Science Highlight
Diamondoids: Molecular Bling with Big Potential

Scientists have figured out how to make the tiniest possible pieces of pure diamond in a variety of shapes and sizes, like molecular LEGO building blocks. They're exploring ways to use these microscopic gems to improve electron microscope images. Next up: enlisting them as tools for assembling materials or printing circuits on computer chips.

What They Are
Diamondoids are tiny interlocking cages made of carbon and hydrogen atoms arranged as they are in diamonds. The smallest one contains just 10 atoms; each weighs less than a billionth of a billionth of a carat.

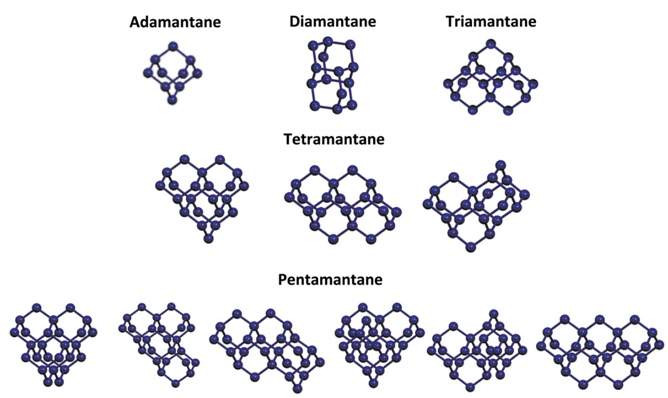
Diamondoid cages are rigid and sturdy; they can be produced with very high chemical purity; and their small size gives them useful properties that diamonds lack. What's more, scientists can tweak their properties by attaching other groups of atoms.

A Brilliant Discovery
Diamondoids are a natural component of petroleum fluids. Scientists first isolated them from petroleum in 1932 and soon synthesized the smallest ones in the lab; they were used to create drugs to fight flu and symptoms of Parkinson's disease, and tested as rocket fuel. But the bigger ones proved harder to make.

In 2002, Chevron scientists found a way to extract the larger diamondoids by distilling petroleum, burning off non-diamond material and separating and sorting the diamondoids. The race was on to find out what these tiny diamonds could do.

Bright Beams for Better Microscopes
One thing they do really well is emit electrons. In 2007, a team led by Stanford/SLAC researchers discovered that a single layer of diamondoids on a metal surface can emit and focus electrons into a tiny beam with a very narrow range of energies. Researchers are working with industry to use these patented beams to improve electron microscopes.

A breakthrough in diamondoid research came in 2002, when scientists discovered how to isolate and purify larger diamondoids such as tetramantane, shown here. This allowed researchers to work with diamondoids that are 99 percent pure, transparent and sorted by size and shape. Their functions can be tweaked by adding other groups of atoms. (Peter Schreiner/Justus Liebig University Giessen)



Diamondoids are tiny cage-like molecules made of carbon and hydrogen, with the same atomic structure as diamond. The smallest one, adamantane, contains just 10 atoms. Larger ones are made of multiple adamantane cages and can exist in multiple configurations, or isomers. (School of Chemistry, University of Bristol)

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And in 2012, a related SLAC/Stanford team showed they could greatly improve certain microscope images by coating the samples they were studying with a thin layer of diamondoids.

Diamondoid Coats

Scientists are exploring other possible uses for thin diamondoid coatings, such as seeding the growth of diamond layers in microchips. These layers dissipate heat while keeping the chips from leaking electrical current. Diamond is ideal for this because it is an excellent electrical insulator and thermal conductor. Stanford and SLAC researchers are working on ways to improve and stabilize diamondoid coatings.

A New Way to Make Computer Chips?

Another exciting possibility: A thousand of these electron beam devices, working together, could write electronic circuits directly onto a chip, bypassing conventional photolithography and achieving much higher quality with a faster, cheaper process.

Molecular LEGOs

Like LEGOs, diamondoids make great building blocks; they come in a lot of sizes and shapes and they stick together. You'd think scientists would want use them to build diamonds, but they have something even more valuable in mind: They want to use diamondoids as tools to assemble new types of semiconductors and other materials that cannot be made today. Diamondoids can grab other atoms or molecules and hold them next to each other until they react and form bonds, creating materials that are atom-by-atom perfect.

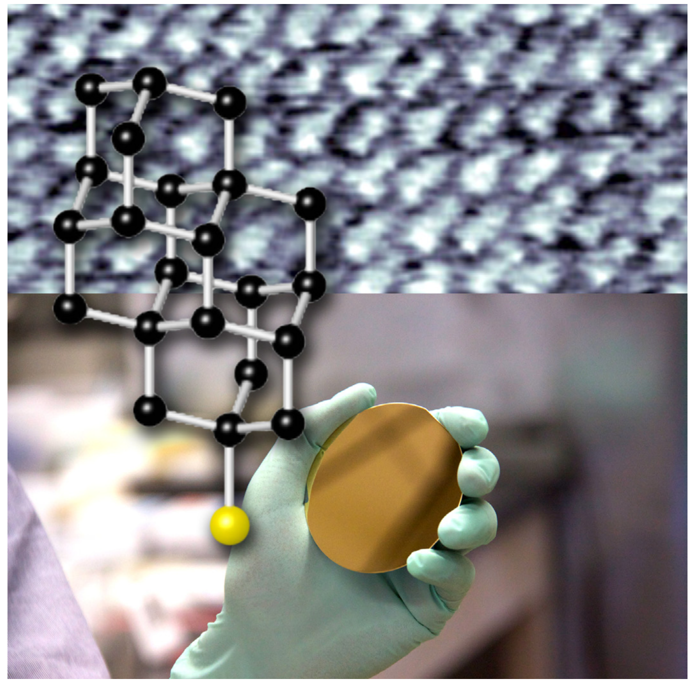
SLAC's Role

Diamondoid research at SLAC and Stanford is led by Nick Melosh, Zhi-Xun Shen and Jeremy Dahl, all members of the Stanford Institute for Materials and Energy Sciences (SIMES). Much of the research takes place in SLAC laboratories.

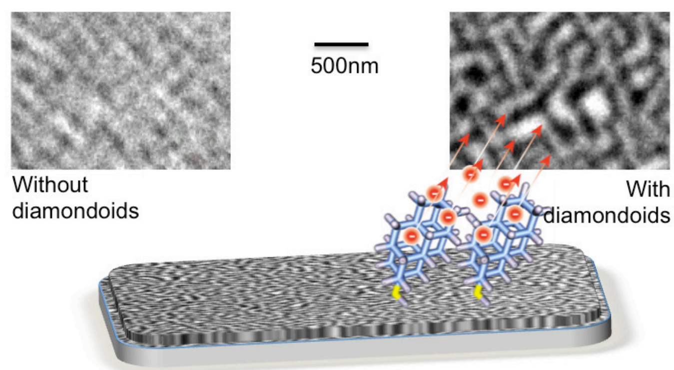
The team also uses SLAC's Stanford Synchrotron Radiation Lightsource (SSRL) to study the properties of diamondoids, determine their atomic structures and study nanostructures that they have made with the help of these tiny diamonds.

Funding

In 2006, Chevron Technology Ventures LLC entered into a four-year, $1.2 million agreement with Stanford to explore the detailed structures and self-assembly of diamondoids. The program got an additional boost in 2009, when a team of SIMES researchers led by Melosh received a $2.5 million Department of Energy Single Individual and Small Group Research grant to study the properties and potential applications of the materials.



Scientists at SLAC and Stanford are exploring applications for diamondoid coatings, which give materials diamond-like qualities. The bottom photo shows the type of gold wafer used in these experiments. The microscopic view at top shows the surface of the wafer after coating with a layer of diamondoid cages, like the one depicted at center left. (Photo by Hao Yan, images by Hari Manoharan/Stanford)



Left: Imaging the bare surface of a sample produces an indistinct view of its magnetic patches, or domains. Right: Coating the surface of the sample with a thin layer of diamondoids greatly improves images, revealing details as small as 10 nanometers. Images were taken with a photoelectron emission microscope. Center: Diamondoid cages attached to the surface of the sample capture electrons (red dots) that the sample emits in response to intense light and re-emit those electrons in a narrow, focused beam, greatly improving the image quality. (Hitoshi Ishiwata/SIMES, Stanford)

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