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Transparent Electronics

Researchers at Oregon State University (OSU) have recently developed a new class of materials. They have used these materials in a laboratory setting to create transparent thin-film transistors (TTFTs). These new materials might one day allow you to transform the windshield of your car into a GPS-activated map at the touch of a button, or turn a picture window in your house into a high-definition video screen. How far into the future you will have to wait for these and other consumer products is hard to say, but HP has already taken the first step by recently licensing OSU's new technology.

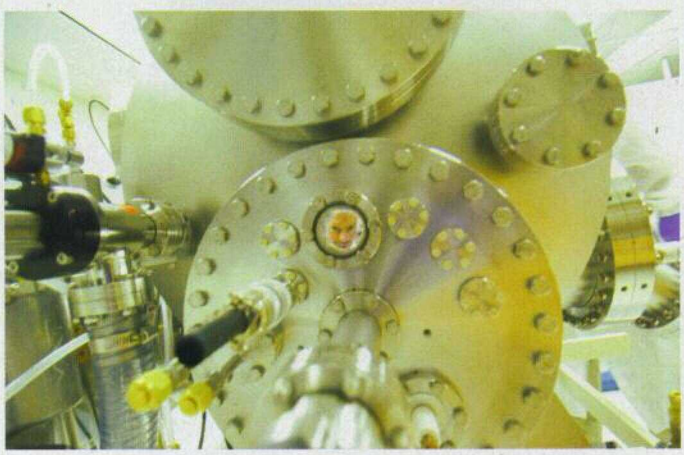
The first transparent electronic circuit was created using a thin film zinc oxide substrate at Oregon State University in 2003. Since then, researchers have made major advances and discovered 28 different new material compounds that can all render transparent electronic circuits.

Looking at Photo 1, you will see the corner of a one-dollar bill covered with a small square glass plate. Since you can see through the glass plate, you will probably assume that the glass is empty. In fact, though, a transparent electronic circuit that contains 56 patterned transistors and 24 resistance test structures covers the glass. "You might be amazed to learn that the thin film that you can see through was created using a zinc oxide thin film, the same zinc oxide that goes into the cream that you put on your nose when you go to the beach to protect your skin from a sunburn," says John Wager, a professor of electrical engineering at OSU.

Since seeing is believing, Photo 2 shows the same glass plate en-

Photo 1—Spin-coated ZnO TTFTs. 56 patterned ZnO TTFTs and 24 contact resistance test structures are present inside the red box.

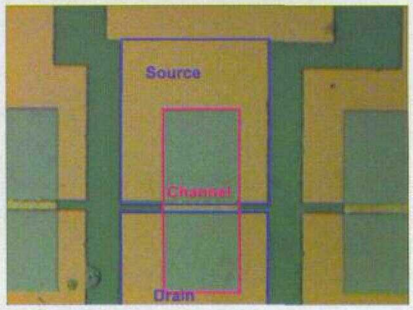
hanced to allow you to see what would normally be invisible. Wager explains that "you see through the electronic circuit in [the first photo] because the material that it is made of has a very wide band gap. You can't see through a silicon circuit or other opaque materials because they have a narrower band gap that doesn't allow visible light to pass through."



This sputtering machine is used to deposit the thin films to make the circuits and other devices.

Wager worked in collaboration with Doug Keszler, a professor of chemistry and Janet Tate, a professor of physics. The development team also included Chris Tasker, the laboratory manager and graduate research assistants working in the three departments. The success with zinc oxide led to combining of the zinc oxide with tin oxide. This combination improved conductivity far beyond what the researchers had achieved with zinc oxide alone.

Photo 3 shows Wager looking through the window of a sputtering machine, which deposits the thin films used to make the circuits and other devices. The zinc oxide and



Photos by John Wager

Photo 2-Sputtered ZnO TTFTs. An enhanced-contrast, magnified image of a bottom-gate transparent transistor test structure.

zinc-tin oxide circuits contain 10-75 nm thick channel layers for electron flow. Wager explains that "a 10 nm thick layer would only be about 40 atoms thick!"

Up to this point, crystalline materials have been used in most electronic circuits because they effectively move electrons through their organized lattice of atoms. The new materials that these engineers and scientists have created by depositing zinc and zinc tin oxides randomly should not have produced a good conducting

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circuit. The researchers were surprised to find that electrons moved through their amorphous material (a material with randomly distributed atoms) efficiently. Wager and I discussed the team's breakthrough in a phone interview. He also e-mailed me a PowerPoint presentation to help me understand the complexities of what he and his colleagues had achieved.

It was easy to understand how electrons move through a crystalline material but hard to understand how they could efficiently move through an amorphous thin-film zinc-tin oxide. I asked if I could use the analogy that the atoms moved through the zinc-tin oxide amorphous material in much the same way that a figure skater creates intersecting circles to move around an ice rink. Wager thought that my analogy worked if we viewed the skater as using his or her circular route to transfer from pond to pond (atom to atom).

Wager and his team have now identified 28 inorganic oxide material combinations that might be just as effective as or even more effective than the zinc-tin oxide that they had first discovered. Each of the 28 material combinations would have the capability to produce transparent, inexpensive, chemically stable, difficult to damage and even environmentally friendly materials that can be turned into electronic circuits. Since the percentage in the mix can vary, Wager says that the new material possibilities are actually infinite in number.

By building electronic circuits using these amorphous noncrystalline materials, you can greatly reduce production cost because you could print the new materials on a plastic substrate at very low temperatures. These very inexpensive electronic circuits could lead to a whole new category of throw-away electronic devices.

The circuits could eventually be printed using gravure, offset, inkjet and/or screen process printing. Since the surface of these amorphous materials is very smooth, it is possible to stack electronic circuits on top of each other by registering a second, third or more printed layer.

Soon, you may very well find yourself purchasing a nonbreakable, bendable computer screen that you can roll or fold up to fit in your pocket! To further explore this topic, Google "transparent electronics," "TTFT," "John Wager" or "amorphous heavy-metal cation multicomponent oxides."

Recalling the Facts

1. What do you see as the greatest advantage of transparent electronics?

2. Can you envision any negative effects or possible misuses of this technology?

3. What is it about this new material that makes it possible for people to create invisible electronic circuits?

4. The new class of materials described in this column share at least five significant characteristics. Name them.