the conducting polymer and then out the nanotubes. Detectors revealed that the electrons came streaming from the array at the same moment. And that stream was "a nice big current," says Rice physics professor Richard Smalley, who has also studied nanotube electron emission—strong enough, he estimates, to elicit an image from a phosphor-coated display.

Still, the researchers do have a way to go before nanotube emitters are ready to challenge liquid crystal displays. Scientists must still figure out how to control the electron emission independently from small patches of nanotubes, which would allow them to turn each picture element, or pixel, on and off separately. They will also have to show that nanotubes in different sections of the array emit equally strong electron streams, insuring constant brightness across the picture. But if successful, a nanotube-based device would have important advantages. The hexagonal arrangement of carbon atoms that forms nanotube walls is easy to fabricate. As well, any nanotube-based display will be able to piggyback on decades of research that has gone into perfecting CRT displays, giving it a strong boost in product development. "Unlike other flat screen technologies," says de Heer, "we wouldn't have to start from scratch."

–Robert F. Service