Is Carbon the Key to Improving the Efficiency of Fuel Cells?

Do not throw away your batteries yet, but researchers are getting closer to pinpointing catalytic systems that may improve the efficiency of direct methanol fuel cells. Using x-ray absorption fine structure spectroscopy (XAFS) at the MR-CAT (10-ID) and PNC-CAT (20-BM) beamlines, a team from the University of Notre Dame and Indiana University Northwest recently found that films produced by incorporating platinum (Pt) nanoparticles onto single-walled carbon nanotubes (CNTs) produced catalytic activity an order of magnitude greater than Pt particles fused onto spherical fullerenes (C60). Further exploration using XAFS revealed that it's the structure of the carbon support that accounts for this dramatic difference in the efficiency of the system.

The carbon support system itself, whether a sphere or a nanotube, has insignificant catalytic properties, but electrochemical deposition of platinum nanoparticles—a common technique to bind noble metals to carbon—changes the overall catalytic activity of the system. Previous XAFS probes of platinum on a carbon support confirmed the reducing potential and formation of platinum nanoparticles. The current study used XAFS and electrochemistry measurements to compare the structure and catalytic activity of platinum particles on two different carbon supports: the spherical C_{60} and the CNT.

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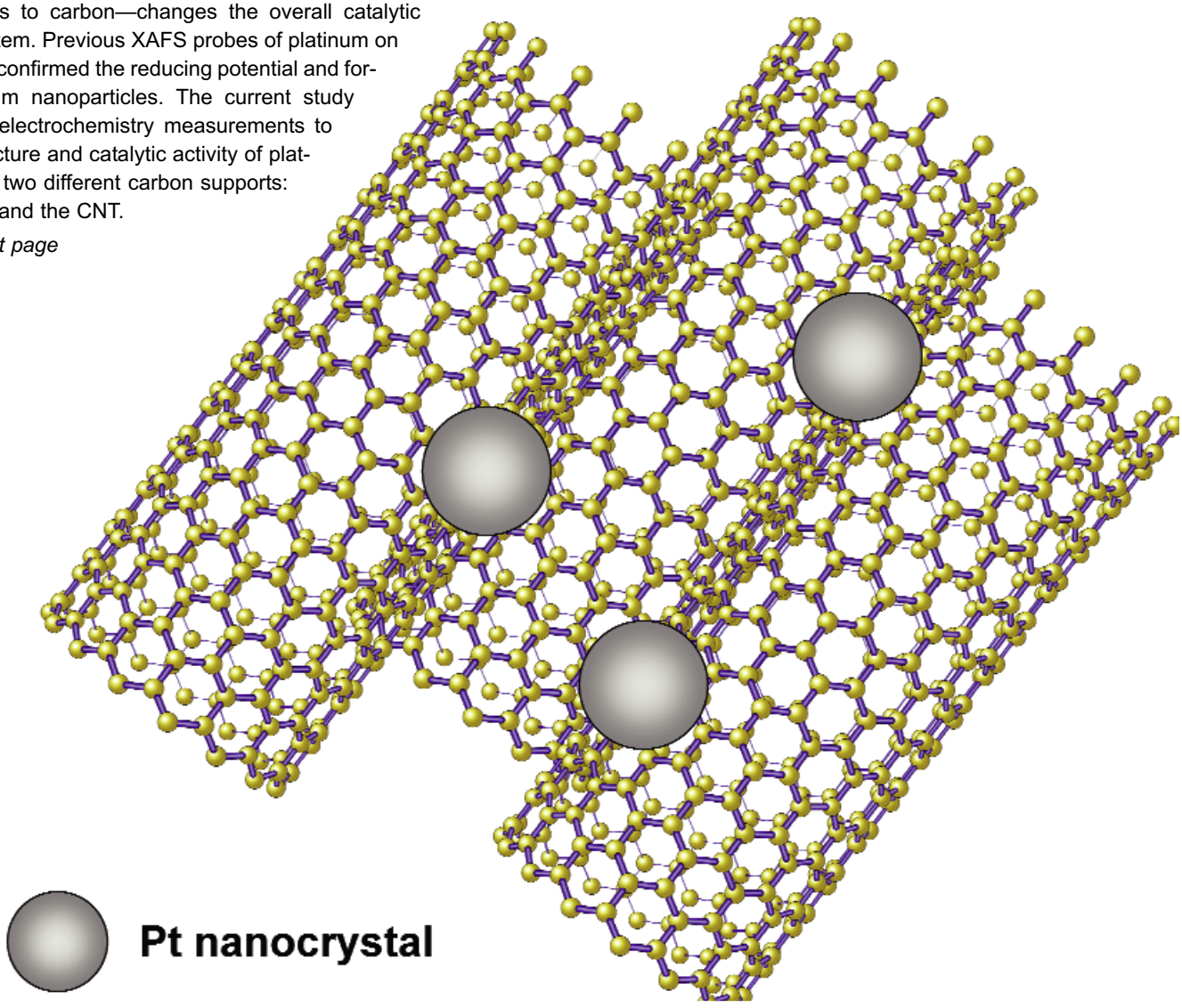

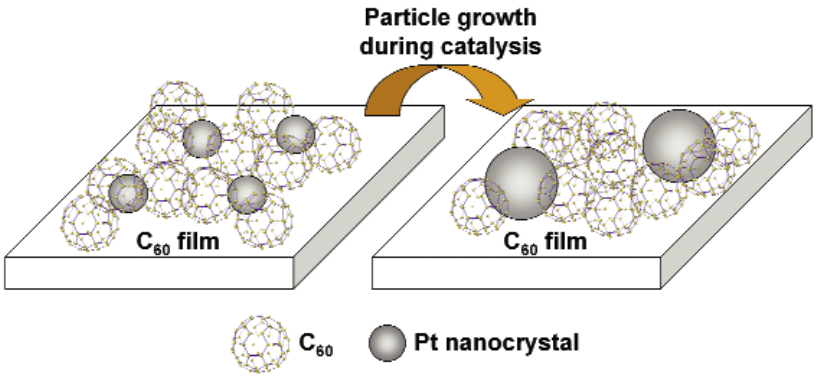

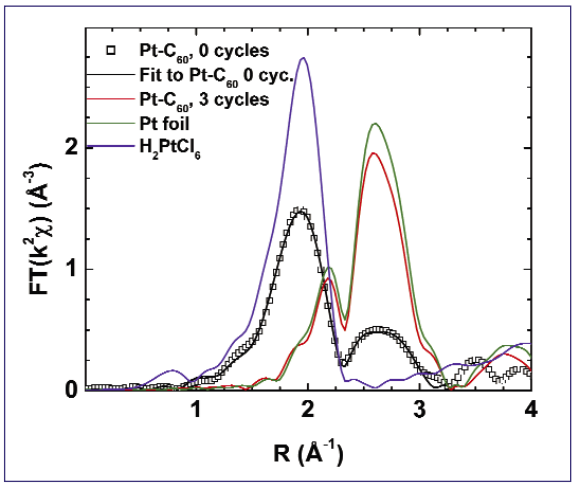

Fig. 2. Above: Pt nanocrystals deposited on C60 films undergo structural changes during the catalytic process. Right: Fourier-transformed EXAFS spectra of Pt–C60 as-prepared (black squares and fit) and after three cycles of methanol oxidation (red) compared to Pt metal (green) and H_2PtC_{l6} (blue) standards.

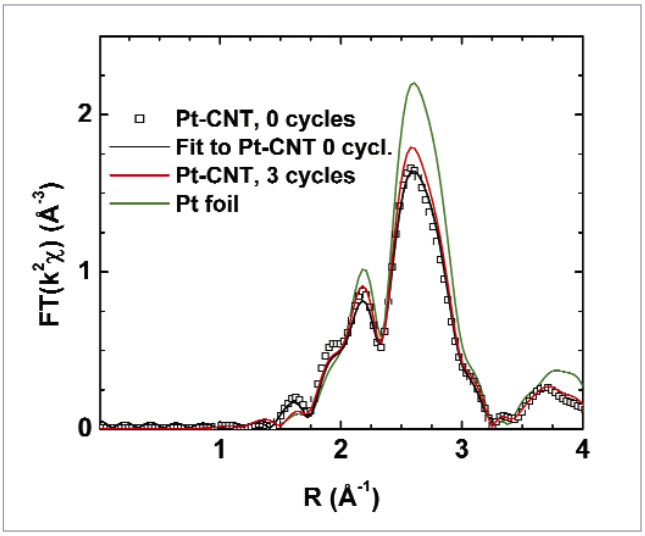

Fig. 1. Opposite page: Pt nanocrystals anchored on carbon nanotube films show a high degree of stability during the catalytic oxidation of methanol. Above: Fourier-transformed XAFS spectra of Pt-CNT as-prepared (black squares and fit) and after three cycles of methanol oxidation (red) compared to Pt metal standard (green).

C_{60} and CNT films were first deposited onto the surface of optically transparent electrodes followed by electrodeposition of Pt nanocrystals. The films were then subjected to multiple catalytic cycles of methanol oxidation in an electrochemical cell. Although both systems showed increased oxidation current during the first four cycles of methanol oxidation, values of the peak currents indicated that Pt-CNT films had much higher catalytic activity than the Pt-C_{60} films.

To determine the structural changes that might explain the large differences in catalytic activity, the team then observed the films before methanol oxidation, after three cycles of oxidation, and after 20 cycles followed by a 48-h period of aging in a mixture of methanol and sulfuric acid. The Fourier-transformed XAFS spectra (Fig. 1) showed no change in the structure of the Pt atoms in the CNT film, even after the 20 cycles and period of aging, indicating the superior stability of this construct. The platinum ions in the Pt-C_{60} catalyst, however, showed dramatic structural changes after exposure to the first three cycles of oxidation and reduced catalytic activity (Fig. 2). The peak in the Fourier-transformed XAFS spectra at 1.9 Å disappears, and the peak at 2.8 Å becomes more prominent, which suggests that a significant fraction of Pt atoms—still in the form of Pt chloride after electrodeposition—is reduced to metallic form after exposure to methanol oxidation.

Materials formed by fusing noble metals (such as platinum) onto carbon supports are promising candidates in the production of direct methanol fuel cells, which may soon power increasingly popular small hand-held devices. Given the expense of noble metals, however, we need to determine the most efficient and affordable systems. Techniques such as XAFS can help determine, before further testing, which materials are the best candidates for use in direct methanol fuel cells.

— Elise LeQuire

See: István Robel[1], G. Girishkumar[1], Bruce A. Bunker[1*], Prashant V. Kamat[1], and K. Vinodgopal[2], "Structural Changes and Catalytic Activity of Platinum Nanoparticles Supported on C_{60} and Carbon Nanotube Films During the Operation of Direct Methanol Fuel cells," Appl. Phys. Lett. **88**, 073113 (2006).
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