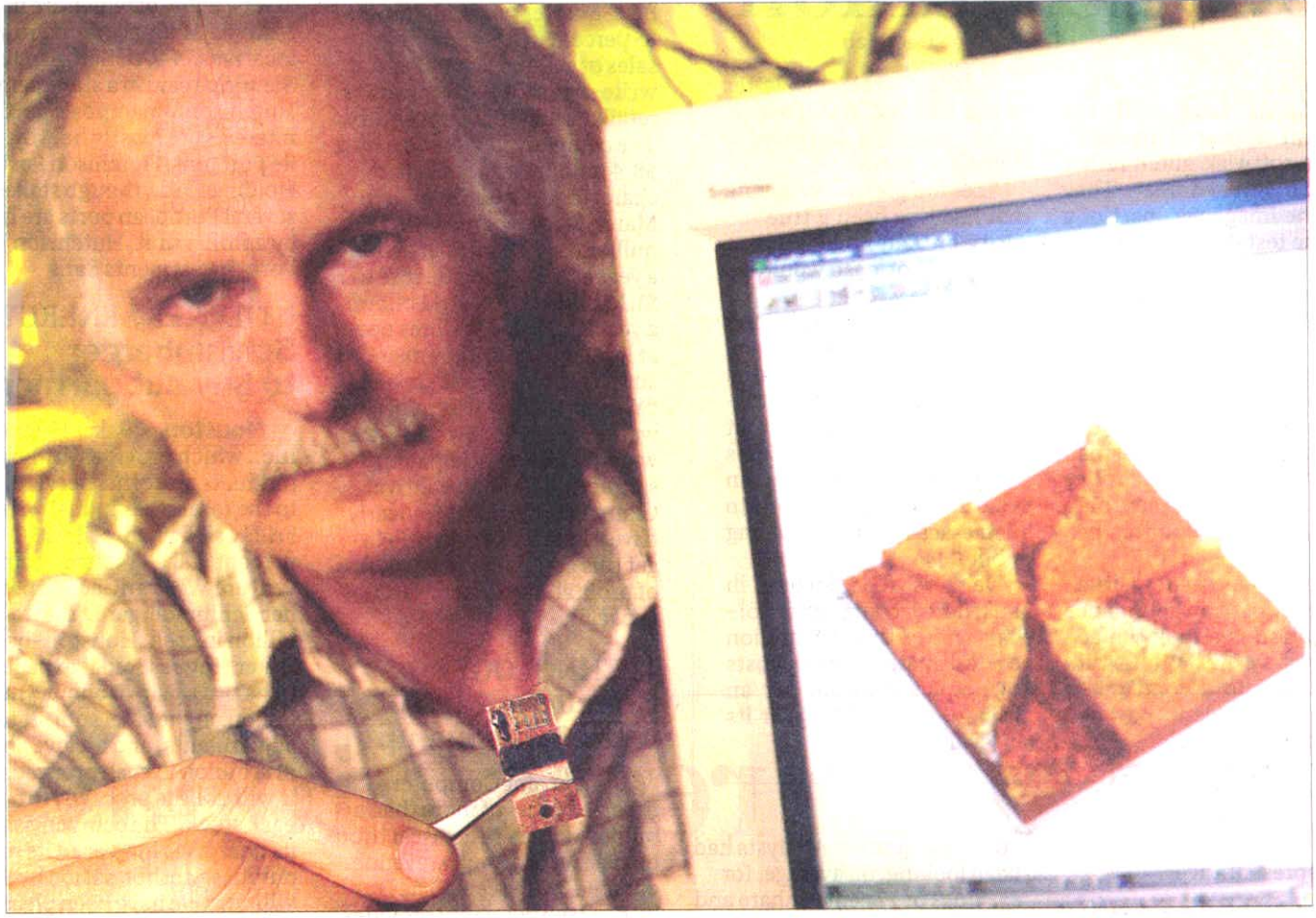

GARY MEEK / Georgia Tech

Georgia Tech professor **Walt de Heer** holds a proof-of-principle device made of graphene. Researchers believe that graphene — ultra-thin layers of graphite — can be used to build transistors superior to silicon-based semiconductors.

THE NEW SILICON?

Georgia Tech scientists experiment with using ultra-thin layers of graphite in semiconductors.

By BOB KEEFE
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There's a reason why the center of the technology world is called Silicon Valley. Semiconductors made from the element are found in virtually every electronic device today.

But with tomorrow's gadgets expected to need more computing muscle and less power consumption from smaller processor chips than silicon can deliver, researchers are seeking new substances that can keep the high-tech innovations coming.

Scientists at Georgia Tech may have found an answer at the point of a pencil.

The researchers have discovered a way to use ultra-thin layers of graphite to build transistors that by some measures can be 25 times more effective than traditional silicon-based semiconductors.

Walt de Heer, a professor in Georgia Tech's School of Physics, cautioned that real products based on the layered graphite — called graphene — may be a decade or more away.

But de Heer's research is beginning to attract some attention in the semiconductor industry, as well as some substantial financial backers, among them semiconductor giant Intel Corp. and the National Science Foundation. The government alone has pumped about $1.8 million into the research.

"This is a new material ... that has a lot of potential," de Heer said. Apparently graphene not only transfers electrons better than silicon, he said, it also has displayed other advantages not seen in other materials.

Nobody, de Heer included, is predicting that silicon will go away anytime soon as the primary building block for semiconductors, or that graphene will become its ultimate replacement.

Still, industry officials and analysts generally agree that with the ever-increasing number of transistors required by today's ever-shrinking electronics, technology companies will start bumping up against the constraints of silicon sometime in the next 10 to 15 years.

"The people who are in charge of the technology road maps for the semiconductor industry ... have basically said: 'We're getting nervous. We're reaching the physical limits of what we can do with silicon,' " said Nathan Brookwood, senior analyst at Insight 64, a semiconductor industry research firm.

"There just isn't another silicon technology that's on the horizon," he said.

That's where research like de Heer's comes in.

Until now, among the most promising potential replacements for silicon have been so-called carbon nanotubes that, at least in laboratories, have proved more efficient.

The technology being de-

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GARY MEEK / Georgia Tech

Researchers **Xuebin Li** (left) and **Claire Berger** monitor high-temperature graphene growth in an induction furnace at Georgia Tech. Researchers believe that real products based on graphene may be a decade or more away.

Graphene: Technology researched

➤ Continued from F1

veloped at Georgia Tech essentially flattens graphite nanotubes and spreads them out in extremely thin layers to form the graphene. The material's properties are similar to those of carbon nanotubes, de Heer said, but are much easier to work with. They can be shaped, sliced and designed with a tried-and-true semiconductor technology called lithography.

"It's exactly what is done in microelectronics [today], but with a different material," de Heer said. "That is the appeal of this process."

Trevor Yancey, vice president and analyst at IC Insights Inc., another semiconductor research firm, said the fact that chip makers could potentially use graphene without replacing very costly equipment or radically altering their processes could be a good selling point.

"Pretty much in all cases, this industry will use a technology that's evolutionary rather than revolutionary," Yancey said.

He said there have been many cases in which a new technology or new material has been shown to be superior, but was never put into production because it would require new types of very expensive equipment, new processes and other major changes.

Yancey is still skeptical that graphene or anything else will supersede silicon as the foundation of the semiconductor industry anytime soon.

"Silicon will be very, very difficult to replace," Yancey said. "It's flexible.... It has very high performance and very low power [consumption] that many different types of materials just can't duplicate."

Cognizant that much of the entire technology industry is overwhelmingly dependent on silicon, and that other nanotechnology innovations have been over-hyped, de Heer is quick to point out that he and fellow researchers are only getting started with graphene.

"This is really the first step in a very long path," he said. "We are at the proof-of principle stage, comparable to where transistors were in the late 1940s. We have a lot to do, but I believe this technology will advance rapidly."

Georgia Tech researchers led by de Heer have actually been working on the technology since 2001, but "we've been working under the radar," he said.

In recent months, though, the researchers and their colleagues at the Centre National de la Recherche Scientifique in France have started discussing the technology at industry conferences. This month, they published a paper on it in Science Express, an online publication affiliated with the journal Science.

"I did not want this to turn into big noise before we had something to show," de Heer said.