Experiments into amorphous carbon monolayer lend new evidence to physics debate

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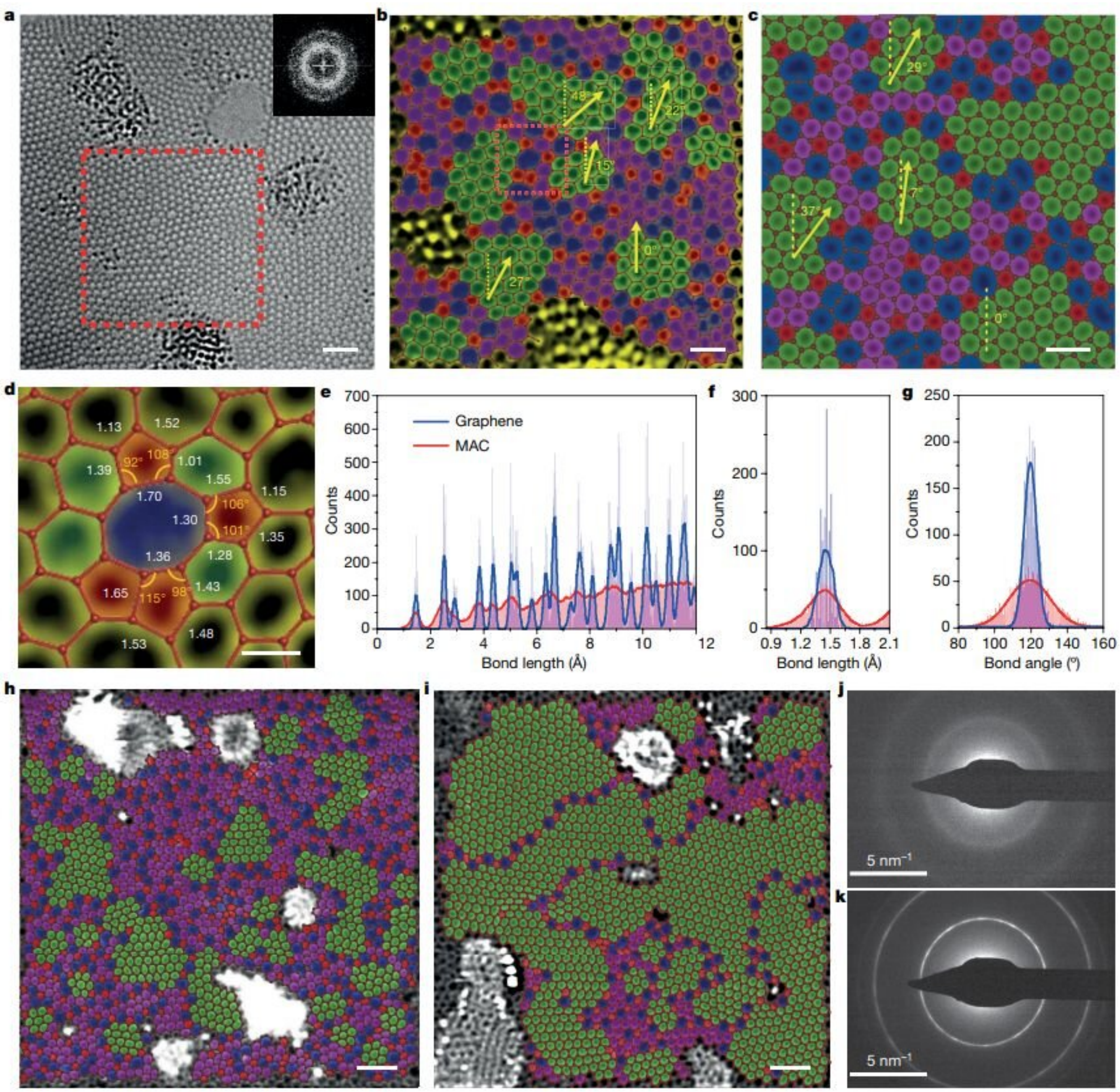


Atomic structure of MAC from TEM. Credit: *Nature* (2020). DOI: 10.1038/s41586-019-1871-2

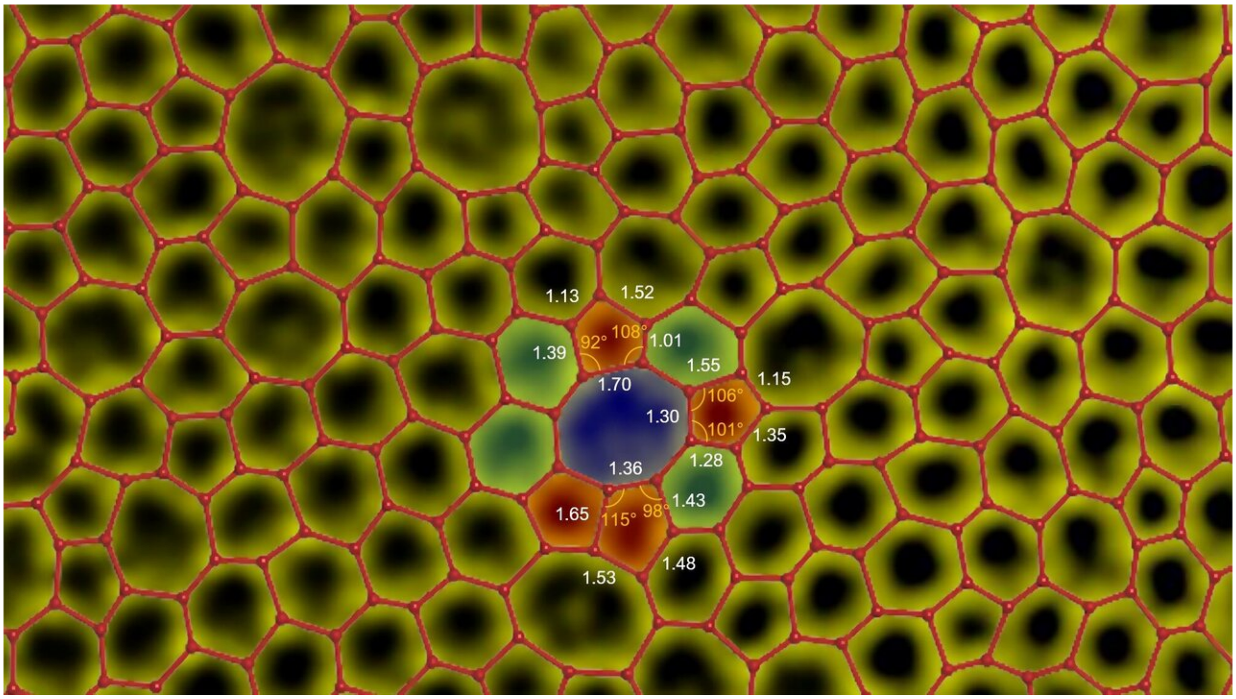
Plastic, glass and gels, also known as bulk amorphous materials, are everyday objects to all of us. But for researchers, these materials have long been scientific enigmas—specifically when it comes to their atomic makeup, which lacks the strict ordered structure of crystals found in most solids such as metals, diamonds and salts.

Although generally believed by the scientific community to be continuous random networks of atoms, a long-standing, fundamental question existed: Are amorphous materials truly continuous random networks or do they have nanocrystallites embedded within them?

Now, we finally have answers—thanks to a new study detailing the first successful experiments growing, imaging with atomic resolution, and investigating the properties of two-dimensional amorphous carbon. The paper appears today in *Nature* and is published by an international team of researchers, including Sokrates Pantelides, University Distinguished Professor of Physics and Engineering at Vanderbilt University.

"For the first time, thanks to the discovery of this monolayer material, we're able to confirm the composition of an amorphous structure as a random network containing nanocrystallites, lending strong evidence to one side of the primordial debate," said Pantelides. "But this work not only provides answers; It presents a physical, two-dimensional carbon material, distinct from the lauded graphene, with potentially promising applications well into our future."

Future device applications of the material, according to Pantelides, could include anti-corrosion barriers for magnetic hard discs in future computers and for current collector electrodes in batteries.



Researchers at NUS have created the world's first atomically thin amorphous carbon film. The amorphous structure have widely varying atom-to-atom distance unlike crystals. This is because of the random arrangement of five-, six-, seven- and eight-carbon rings in a planar carbon network, leading to a wide distribution of bond lengths (in Å) and bond angles. Credit: National University of Singapore

The questions regarding amorphous material composition persisted for years due to long-standing technological issues for researchers, which included limitations in small-scale microscopy that prevented physicists from accurately imaging three-dimensional amorphous materials at the atomic scale. And while researchers were able to accurately image amorphous monolayers, such monolayers were until now fabricated by using high-energy electron beams to disorder crystalline monolayers.

The first-ever stable monolayer of amorphous carbon, grown by a team led by Barbaros Özyilmaz of the National University of Singapore and imaged by the group of Kazu Suenaga in Tsukuba science city, Japan, makes these issues problems of the past.

A theoretical physicist, Professor Pantelides worked remotely with the teams in Singapore and Tokyo to integrate experimental data, theory fundamentals, and results of calculations. A former graduate student of Pantelides, Junhao Lin, a post-doctoral fellow in the Suenaga group, performed the key microscopy. Vanderbilt post-doctoral fellow Yun-Peng Wang constructed an appropriate model and performed calculations.

The growth method, which uses a cold substrate, and uses a laser to provide energy in a controlled way, yields reproducible monolayer films and led to newfound knowledge of atomic arrangements and electrical, mechanical and optical properties.

Thanks to the team's successful development and findings, the reproducible approach opens the door for research into the growth of other amorphous two-dimensional materials.

More information: Synthesis and properties of free-standing monolayer amorphous carbon, *Nature* (2020). DOI: 10.1038/s41586-019-1871-2 , nature.com/articles/s41586-019-1871-2

Provided by Vanderbilt University

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