They may not be super, but semis are hot

A hot subject of late has been the new high-temperature superconductors and how they may revolutionize various technologies by allowing electricity to flow without losses and without much cooling — making magnetically levitated trains feasible, for example. But at the same time, advances in much higher-temperature *semi*conductors — the materials that make up transistors and other devices — have also been quietly brewing. And while these may not usher in any new physics or lead to quite as dramatic technological changes, semiconductor research is much closer to producing commercial high-temperature devices for use in a number of their own important applications — providing electronics in the hot environs of jet engines, drilling deep oil wells or operating the space station, to name a few.

One recent semiconductor advance comes from materials scientists Robert F. Davis, John Palmour and their colleagues at North Carolina State University in Raleigh. They have made silicon carbide transistors that perform at 650° C — the highest operating temperature ever reported for any transistor made from any material. Moreover, says Palmour, the electronic properties of these transistors are "astoundingly good. Their current-voltage characteristics are textbook [examples]," he says, and are comparable to the performance of more conventional silicon transistors operating at room temperature (20°C).

What Davis's group has done, says Tony Powell at NASA Lewis Research Center in Cleveland, "is extremely important . . . and represents a turning point in [30 years of] silicon carbide research."

Davis discussed his group's achievements last week at the first International Conference on Amorphous and Crystalline Silicon Carbide, hosted by Howard University in Washington, D.C. A paper on the researchers' "metal-oxide-semiconductor field-effect transistor" (MOSFET), a switching device typically used to amplify signals, also appears in the Dec. 15 APPLIED PHYSICS LETTERS.

The need for electronic devices that can operate at high temperatures has been growing in part because automobile and jet engines are being designed to run at increasingly higher temperatures to maximize their performance. At the same time, the demand has grown for electronics to monitor pollution, increase engine efficiency and help diagnose problems from directly inside engines.

The best commercial silicon sensors can operate at temperatures of up to 250°C, and usually the other silicon devices that amplify and process the sensors' signals are connected by wires and kept in a remote, cool spot. This arrangement adds cost and bulk and degrades reliability.

At temperatures much higher than 200°C, silicon becomes a full conductor, like a metal, and all control over the current, which is crucial for a semiconductor device's operation, is lost. In the language of semiconductor physics, these high temperatures excite most of the bound electrons in the silicon's "valence band" to jump up across silicon's "energy band gap" into the "conduction band."

To make devices for higher temperatures, researchers have been hunting for materials with a much larger energy band gap than silicon — in other words, materials that become fully conducting at higher temperatures. Candidates being considered include boron nitride and diamond films (SN: 10/17/87, p.247; 8/23/86, p.118), but researchers have made the most progress with silicon carbide.

One of the main contributions of Davis's group is to grow electronic-quality silicon carbide crystals. In much of the past work, scientists had grown a cubic form of silicon carbide atop a pure silicon substrate. But, possibly because of a mismatch between the silicon carbide and silicon lattices, the silicon carbide film had too many defects to be useful. Davis's group instead was able to grow the cubic form on top of hexagonal silicon carbide crystals, which came from a factory that uses these tiny crystals to make sandpaper. The result was devices with fewer defects and better performance. The researchers have also learned how to grow much purer hexagonal crystals themselves, which they expect will lead to even better devices.

Davis's group has formed a spinoff company that is beginning to make prototype high-temperature diodes. The company is also interested in using silicon carbide to make light-emitting diodes that emit blue light; these are needed for digital color imaging and printing, processes that would produce color pictures without the use of film. In addition to high-temperature applications, silicon carbide's properties could make it ideal for high-power, high-frequency use in military and satellite communications, among other applications.

Davis's recent work, notes Powell, finally "brings silicon carbide close to being a viable commercial product. It's no longer a question of whether it's going to be successful, but when." — *S. Weisburd*

Water, water everywhere, but . . .

Two new reports released within a week of each other have left some consumers feeling a bit parched. Connoisseurs of bourbons, sherries and fruit brandies were treated to the news that many of their favorite brands contain dangerously high levels of urethane, a potent carcinogen. Meanwhile, testimony before members of Congress revealed that many of the drinking fountains in the United States are spouting water that is contaminated with lead.

The report on tainted alcohol, released last week, lists urethane levels in more than 1,000 alcoholic beverages as determined by government and beverage industry laboratories. The data were compiled and released by the Center for Science in the Public Interest, a Washington, D.C.-based consumer group that obtained the test results through the federal Freedom of Information Act.

"Unlike some of the chemical controversies of the past, such as DDT and saccharine, there is no disputing the fact that urethane is a carcinogen," says Michael Jacobson, the group's executive director. However, he says, while Canada established two years ago strict limits on urethane levels in alcoholic beverages, ranging up to 400 parts per billion (ppb), the U.S. Food and Drug Administration (FDA) "has neither set limits nor recalled products from the marketplace."

Part of the problem, say beverage producers and federal regulators, is that urethane is a natural by-product of the fermentation process; none is intentionally added in the production process. Tiny amounts of it are present in such commonly consumed foods as bread and yogurt. According to Emil Corwin, a press officer with the FDA, the agency "has been meeting with key [beverage] industry groups in an effort to find production methods that will reduce urethane levels in alcoholic beverages. But we still need to figure out how it's produced and how to reduce it."

The new report shows that most beers, with the notable exception of Foster's (Australia) and Golden Dragon (China), contain extremely low or undetectable levels of urethane. Fruit brandies have the highest levels — in some cases more than 2,000 ppb — with generally decreasing amounts appearing in bourbons, sherries and table wines, though many of them are still higher than Canadian standards. Backed by cancer specialist Marvin Schneiderman, a member of the National Academy of Sciences and a former associate director of the National Cancer Institute, Jacobson calculates that consumption of two drinks a day at levels just under the Canadian limit could lead to a cancer risk from 10 to 4,700 times greater than the FDA's "acceptable" cancer risk level of 1 in 1 million.

Lois Gold, a cancer risk specialist at the Lawrence Berkeley (Calif.) Laboratory, told SCIENCE NEWS that because the car-