

Carbon Colloids Prepared by Hydrothermal Carbonization Power Indirect Carbon Fuel Cells

Electrochemical conversion of carbon to electrical energy has its origins in the late 19th century. A carbon fuel cell is conceptually much more efficient than combustion for converting the chemical energy in coal into electrical energy. Because the activation energy for the electrochemical oxidation of carbon is high, direct carbon fuel cells (DCFCs) require high temperatures (between 500°C and 1000°C), which limits their application. Alternatively, indirect carbon fuel cells (ICFCs) employ a secondary oxidant to oxidize carbon. The secondary oxidant is renewable, that is, it is re-oxidized at the anode. ICFCs can therefore operate at temperatures in the range of about 80–100°C, although the theoretical decrease in cell voltage is about 50%—from about 1 V (for DCFCs) to 0.5 V. Promising results were previously reported for an ICFC with a $\text{Fe}^{3+}/\text{Fe}^{2+}$ secondary redox system in the anodic half-cell using a

fuel of subbituminous fossil coal. Recently, J.P. Paraknowitsch, A. Thomas, and M. Antonietti of Max-Planck-Institute of Colloids and Interfaces, Potsdam-Golm, Germany, have shown that the efficiency of ICFCs can be increased even further with a fuel of carbon colloids.

As reported online on March 3 in *Chemistry of Materials* (DOI: 10.1021/cm801586c), the research team obtained water-dispersible carbon colloids from a process called hydrothermal carbonization (HTC), which dates back to early 20th-century studies of coal formation from carbohydrates. Specifically, D-glucose, which the researchers regard as a model compound for several biomass sources, was heated in water in a closed reaction vessel for 4–24 h at a temperature of about 200°C to form HTC coal. In addition to the expected zero balance for CO_2 , the researchers said that another advantage of HTC coal is the hydrophilic surface structure; Fourier transform infrared spectra show bands of hydroxylic and carbonylic groups. Other advantages include the

micrometer spherical particles and the HTC coal's amorphous structure, which are ideal for a water-based fueling system. Furthermore, the low contents of sulfur and ash in HTC coal from biomass will serve to minimize interactions with the secondary redox system.

The researchers used an ICFC similar to the one previously proposed but replaced the cathodic oxygen half-cell with a $\text{VO}^{2+}/\text{VO}^{3+}$ cathodic half-cell in order to make the fuel cell more suitable to a laboratory scale (see Figure 1). Reference measurements made with a half-cell containing only an Fe^{3+} solution showed negligible current, as expected. However, when the reference solution was replaced with a mixture of 50 ml Fe^{3+} solution and 1 gram of HTC coal that had been stirred (in order to disperse the HTC carbon particles) at 100°C for 1 h, the measured current increased markedly, leveling off at about 2–2.5 mA after about an hour. The researchers said that formation of Fe^{2+} ions from oxidation of the carbon source leads to an increase of both open-circuit potential and, when both half-cells are short circuited, electric current. The researchers found very similar results when lignite was used as a carbon source. However, anthracite performed poorly, attaining a current of less than 1 mA.

These ICFC results are consistent with the oxidation rates previously obtained by the researchers from a standard oxidation assay. An efficiency of about 4% was achieved for HTC coal and for lignite in a salt bridge-based ICFC, which improves to about 14% for a Nafion membrane-based ICFC, which the researchers attribute to better charge equilibration in the latter ICFC. The researchers said that “using carbon colloids derived from hydrothermally treated biomass would indeed yield an indirect carbon fuel cell with an overall zero-emission balance concerning the green house gas CO_2 .”

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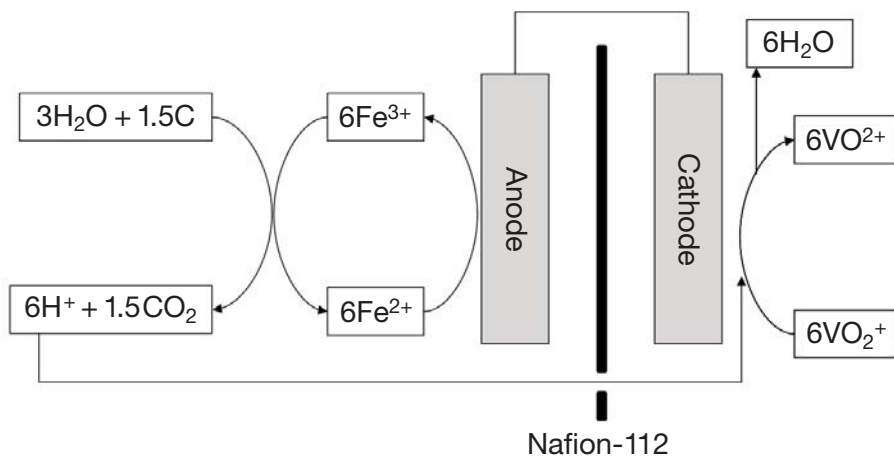


Figure 1. Schematic representation of the secondary redox concept for an indirect carbon fuel cell.

Nanostructured Device Design Based on Plasmonic Crystal Confinement May Enable Single-Molecule Detection

The ability to detect single molecules in a rapid and reliable fashion would bring enormous benefits in many areas, from homeland security to medical research to early disease detection. Many researchers pursuing this goal have focused on optical techniques, which can operate extremely quickly and potentially from a distance. However, obtaining a detectable interaction from a single molecule at rele-

vant optical wavelengths requires light to be compressed many times smaller than the diffraction limit, a challenge that has hindered progress in this area. Now, R.M. Gelfand, L. Bruderer, and H. Mohseni at Northwestern University have demonstrated the design of a nanostructured device that may represent a solution, which they report in the April 1 issue of *Optics Letters* (DOI: 10.1364/OL.34.001087; p. 1087).

The basic concept of optical single-molecule detection is to observe the spectral absorption fingerprint of target mole-

cules. To be practical, the interaction between the light and the molecule must be made much stronger than in free space, which generally requires confinement of the light and molecule in some structure that enhances the optical intensity and increases the interaction time. Unfortunately, standard cavity structures generally have too small a spectral bandwidth to allow detection of the molecular spectral fingerprint, and are also overly sensitive to small manufacturing or environmental variations.

The Northwestern team addressed this