Turning Lead Into Carbon

Two primary effects reduce the life of a lead-acid battery—corrosion of the battery's positive plate and sulfation of the battery's negative plate. Kurt Kelly at Firefly Energy, Inc., Peoria, Ill., found a solution to both of these problems by incorporating carbon-graphite foam technology into a conventional battery structure, with the **Carbon Foam Graphite Battery**. Firefly's 3-D cell architecture involves replacing the conventional lead metal-based plate with a carbon foam electrode in such a way as to be easily incorporated into existing lead-acid manufacturing processes.

For identical configurations, the Carbon Foam Graphite Battery occupies a volume of 3.8 L vs. 5.6 L for the conventional device. The weight is reduced from 14.1 kg to 11.8 kg, and its delivered capacity is increased from 23.3 A/hr to 27 A/hr. Specific energy is similarly increased, as are energy density and cycle life, which is more than doubled. The safety aspect of the batteries is similarly improved. The similarity to conventional devices carries over to permitting the use of conventional lead-acid chargers with the new batteries.

Firefly Energy, Inc., www.fireflyenergy.com

Enabling Fuel Cell Commercialization

In fuel cell assemblies, the flow field plates make up the bulk, by weight and volume, of the fuel cell stack, as well as being one of the most expensive components to manufacture. A research team at GrafTech International Ltd., Lakewood, Ohio, has addressed this situation with the creation of **GRAFCELL Expanded Graphite Flow Field Plates**. Their high corrosion resistance, good electrical and thermal properties, light weight, and low production costs make these flow field (bipolar) plates a key enabling technology for the commercialization of fuel cells.

Developed for polymer electrolyte membrane (PEM) fuel cells with applications in back-up power systems, stationary power, portable electronics, and automotive systems, the plates have significant advantages over competitive metal and graphite-filled polymer technologies. The GRAFCELL plates have an exceptional electrical conductivity and a high thermal conductivity. They also have the best overall balance of properties for flow field plate applications. Unlike metals, they're not corroded by water or hydrogen, yet they can be made much thinner and possess superior electrical and thermal conductivities over graphite-filled polymers. The costs are also well within the Dept. of Energy targets of less than $2.00/plate by 2010 due to low materials costs and high-volume manufacturing.

GrafTech International Ltd., www.graftech.com

Hot to Generate

Richard King and Raed Sherif at Spectrolab, Inc., Sylmar, Calif., and Martha Symko-Davies at the National Renewable Energy Laboratory, Golden, Colo., have collaborated to develop a **High-Efficiency Metamorphic Multijunction Concentrator Solar Cell (HEMM)** that is the first solar cell to surpass the 40% efficiency barrier. This new technology is a lattice-mismatched triple-junction device that can generate utility-scale electricity with ultra-high performance under high solar concentrations.

The mismatch concept opens up design options for using other materials for active solar layers with optimal bandgaps that raise the theoretical and practical efficiencies of solar devices. Producing the HEMM solar cell also will stimulate the push for clear large-scale power generation using concentrator solar systems.

It is realistic to consider an installed HEMM system cost of $3.00/W or less (with the cells alone costing less than $1.00/W), producing electricity at a cost of $0.08 to $0.10/kWh—which is competitive with conventional electricity generation technologies.

More junctions can also be added to the device so as to capture and exploit an even greater portion of the solar spectrum with the possibility of even higher conversion efficiencies. As such, the cost of balance-of-systems items—which include support structures and electrical conductors—can be reduced to very low levels.

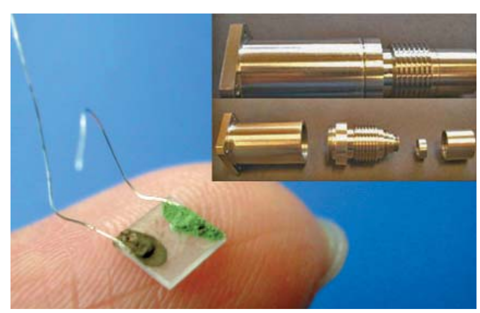
National Renewable Energy Laboratory, www.nrel.gov

Simple Sensor, Big Potential

There is a significant need for measurements of NO_x species in combustion environments due to the negative effects these gases have on ecosystems, health, and government regulations. Solid-state electrochemical sensors are attractive due to their small size, portability, lower costs, and operation at high temperatures and in harsh environments. Potentiometric solid-state sensors have been developed, but NO and NO_2 produce responses in opposite directions in them.

Researchers at Ohio State Univ., Columbus, have solved this problem with their **High-Temperature Total NOx Sensor**. By using a Pt-loaded zeolite as a catalyst filter placed before the sensing element, NO_x species in the gas stream are brought to an equilibrium concentration of NO and NO_2. The equilibrated NO_x is then measured with an yttria-stabilized zirconia-sensing element using a metal oxide-sensing electrode in a potentiometric mode.

The resulting sensor measures total NO_x, as NO and NO_2 produce the same signal. It also has minimal interference from other combustion gases (CO, CO_2, NH_3, H_2O, and O_2), is simple to install (two wire leads to a multimeter), and can operate in environments up to 700°C. The signal is also linear with logarithm to NO_x concentrations, making calibration



straightforward. It has much faster response times (less than 1 sec) and can be used for feedback controls. The sensitivity of the device is also at least 100x better than competing devices, with comparable accuracies.

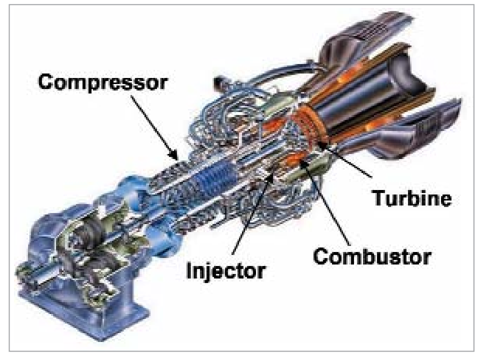
Ohio State Univ., www.osu.edu

Planning for the Future

Low-Swirl Combustion for Fuel Flexible Near-Zero Emissions Gas Turbines (LSI) is a tremendously promising, elegant, cost-effective technology for significantly reducing greenhouse emissions, including nitrogen oxides, from electricity generation systems. Developed by a research team at Lawrence Berkeley National Laboratory, Calif., and Solar Turbines, Inc., San Diego, Calif., the LSI system has a unique fuel flexibility capability and is scalable up or down. LSI does not have any impact on turbine operation during startup, shutdown, or load cycles. It also is expected to increase the anticipated hours of operating time between inspections and overhauls by reducing material heating.

Gas turbines of all sizes, ranging from 70 kW to well over 250 MW, using the LSI system can burn a variety of gaseous hydrocarbons including natural gas, liquefied natural gas, petroleum production and refinery gases, waste gas, and biogas. Running all of these gases, the LSI system will still meet the stringent below 2.5 ppm NO_x emission limit.

LSI also is a critical enabling technology for integrated gasification combined cycle (IGCC) coal power plants with CO_2 capture. LSI will allow these plants to produce near-zero emissions by the year 2025. Coal-based IGCC plants will be the technology of choice over the next 15 years to significantly curtail



and eventually eliminate greenhouse gas emissions. LSI will provide the advanced combustion technology that will allow these power plants to meet their efficiency, emissions, and capital and operational costs goals.

▶ **Lawrence Berkeley National Laboratory,** www.lbl.gov

Free Power

Geothermal power is an ideal renewable base load; however, all of the high-temperature steam-dominated resources located close to U.S. population centers have already been developed. What remains is a large number of moderate temperature (74°C to 121°C) water-dominated geothermal resources. The technology to generate power from these resources has been available for 30 years, but its high cost has limited its development. The **UTC Power PureCycle** geothermal system can change that picture with its ability to operate on geothermal resources as low as 74°C. Developed by the United Technologies Research Center, East Hartford, Conn., UTC Power, South Windsor, Conn., and Chena Hot Springs Resort, Fairbanks, Ark., the PureCycle geothermal system is built using modified mass-produced refrigeration equipment. UTC Power's closed-loop organic Rankine cycle is entirely enclosed, meaning it produces no emissions. The only byproduct is electricity.

▶ **United Technologies Research Center,** www.utrc.utc.com

Superconducting Milestone

The **SuperPower/ORNL High-Performance, LMOe-HTS Wire** is the culmination of several years of research aimed at developing a superconducting cable that can replace copper cables in the U.S. power grid. In addition to having a high current-carrying capacity, the LMOe-HTS wire is flexible, strong, economical, and can be mass-produced in useful (km-long) lengths. The LMOe-HTS wire succeeds where other superconducting wires have not because an $LaMnO_3$ (LMO) buffer layer is used which can be deposited 20x faster than any other buffer layer deposition process currently employed in the fabrication of second generation (2G) HTS wires. The resultant wire is also mechanically robust with a high yield strength (1,200 MPa).

The LMOe-HTS enabled the research team at SuperPower, Inc., Schenectady, N.Y., along with Oak Ridge National Laboratory, Tenn., to deliver nearly 10,000 m of 2G HTS wire to Sumitomo Electric Industries in Japan in Dec. 2006, the world's first significant delivery of 2G wire.

▶ **SuperPower, Inc.,** www.superpower-inc.com

Really Fast Switching

Power device users have long assumed that the temperature, switching, and packaging limitations of thyristors and GTOs (gate turn-off thyristors) would improve over time. They have not. A research team at Silicon Power Corp., Malvern, Pa., the Electric Power Research Institute (EPRI), Palo Alto, Calif., the Office of Naval Research (ONR), Arlington, Va., and the U.S. Army Research Laboratory, Adelphi, Md., have developed an IC-foundry fabrication process to substantially increase the conduction and switching efficiency in an ultra-high density package.

This **Super-Gate Turn-Off Thyristor (S-GTO)** is a paradigm shift in the system size and performance for next generation power delivery, conversion, and conditioning systems. The IC process capability allows a uniquely high gain upper transistor, combined with the ability to design with more than three orders of magnitude cell density.

The SGTO and its novel thinPak package feature a 10x reduction in system size and weight compared to standard GTO systems. The trade-off between forward drop and switching loss, controlled by a combination of proton and electron irradiation, allows the SGTO to approach the physics limit for a four-layer structure.

These devices can be paralleled and stacked in series with fewer problems than those faced with standard GTOs.

▶ **Silicon Power Corp.,** www.siliconpower.com