Engineering graphene-based quantum circuits with atomic precision

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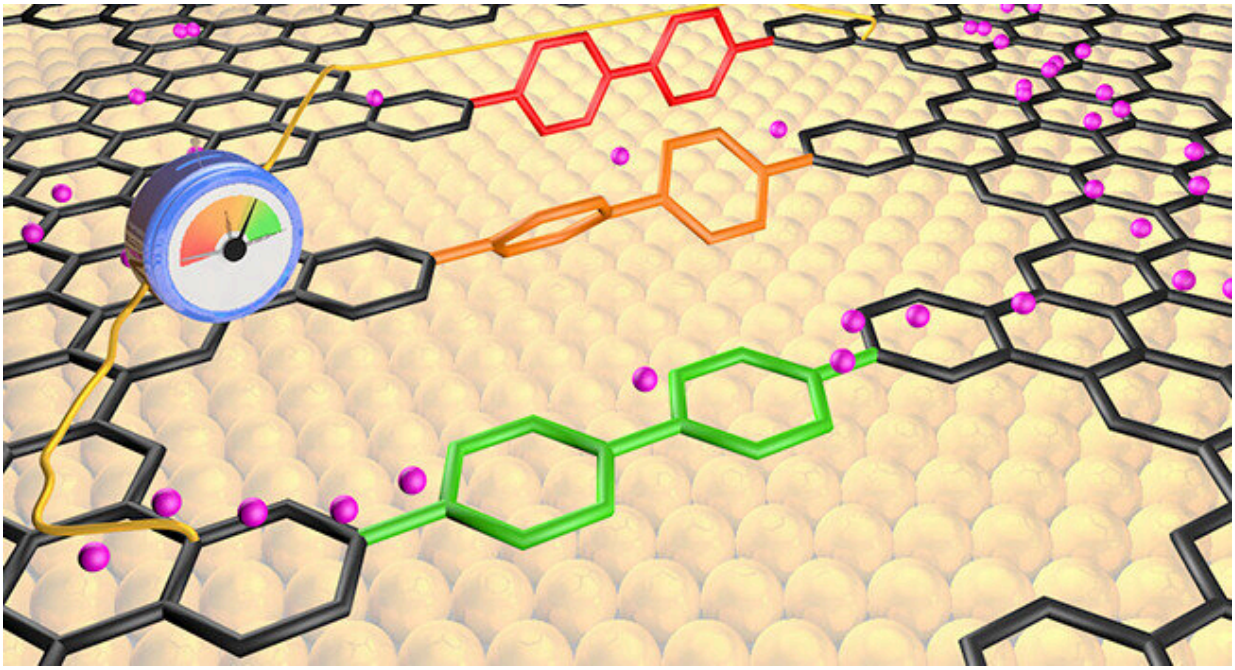

Graphical abstract. Credit: *Journal of the American Chemical Society* (2023). DOI: 10.1021/jacs.3c00173

Imagine having a building made of stacks of bricks connected by adaptable bridges. You pull a knob that modifies the bridges and the building changes functionality. Wouldn't it be great?

A team of researchers led by Prof. Aitor Mugarza, from the Catalan

Institute of Nanoscience and Nanotechnology (ICN2) and ICREA, together with Prof. Diego Peña from the Center for Research in Biological Chemistry and Molecular Materials of the University of Santiago de Campostela (CiQUS-USC), Dr. Cesar Moreno, formerly a member of ICN2's team and currently a researcher at the University of Cantabria, and Dr. Aran Garcia-Lekue, from the Donostia International Physics Center (DIPC) and Ikerbasque Foundation, has done something analogous, but at the single-atom scale, with the aim of synthesizing new carbon-based materials with tunable properties.

As explained in a paper just published in the *Journal of the American Chemical Society* (*JACS*) and featured on the cover of the issue, this research is a significant breakthrough in the precise engineering of atomic-thin materials —called "2D materials" due to their reduced dimensionality. The proposed fabrication technique opens exciting new possibilities for materials science, and, in particular, for application in advanced electronics and future solutions for sustainable energy.

The authors of this study synthesized a new nanoporous graphene structure by connecting ultra-narrow graphene strips, known as "nanoribbons", by means of flexible "bridges" made of phenylene moieties (which are portions of larger molecules).

By modifying in a continuous way the architecture and angle of these bridges, the scientists can control the quantum connectivity between the nanoribbon channels and, ultimately, fine-tune the electronic properties of the graphene nanoarchitecture. The tunability could also be controlled by external stimuli, such as strain or electric fields, providing opportunities for different applications.

These ground-breaking findings, resulting from a collaboration between top-tier Spanish institutions (CiQUS, ICN2, University of Cantabria, DIPC) and the Technical University of Denmark (DTU), shows that the

proposed molecular bridge strategy can have a great impact on the synthesis of new materials with tailored properties and is a powerful tool for the realization of quantum circuits.

These perform operations similar to those of conventional circuits, although unlike the latter, quantum circuits leverage quantum effects and phenomena. The design and implementation of these systems are extremely relevant to the development of quantum computers.

But the potential applications of the approach proposed in this study go beyond future electronic devices and computers. In fact, it could also lead to the development of thermoelectric nanomaterials, which can have an important impact in renewable energy generation and waste heat recovery, therefore addressing another crucial societal challenge.

More information: César Moreno et al, Molecular Bridge Engineering for Tuning Quantum Electronic Transport and Anisotropy in Nanoporous Graphene, *Journal of the American Chemical Society* (2023). DOI: 10.1021/jacs.3c00173

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