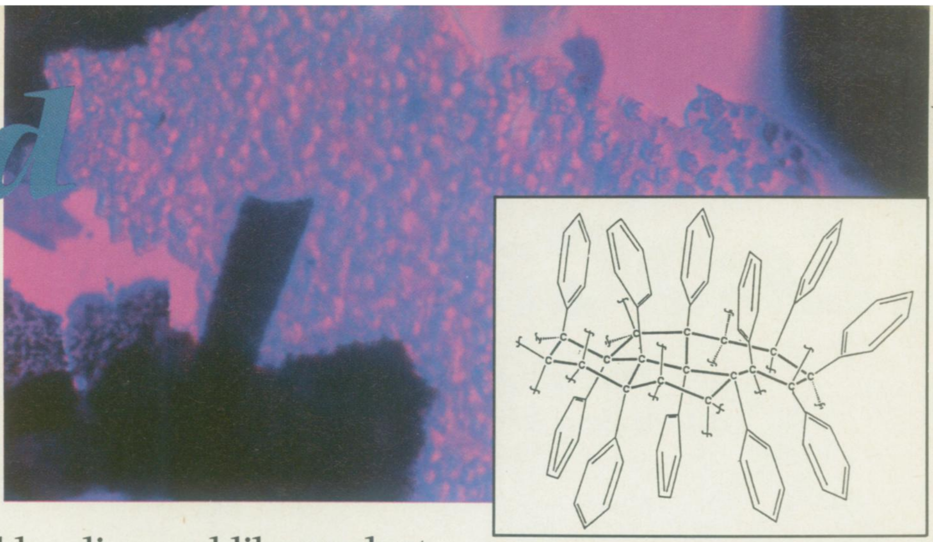
Liquid Gem

By KAREN F. SCHMIDT



Visscher/Penn State

Bianconi *et al.*/SCIENCE

***B**aked protodiamond polymer on a pink background shows transparent crystalline diamond and black-graphite-coated microscopic diamond. The polymer has a tetrahedral carbon backbone (inset).*

A new carbon polymer yields a diamond-like product

It started as just another day in the lab for chemists Patricia A. Bianconi and Glenn T. Visscher. They were preparing germanium and silicon compounds and baking them, trying to develop improved ceramics for microelectronic devices. Then the Pennsylvania State University researchers had an idea: How about trying the technique with carbon?

That flash of curiosity two years ago led the pair to discover a new kind of carbon compound. "Chemically, this is a unique carbon polymer and in fact, one that chemists thought could not exist," Bianconi says. A polymer is a large molecule composed of smaller chemical units that link up in a repeating pattern.

Although Bianconi and Visscher had already made germanium and silicon polymers with tetrahedral linkages — a pyramid-shaped arrangement of atoms — they never expected carbon to form that same kind of network. In nature, tetrahedral carbon, which has four single bonds, forms only under the extreme temperatures and pressures that yield natural diamond deep within the Earth. Much more commonly, carbon atoms align themselves to form graphite, a soft black material rich with double bonds, Bianconi notes.

The two researchers dissolved their brown-sugar-like polymer and heated it at kitchen-oven temperatures. When Visscher tried grinding the resulting solid, it clearly wasn't just graphite. The powder proved so hard that it began to eat away at the mortar and pestle. When they analyzed the material, "there was this lovely X-ray diffraction pattern for crystalline diamond," Bianconi recalls.

Since this discovery, the researchers have analyzed the carbon polymer and its diamond-like product using a variety of spectroscopic techniques. They report their results in the June 4 Science.

The new polymer differs from other carbon polymers in several ways. Unlike the usual "beads-on-a-string" polymer, it does not form a linear chain. And compared with intricately branched polymers called dendrimers, the new material appears to be more "densely knitted" in structure, rather than "crocheted," Bianconi says. Spectroscopic evidence suggests that the polymer does indeed have a backbone that could readily convert to diamond, she asserts. But slight structural variations occur from molecule to molecule. Says Bianconi, "Probably every individual molecule has a slightly different construction."

Bianconi and Visscher found they could convert their polymer to a tetrahedral carbon solid by heating it to between 390° and 750°F. Further heating to 1,000° produced a sizable fraction of clear crystalline diamond, while the rest turned to graphite. After sloshing the solid mixture with strong acid — a process called wet etching — they rinsed away the dissolved graphite and determined the amount of acid-resistant material that remained: 67 percent by weight. Using Raman spectroscopy, the researchers identified this transparent substance as diamond.

"I think if they modify the process, they might be able to get pure diamond," comments Robert P.H. Chang, a materials scientist at Northwestern University in Evanston, Ill.

To grow a film of diamond crystals on a surface, industrial scientists currently use a technique called chemical vapor deposition (CVD), which, unfortunately, is a slow and difficult-to-control process (SN: 8/4/90, p.72). To make CVD diamond, scientists shoot microwaves at methane gas molecules to wrench free the carbon atoms, which then settle on a surface, such as glass, and stack into diamond-like carbon.

Many researchers, including Chang, have long sought a new route for making diamond. The Penn State results look promising, he says.

The new carbon polymer may offer an alternative method for making ultrahard, chip-resistant diamond films that industry could use to coat everything from sunglass lenses to computer disk drives. Because the polymer dissolves quite readily, parts might be dipped into the solution and then heated to harden the coating, says Bianconi. The polymer can also be spun into films of varying thicknesses, she says.

The polymer does not yet yield crystals of the size and quality of CVD diamond. But Bianconi, like Chang, sees plenty of room for improvement. To start with, her group will try to reduce the proportion of graphite in their product by altering the carbon starting materials, which have phenyl-ring side groups. Bianconi believes that these rings, which contain double bonds, convert into graphite. She and her colleagues will now try to build the same network backbone, but with single-bond side groups that favor diamond formation.

The researchers also plan to return to their original interest in microelectronics by investigating the possibility of making melt-resistant, diamond features on computer chips (SN: 9/29/90, p.197). They'll try "writing" a tiny circuit pattern in diamond using a laser that, wherever they aim it, will heat and harden the polymer on a chip.

Regardless of how far the practical applications carry them, they will continue to study and characterize their novel polymer. Jean M.J. Fréchet, a polymer chemist at Cornell University, says he's impressed by the work, but he wants to know more about this random network structure that yields diamond. "I wonder if, in fact, the molecule is more organized than they give it credit for," he remarks.

Polymer chemists and materials scientists alike now have exciting new vistas to explore. Says Fréchet, "This is an example of science at the frontier." ☐