

tational conclusion that carboxylic acids are good targets for CO<sub>2</sub> capture. Although the CO<sub>2</sub> binding might be too strong for CO<sub>2</sub> capture applications

because of the energy penalty due to recycling the material, the researchers said that “the ability to fine tune CO<sub>2</sub> affinity in this way [with the selection of

functional groups] is of potential value for both CO<sub>2</sub> capture and storage as well as gas separation.”

**Steven Trohalaki**

### Bio Focus

#### Liquid STEM used for particle uptake studies in living cells

The uptake of nanoparticles into cells has conventionally been studied with transmission electron microscopy of thin sections. However, the preparation into thin sections leads to a loss of nanoparticles, and also prevents the analysis of the whole three-dimensional cellular volume. Furthermore, conventional electron microscopy is not capable of studying live cells. D.B. Peckys and N. de Jonge from Vanderbilt University Medical Center have now improved upon a liquid scanning transmission electron microscopy (STEM) method that allows for quantitative assessment of nanoparticle uptake in living cells. The researchers used a microfluidic chamber composed of microchips where fibroblast cells were imaged with minimal radiation damage to reveal the distribution of gold-nanoparticles (Au-NP) within the cells.

In the March 16th issue of *Nano Let-*

*ters* (DOI: 10.1021/nl200285r; p. 1733), the research team described the application of a novel microfluidic chamber device for live-cell examination. The device was made from two parallel silicon microchips. Each microchip contained a central silicon nitride (SiN) membrane of 50 nm thickness that was transparent to the electron beam as well as light. One microchip was coated with poly-L-lysine (PLL) for increased cell adherence; the other chip had an attached 6 μm spacer to form a reservoir for the cells and buffer. Live green monkey kidney fibroblast cells (COS-7) were incubated for 2 hours in the presence of 30 nm Au-NPs. The cells were then washed and incubated in a medium. Twenty-four hours later, the cells were enclosed in the chamber and imaged live with a STEM under a continuous flow of buffer. Experiments demonstrated that COS-7 cells remained viable in the microfluidic chamber.

STEM analysis was carried out shortly after the cells were loaded. The cells were viewed at 16,000x magnification using an accelerating voltage of

200 kV and a probe current of 0.16 nA. The researchers were seeking to identify several quantitative values pertaining to the number and placement of the Au-NPs inside the cell vesicle. The STEM images showed high concentrations of Au-NPs as dark spots clustered inside cell vesicles, which were 200–300 nm in diameter. However, there was a degree of image distortion due to certain factors including beam-specimen interaction, the liquid medium, distance to focal plane, and the degree of pixelation.

Despite these conditions, the researchers were still able to resolve separate nanoparticles by enhancing the image using image processing software, Image J. They conducted quantitative measurements of several factors such as the total number of Au-NPs per vesicle cluster and the average density of Au-NPs on the surface of the vesicles.

The researchers concluded that their research showed this method of liquid STEM is suitable for further study of nanoparticles uptake into living cells.

**Tara D. Washington**

### Nano Focus

#### Nanofiltration membrane improves performance of vanadium redox flow battery

Integrating renewable energy sources such as wind and solar into the electric grid will require energy storage systems to handle their intermittent nature. One promising possibility is the vanadium redox flow battery (VRB), based on active species of vanadium dissolved in electrolyte. To date, VRBs have been limited by their use of perfluorinated-polymer ion-exchange membranes, which are expensive and have low selectivity between vanadium and other ions. Now a group from the Dalian Institute of Chemical

Physics in China has demonstrated a VRB based on a much cheaper nanofiltration membrane. H. Zhang and colleagues reported their findings in a recent issue of *Energy & Environmental Science* (DOI: 10.1039/c1ee01117k; p. 1676).

VRBs were first proposed and demonstrated 25 years ago, and have a number of advantages for grid-scale storage, including fast response times and the ability to scale to essentially unlimited storage capacity. They function by flowing solutions of vanadium ions in a sulfuric acid electrolyte by either side of an ion-exchange membrane. The researchers hypothesized that it would be possible to eliminate the use of the expensive ion-exchange membrane by using a nanofil-

tration (NF) membrane, which conducts ions mechanically through nanometer-scale pores, and costs (by their estimate) roughly 1/20th as much.

To test this idea, the researchers prepared samples of polyacrylonitrile NF membranes using a phase-inversion method, varying the polymer concentration and the addition of volatile co-solvents in order to control the distribution of pore sizes. They next tested the ionic selectivity of the membranes by measuring the permeation rate of VO<sup>2+</sup> and H<sup>+</sup> in a 3 M H<sub>2</sub>SO<sub>4</sub> solution across the samples into deionized water, finding that the rate for H<sup>+</sup> exceeded that of VO<sup>2+</sup> by factors ranging from 6.9 to 14.9, with the largest ratio occurring for the sample



with the smallest membrane pore sizes. The researchers then constructed single VRB cells using the samples, finding a coulombic efficiency (CE) of 95% and energy efficiency (EE) of 76% at a current density of 80 mA/cm<sup>2</sup> (comparable to the performance of standard VRB cells),

which remained stable over 200 cycles.

These results are particularly noteworthy in light of a recent result from a team of researchers at Pacific Northwest National Laboratory in Richland, WA, who found that adding HCl to the electrolyte increased the energy density

of VRBs by up to 70% and improved their operating temperature range. Taken in combination, these advances suggest that vanadium redox flow batteries may someday be the technology of choice for grid-scale energy storage.

Colin McCormick



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