U.S. Department of Energy
National Energy Technology Laboratory • Pacific Northwest National Laboratory

The High Temperature Electrochemistry Center

Solving technical challenges for the Department of Energy's energy plants of the future

HiTEC

Vision

The High Temperature Electrochemistry Center (HiTEC) is supporting a revolutionary change in power production. By bringing together research at national laboratories and universities, it focuses on building scientific understanding and advancing new technologies needed to design and build energy plants that maximize efficiency while minimizing the environmental effects of using fossil fuels.

HiTEC was established in 2002 to coordinate research efforts and develop new technologies that align with the vision of the Department of Energy's Office of Fossil Energy. HiTEC also responds to the FutureGen Initiative announced by the President in 2003. The technology underpinnings provided by HiTEC today will help make possible energy plants of tomorrow that will—

- **Serve multiple functions—generating electricity and producing clean fuels, chemicals, hydrogen, and heat or steam**
- **Generate electricity twice as efficiently as today's power plants**
- **Produce virtually no air or water pollutants**
- **Process a variety of fuels, including coal gas, biomass, and municipal waste**

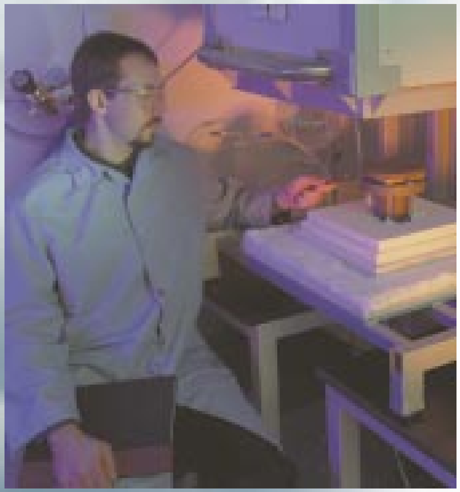
HiTEC is advancing the technology underpinnings necessary to bring together components of future fossil energy plants, including turbines, fuel cells, and hybrid energy generation systems.

Taking steps toward FutureGen

The High Temperature Electrochemistry Center (HiTEC) is a research collaboration focused on technical breakthroughs needed to accomplish the Department of Energy's vision for energy plants of the future. Its mission is to provide crosscutting, multidisciplinary research that leads to advanced electrochemical technologies for minimizing the environmental consequences of using fossil fuel in energy generation. This collaborative effort is managed by the National Energy Technology Laboratory and Pacific Northwest National Laboratory. As part of this program, researchers are delivering the technical foundation necessary to bring together components of future fossil energy plants, including fuel cells, turbines, and hybrid energy generation systems.

Thermoelectric materials like these silicon nanowires are capable of transforming waste heat into electricity. While promising, these materials require greater stability at elevated temperatures and greater efficiency for use in fossil energy conversion systems.

Research conducted through HiTEC will be used on the FutureGen test platform. FutureGen is a $1 billion venture to build a prototype of the world's first fossil fuel power plant that combines electricity and hydrogen production with carbon sequestration technologies for the virtual elimination of harmful emissions, including greenhouse gases.



The center's high-temperature electrochemical research, combining experimental and modeling activities, will address—

- **Energy conversion**
- **Hydrogen production and use**
- **Gas separation and purification**
- **Electrolysis**
- **Energy storage**
- **Emissions reduction**
- **Thermoelectrics**
- **Sensing**
- **Low-cost materials manufacturing technologies**

The texture used on the cover of this brochure comes from an image of a nanostructure that could be effective in achieving the high thermoelectric efficiencies necessary in materials that transform waste heat into electricity.

A need for breakthroughs

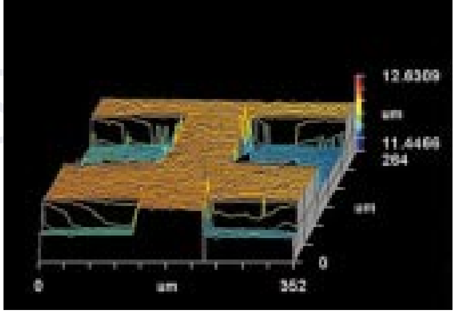
As part of the core research team for HiTEC, PNNL applies its expertise in material science, solid-state electrochemistry, and surface chemistry to develop new materials and ways to form and manufacture them that achieve the cost and performance goals of future energy plants.

The Environmental Molecular Science Laboratory, a DOE user facility at PNNL, provides cutting-edge facilities, equipment, and instrumentation that can support research in high-temperature electrochemistry. Resources that PNNL researchers, collaborators, and visiting scientists can access include an ion accelerator facility for Rutherford backscatter and nuclear reaction analysis, extensive surface science instrumentation, vibrational spectrometry, analytical electron microscopy, x-ray diffraction, and nuclear magnetic resonance.

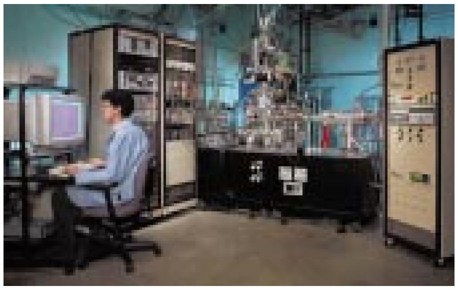
Collaborating with universities

In addition to the core research activities at PNNL, the first HiTEC satellite research center was established at Montana State University in 2002. This satellite center is concentrating on research related to the deposition of metal oxide thin films and electrochemical reactions at buried interfaces.

HiTEC coordinates the satellite center research and plans to add new satellite centers at other universities across the country. Each satellite center will focus on specific topical areas or disciplines where new scientific knowledge and innovations are needed to overcome the technical challenges of the FutureGen Initiative.



Studying patterned electrodes such as this one, prepared using a combination of lithographic techniques and magnetron sputtering, have led to significant improvements in oxygen-reduction electrodes. The ability to reduce oxygen at the interface of the cathode and the electrolyte addresses a key factor that limits performance of fuel cells, oxygen separators and certain sensors.



The ion accelerator at the Environmental Molecular Sciences Laboratory is being used by collaborators at Montana State University who are studying the oxidation mechanisms of novel electrical interconnect materials.

Areas of emphasis

By addressing technical challenges associated with these areas, Pacific Northwest National Laboratory and the satellite research centers of HiTEC are advancing electro-chemical systems for clean, efficient energy production.

Electrode performance

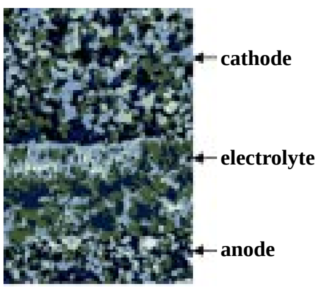
Inefficiencies in electrode reactions critically affect the performance of high-temperature electrochemical devices such as fuel cells, sensors, and gas separators.

HiTEC research will build an understanding of electrode reactions, including the complexity of buried interfaces. Improvements are needed in the electrocatalytic future

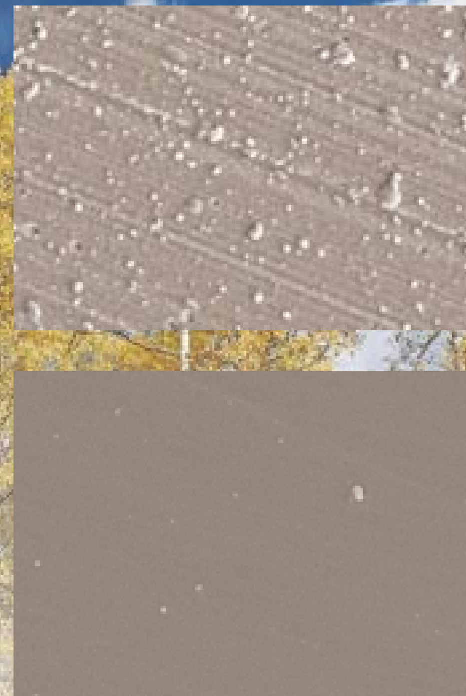
A look to the future

The satellite research center at Montana State University is the first of several satellite centers that HiTEC plans to establish in the United States. Through participation in HiTEC, these universities can apply their capabilities and areas of expertise to address a national priority while enhancing their educational programs.

Partnerships with university satellite centers also create opportunities for student interns and visiting scientists to help develop scientific resources needed for energy generation in the future.



Researchers are building an understanding of the inefficiencies of electrode reactions, which critically affect the performance of high-temperature electrochemical devices. In addition to learning about the mechanisms of electrode reactions, they are working to improve the electrocatalytic activity, selectivity, and stability of electrode materials.



Researchers at Montana State University are developing advanced coating techniques for thin ceramic structures. The top image shows conventional plasma coating techniques, while the bottom image shows the deposition of an exceptionally high-quality coating using large-area filtered arc plasma facilities.

activity, selectivity, and stability of electrode materials.

Thermoelectric materials
Thermoelectric materials could be used to generate electrical power using waste heat from steam generating plants, fuel cells, or vehicles.

New materials and structures are needed to achieve high efficiency and stability at high temperatures.

Regenerable Fuel Cells
A “reversible” solid oxide fuel cell can produce hydrogen from water during periods when extra capacity is available on the electricity grid and then use the stored hydrogen to produce electricity at a later time.

Electrolysis, using electricity to split water molecules, is more efficient in high temperature electrochemical systems than in lower temperature systems. Research will focus on developing high-temperature systems and new materials that are tolerant of high temperatures and oxidation.

Membranes
Membranes separate oxygen from air and hydrogen from gas mixtures such as gasified coal for use in fuel cells or turbines.

Low-cost membranes that provide high gas fluxes, result in low impurity concentrations, and remain stable in harsh, high-temperature environments are needed.

Sensors
Sensors in electrochemical systems will measure temperature and pressure and detect gases including oxygen, carbon monoxide, carbon dioxide, hydrogen, hydogen sulfide, ammonia, water, and hydrocarbons.

New technologies are needed for the harsh environments of advanced energy production systems based on fossil fuels, which include temperatures up to 1,000 degrees Celsius and pressures up to 500 pounds per square inch.

Mark Williams
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
www.netl.doe.gov
mark.williams@netl.doe.gov
304-285-4747

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

Larry Pederson
Pacific Northwest National Laboratory
P.O. Box 999, K2-70
Richland, WA 99352
www.pnl.gov
larry.pederson@pnl.gov
509-375-2731

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