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Catching up with carbon

Japan fights to stay on top of a field it pioneered.

BY TIM HORNYAK

ILLUSTRATION BY PETER HORVATH; PHOTOS: GETTY

In September last year, a handful of researchers were sitting around a computer monitor in chemist Kenchiro Itami's lab at Japan's Nagoya University as one loaded a file showing the results of an X-ray crystallography scan. Within seconds, the room erupted: scientists were on their feet, cheering and exchanging high fives. In front of them was a 3D representation of a carbon nanobelt — a new molecule of carbon that the team had successfully synthesized a… painstaking effort.

"Without these data, we co… structure 100%," says Itami, … Institute of Transformative Bi… Nagoya University. "It was the most exciting moment I ever had in my life."

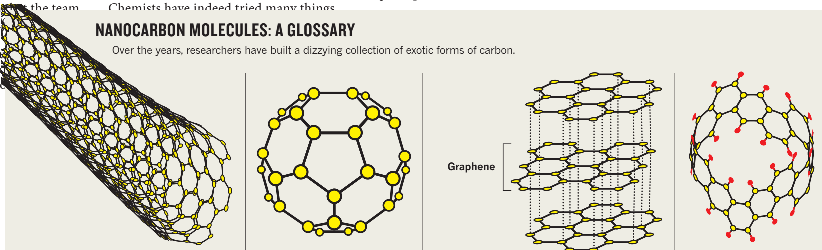
Itami thinks he has good reason to be so excited. "The discovery of a new form of carbon has always opened up new science and technology — fullerenes are a great example," he says, referring to the all-carbon molecular spheres created by scientists at Rice University in Houston, Texas, in 1985.

Chemists have indeed tried many things… the stability and strength to build complex molecules — into new materials with useful properties, and it has built a strong industrial sector from those basic research efforts.

But in the past decade or so, Japan has found itself beset by international competition, as progress in the field has shifted abroad. Now, Japanese researchers are fighting to maintain their global prominence.

NANOCARBON MOLECULES: A GLOSSARY

Over the years, researchers have built a dizzying collection of exotic forms of carbon.

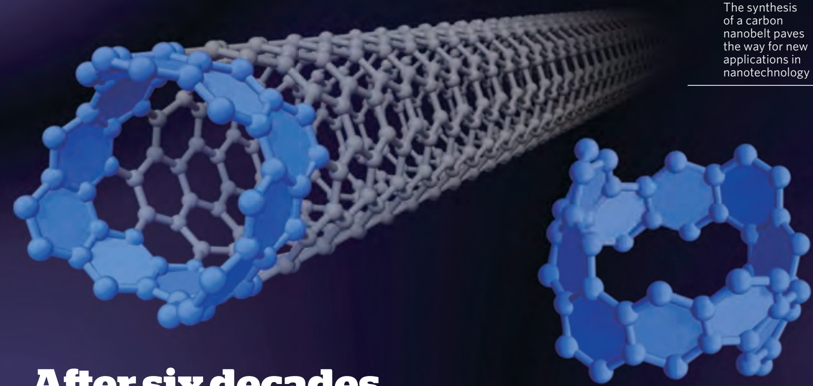


NANOTUBE
A sheet of hexagonally arranged carbon atoms, stretched to make a pipe shape. First formally described by scientists in 1952.

FULLERENE
A hollow sphere of carbon resembling a football. Synthesized in 1985.

GRAPHITE
Layers of hexagonally arranged carbon stacked on top of one another. Graphene — a single layer of this lattice — was isolated in 2004.

NANOBELT
The single repeating unit of a tiny carbon nanotube. Synthesized in 2016.



The synthesis of a carbon nanobelt paves the way for new applications in nanotechnology

After six decades of anticipation, the nanobelt has arrived

CHEMISTS HAVE SYNTHESIZED the smallest member of the carbon nanotube family.

In a way, the world of nanocarbons resembles origami — small manipulations can bring changed forms and functions. Graphene, a semi-metallic single layer of carbon atoms, is like a flat sheet of paper. Shape it into a sphere, and it becomes insulating. Wrap it into a tube, and it becomes a semiconductor that is transparent to light below a certain energy level. Twist that tube slightly, and it becomes a metal that absorbs light of all energies.

Unlike paper though, the shape of atomic-scale nanocarbons is extremely difficult to control. Lacking tools to use more direct means, scientists have had to resort to painstaking filtering techniques. To make a nanotube transistor, for example, the required semiconducting nanotubes are typically filtered from a mixture of nanostructures produced at high temperatures.

But despite decades of work, filtering remains highly imperfect. "The key issue in the field remains the preparation of well-defined materials," says Kenichiro Itami, research director of the JST-ERATO Itami Molecular Nanocarbon Project and professor of chemistry at Nagoya University.

CHEMISTS TEND TO BELIEVE THAT BEAUTIFUL STRUCTURES WILL EXHIBIT AMAZING PROPERTIES

An approach enabling more control over the shape would be a chemical synthesis of a single desired structure. Now, after an extraordinary 12 years of effort, a team of researchers led by Itami has succeeded in doing just that with one of the most sought-after nanostructures in the field — the carbon nanobelt.

Chemists have been trying to synthesize the nanobelt for over 60 years. "It's a simple and beautiful structure," says Itami, "and chemists tend to believe that beautiful structures will exhibit amazing properties."

The nanobelt consists of a thin ring of carbon atoms joined in a loop, as if someone had taken a vertical slice from the centre of a nanotube. Crucially, this means that the nanobelt can be used to grow metallic or semiconducting nanotubes with perfect fidelity — no filtration required. "In this regard," Itami says, "carbon nanobelts are the ultimate seed."

Nanobelts may also be useful in nanomachines, single-molecule electronics, photonics, and spin transport.

They may even make a perfect nanocar 'tyre'. Being both the newest and the smallest well-defined member of the carbon nanotube family, many new applications may be found, says Itami. "People can't predict how it will change the game."

Scientists around the world will soon get the chance to try. Tokyo Chemical Industry Co., Ltd. (TCI) is collaborating with Nagoya University to efficiently scale up the synthesis of the nanobelt, and aims to make it commercially available within six months. Inquiries, they say, are already coming in. ■

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