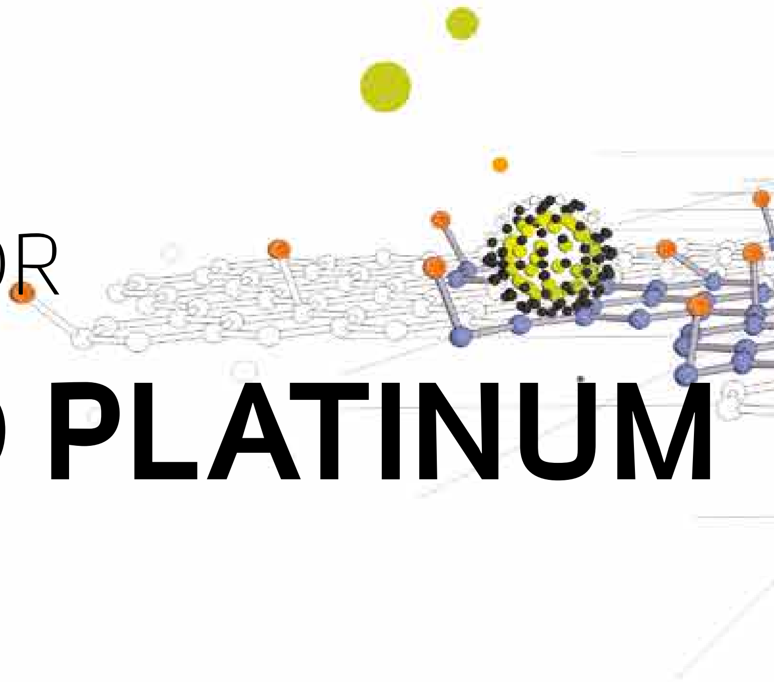


# NEW ENERGY APPLICATIONS FOR GOLD AND PLATINUM

Platinum-coated gold nanoparticles could enhance the efficiency of fuel-cell catalysts

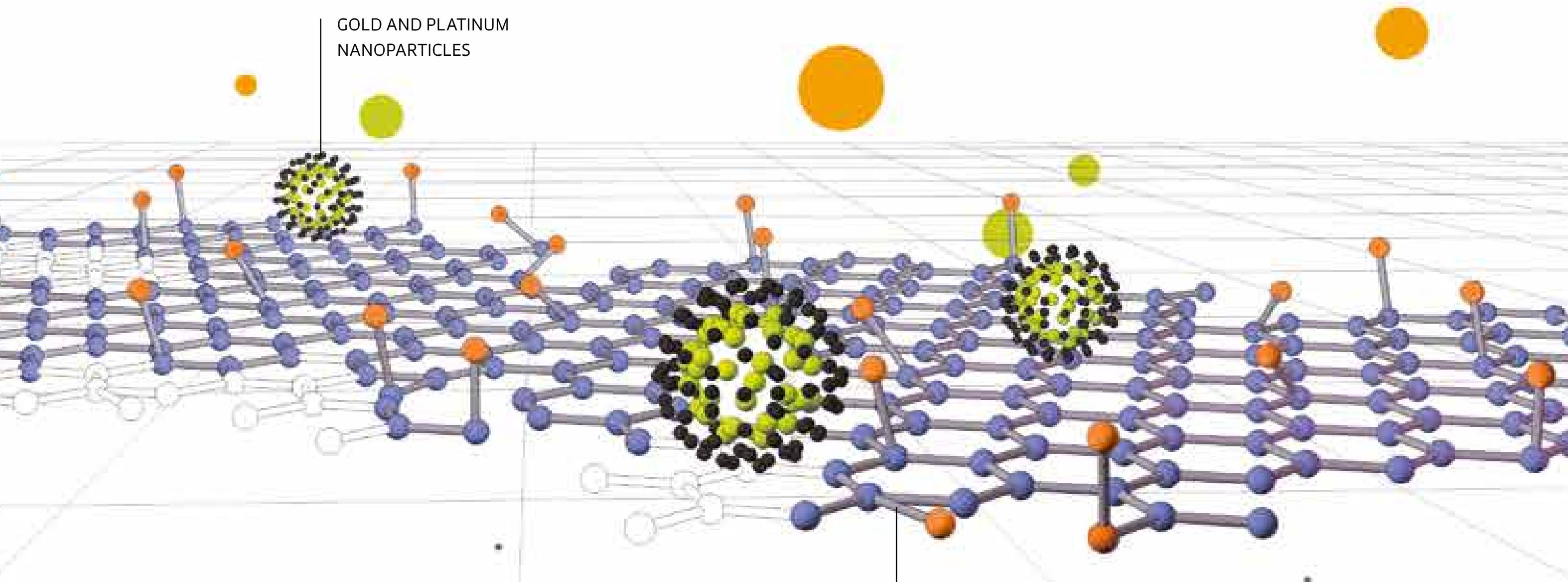
PUBLISHED IN MAY 2019

A research team at the Center for Advanced Research on Graphene, Nanomaterials and Nanotechnology (MackGraphe) at Mackenzie Presbyterian University, in São Paulo, has developed a prototype bimetallic catalyst that could improve the efficiency of hydrogen fuel cells—devices that convert hydrogen into electricity in a silent and pollutant-free process. Fuel-cell catalysts—which are generally made of platinum, a rare and expensive element—are used to break down water molecules ($H_2O$) into their component atoms to produce oxygen and hydrogen. The hydrogen gas is fed to fuel cells that, like electric batteries, can be used to power vehicles. The catalyst is embedded in the fuel-cell electrodes, which apply an electric discharge in the water during electrolysis. This process causes hydrogen nuclei to bind to each other rather than forming new water molecules as would occur normally.

The material developed by the São Paulo-based researchers consists of a graphene oxide membrane with added gold nanoparticles coated with an atom-thick layer of platinum. The superior performance of the material is credited to its special nanostructure, formed by joining particles of the two metals together. The secret to the catalyst lies in the monoatomic layer of platinum on a gold core, which enhances the electronic properties of the nanomaterial and its ability to act as a catalyst. "The nanoparticles are arranged to form a gold core approximately 1.2 nanometers in diameter with a platinum shell," explains theoretical physicist Leandro Seixas of MackGraphe, one of the authors of a study describing the development of the material, published January 29 in *ACS Applied Materials & Interfaces*. With the platinum shell and gold core, the nanoparticles are a maximum of 1.8 nanometers in diameter.

The new catalyst not only has been shown in tests to be more efficient but could also be less expensive to produce, as it would require smaller amounts of platinum than that needed for current materials, according to the researchers. "Platinum is extremely expensive, and producing fuel with this kind of catalyst is still a very inefficient process," says Seixas. These limitations led the MackGraphe team to leverage their expertise in graphene and nanostructures to develop a modified platinum material to improve the hydrogen production process.

In their experiments and simulations, the platinum-coated gold nanoparticles functioned better as catalysts than did structures made of macroscopic platinum particles, gold-platinum alloys, and even pure platinum nanoparticles. "Platinum on top of gold is more active than pure platinum," says chemist Camila Maroneze of MackGraphe, a coauthor of the study. "This was an interesting property that was predicted theoretically and then proven experimentally." For the theoretical part of their research, the team used a supercomputer at the Center for Advanced 2D Materials at




The illustration shows platinum-coated gold nanoparticles on graphene oxide membranes

the National University of Singapore to run simulations with the new material. In the experimental stage, electron transmission microscopes at the Brazilian Center for Research in Energy and Materials (CNPEM), in Campinas, were used to view nanostructures produced at the laboratory.

**ENERGY STORAGE**

Seixas and Maroneze's work, which is still in a basic research phase, has not yet generated patents. The manipulation of gold on a graphene oxide substrate has been previously described in a paper published last year in *Nanoscale*. Producing these nanoparticles is, however, only the first stage in a broad and exciting new research front. Hydrogen is used today not only in early fuel-cell powered vehicles but also in energy storage applications. "Demand for this second type of application should increase in tandem with solar and wind power deployment," says physicist Ennio Peres of the University of Campinas (UNICAMP). "Power from solar and wind farms is intermittent and needs to be stored for use in peak periods. If we use surplus electricity to produce hydrogen fuel, we can store it for later use in fuel cells to generate electricity."

Before retiring, Peres served for ten years as head of UNICAMP's Hydrogen Laboratory (LH2), which founded Hytron, a Brazilian spinoff firm operating in the hydrogen-based energy storage market. In real-world applications, the cost of catalysts is a crucial constraint, explains Peres. In fuel cells, which function as "engines" for vehicles and generators, an effective substitute for platinum has yet to be developed, and a technological race is currently underway to lower the cost of these devices.

The MackGraphe research group, like others at many universities and research centers around the world, is working on two fronts. The first is improving the effectiveness of platinum, as in the current study. The second is developing alternatives to platinum. "One metal we're currently evaluating, molybdenum, is far cheaper than platinum," says Seixas. "When combined with sulfur, molybdenum becomes lamellar, or two-dimensional, like graphene." Molybdenum disulfide, as it is called, can then be tuned at the nanometric scale to create different electronic properties, explains Seixas. This compound has been frequently described in recent scientific literature in the field and should be the subject of the group's next research papers. ■ **Rafael Garcia**

## Project

Graphene: photonics and opto-electronics. UPM-NUS collaboration (No. 12/50259-8); **Grant Mechanism** Research Grant; **Program** Spec; **Principal Investigator** Antonio Helio de Castro Neto (Mackenzie Presbyterian University); **Investment** R$13,561,689.05 (for entire project).

## Scientific article

GERMANO, L. D. *et al.* Ultrasmall (<2 nm) Au@Pt Nanostructures: Tuning the surface electronic states for electrocatalysis. **ACS Applied Materials & Interfaces**. Jan, 29, 2019.

ILLUSTRATION FABIO OTUBO