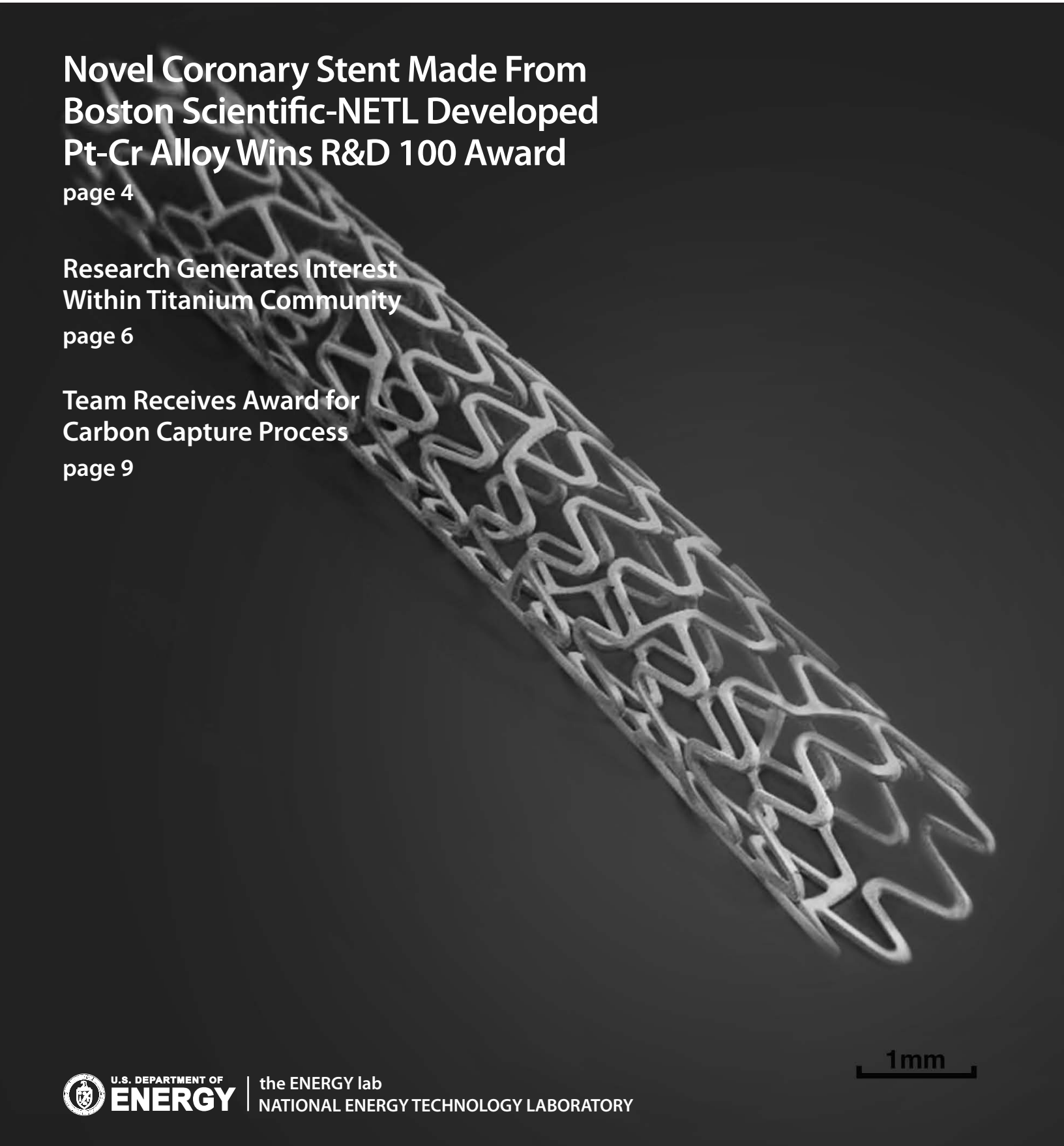
netlognews

NETL's R&D newsletter *July 2011, Issue 22*



Novel Coronary Stent Made From Boston Scientific-NETL Developed Pt-Cr Alloy Wins R&D 100 Award

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newlognews is a quarterly newsletter that highlights recent achievements and ongoing research at NETL. Any comments or suggestions, please contact Paula Turner at paula.turner@netl.doe.gov or call 541-967-5966.

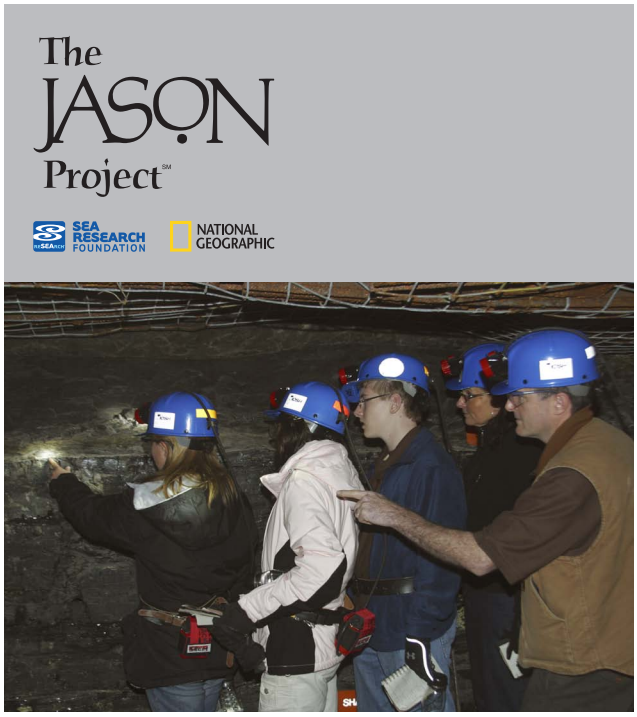
NETL Director of Research and Development Dr. Cindy Powell addresses the KIER team.

Second NETL-Korea Institute of Energy Research Workshop held in Korea

—As part of a five-year Memorandum of Understanding signed in September 2007 between NETL and the Korea Institute of Energy Research (KIER), the second NETL-KIER workshop was held in Korea the week of April 19th. The Korea-U.S. Energy Technology Innovator Forum 2011 was held in Seoul, with about 250 scientists and engineers in attendance. The balance of the workshop took place in Daejeon at the KIER site. Two keynote speeches were made: the first by the President of KIER, which focused on Korea's energy R&D and KIER's strategy to increase Korea's energy independence; the second, by Dr. Cynthia Powell, NETL's Director of Research and Development, focused on the role of fossil energy in creating a clean, sustainable energy future for the United States, and NETL's role in this endeavor.

Discussions following the workshop focused on cooperative research between the two organizations. NETL personnel also attended the U.S. - Korea Energy Consultations in Seoul as part of the DOE Science Mission. Presentations by both the Korean delegation and the U.S. delegation focused on energy issues involving both nations.

Contact: Paul Turner, 541-967-5863



The JASON Project's "Argonauts" crew tours NIOSH'S researchers coal mine in Pittsburgh, PA.

NETL Collaborates with National Geographic's JASON Project and Wins CODie Award

—A new JASON Project middle school geology unit, developed with assistance from NETL, has earned a prestigious "CODiE Award" as the nation's Best Science or Health curriculum.

Operation: Tectonic Fury, which unlocks the Earth's geologic mysteries through investigation of its past, present and future, is the fourth unit in a new line of middle school science curricula developed by the nonprofit subsidiary of the National Geographic Society. The CODiE Awards are presented annually by the Software & Information Industry Association (SIIA) to recognize excellence and vision in educational technology, digital content, and software. NETL was one of four host sites used in making the unit.

To create *Operation: Tectonic Fury*, JASON selected a small number of teachers and student "Argonauts" to conduct fieldwork with host researchers. The students and teachers spent three days at NETL investigating rocks, fossils, and coal, with a focus on predicting what happens underground during geologic carbon sequestration. Interactions among teachers, students, and researchers were photographed and videotaped, becoming part of the resulting curriculum.

Each JASON curriculum integrates digital and print content into inquiry-based instruction and is designed to fit within school districts' core curriculum. *Operation: Tectonic Fury* includes a full-color magazine that introduces students to the program, a detailed teacher's manual, videos, online resources, and digital labs and games. Complete curriculum units are free to download from the JASON website. Additional resources, including professional development and DVDs with up to two hours of video, are available for purchase.

NETL previously collaborated on JASON's award-winning energy curriculum, *Operation: Infinite Potential*.

Researchers Study Integration of Air Separation Units within IGCC Plant

—The air separation unit (ASU) plays a key role in improving the efficiency, availability, and operability of an oxygen-fed integrated gasification combined cycle (IGCC) power plant. Optimal integration between the ASU and the balance of the plant, especially the gasifier and the gas turbine (GT), can significantly enhance overall plant efficiency. To increase the net power generation from an IGCC plant with CO_2 capture, NETL and NETL-Regional University Alliance researchers from West Virginia University studied the integration and performance of various configurations of low- and elevated-pressure ASUs using both pumped liquid oxygen cycles and more traditional gaseous oxygen cycles.

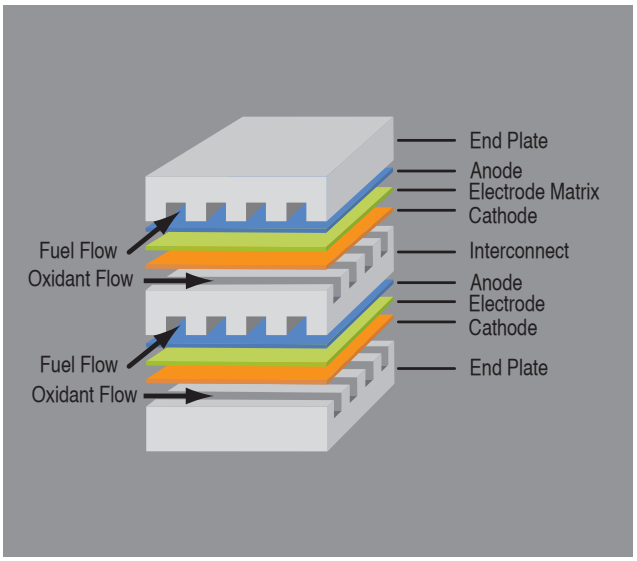
The team also analyzed the impact of several GT fuel diluents and their concentrations on the optimal operating pressure of the ASU configurations. As published in a recent issue of the Elsevier journal Fuel Processing Technology, steady-state process simulation results showed that an optimal integration between the ASU and GT and an optimal design of an ASU under various degrees of integration can increase the net power generation from an IGCC plant with CO_2 capture.

Contact: Stephen E. Zitney, 304-285-1379

NETL Wins Three R&D 100 Awards

Three technologies developed by NETL researchers have been recognized by *R&D Magazine* as among the 100 most technologically significant products to enter the marketplace in the past year. The annual awards, known as the "Oscars of Invention," are selected by an independent panel of judges and the editors of *R&D Magazine*.

The technologies chosen to receive the prestigious 2011 R&D 100 Awards include a software toolkit for designing next-generation power plants, a coating for interconnects in solid oxide fuel cells, and a novel alloy for the manufacture of coronary stents.



APECS v2.0 with ANSYS® DesignXplorer™ and ROM Builder

—The grand challenge facing the power and energy industries is the development of efficient, environmentally friendly, and affordable technologies for next-generation power production and chemical processing plants. These vital industries are relying increasingly on the use of sophisticated computer-aided process design and optimization tools, such as APECS v2.0 with ANSYS® DesignXplorer™ and ROM Builder. This versatile, innovative, and powerful software toolkit makes it easier, faster, and cheaper to design future plants with a high degree of confidence using advanced process/equipment co-simulation and comprehensive design optimization. Developed jointly by NETL and ANSYS Inc., the toolkit is a major enhancement of a previous R&D 100 Award–winning software tool, APECS v1.0 with ANSYS® Engineering Knowledge Manager™.

Mn-Co Coating for Solid Oxide Fuel Cell Interconnects

—This manganese-cobalt (Mn-Co) spinel coating was specifically tailored for solid oxide fuel cell (SOFC) interconnects. The coating was designed to prevent the evaporation of chromium from the ferritic stainless-steel-based interconnect while maintaining the electrical conductivity of the interconnect system. Chromium acts as a poison, increasing the resistance of the interconnect and thus reducing the electrical conductivity and operating lifetime of the fuel cell. Chromium poisoning is one of the major challenges to be overcome before SOFCs can become commercially viable power sources, and this coating successfully addresses the problem. The coating was co-developed by NETL and West Virginia University and was then transferred to Faraday Technology Inc., which has continued to develop and optimize the coating.

Novel Platinum/Chromium Alloy for the Manufacture of Improved Coronary Stents—This novel alloy is the first austenitic stainless steel formulation with a significant concentration of a highly "radiopaque" element to be produced for the coronary stent industry. Previous stents composed of standard 316 stainless steel made installation of the stent difficult due to poor visibility. The high radiopacity of the new alloy increases the x-ray visibility of the stent inside a patient thus solving this longstanding problem. Better visibility means greater ease and precision of placement of the stent inside the patient's artery and less chance of damage to the artery. In addition, the greater yield strength of the alloy allowed the stent's designers at Boston Scientific Corporation to make a thinner, more flexible stent that is more easily threaded through the winding path of the artery without doing damage along the way.

The alloy was jointly developed by NETL and Boston Scientific Corporation Inc. After a lengthy series of clinical trials, BSCI succeeded in having the stents approved for sale on November 2, 2009. They were first marketed in 2010 as the PROMUS® ELEMENT™ in Europe and the rest of the world, selling 206,000 units in Europe, the Middle East, and Africa up to December 2010. This represented a 22 percent market share of coronary stents in these regions. On April 25, 2011, the stents, under the TAXUS ION™ label, were approved for sale in the United States. The total sales since introduction have exceeded $1 billion.

Furnace tube with samples for exposure in mixed oxidants.

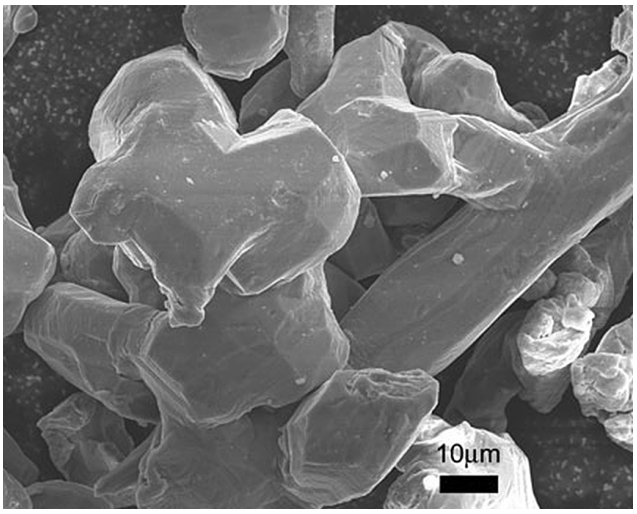
Oxidation of Ferritic Alloys in Oxyfuel Environments

—NETL is conducting research on how oxyfuel combustion environments affect the performance of ferritic-martensitic Fe-Cr steels, an important class of alloys used in boiler construction. Oxy-fuel combustion, as compared to air-fired combustion, has much higher CO_2 to H_2O ratios. In addition, different oxy-fuel refit designs have different flue gas recirculation back to the boiler paths (required to mimic the heat transfer characteristics of the air-fired boiler), which will result in different H_2O levels in the boiler. So understanding the competition between the different oxidants in the flue gas (O_2, H_2O, and CO_2) is vital to understanding the corrosion ramifications of oxy-fuel combustion and the design choices made to refit existing boilers to oxy-fuel.

The oxidation behavior of ferritic-martensitic Fe–Cr base alloys exposed to atmospheres containing various combinations of O_2, CO_2, and H_2O was studied at various temperatures relevant to oxy-fuel combustion. Oxidation in either CO_2 or H_2O disrupts the selective oxidation process such that substantially higher chromium concentrations are required to develop a protective chromia scale, even though the oxygen partial pressures in these gases are low. However, the mechanisms for the effects are different. For oxidation in CO_2, formation of Cr carbides reduces the flux of Cr to the alloy/scale interface. The presence of excess oxygen in the gas tends to diminish this effect. For oxidation in H_2O, there are several contributing effects including enhanced oxygen permeability and accelerated growth of the chromia scales. Excess oxygen tends to exacerbate this effect by enhancing the reactive evaporation of chromia. Small silicon additions were found to dramatically improve the ability of Fe–Cr model alloys to develop protective chromia scales in H_2O.

These findings were recently published in *Oxidation of Metals*, Vol. 74, Nos. 5-6, pp. 319-340, 2010 and were due to a collaboration between the NETL-Regional University Alliance and Forschungszentrum Jülich (Germany).

Contact: Gordon R. Holcomb, 541-967-5874



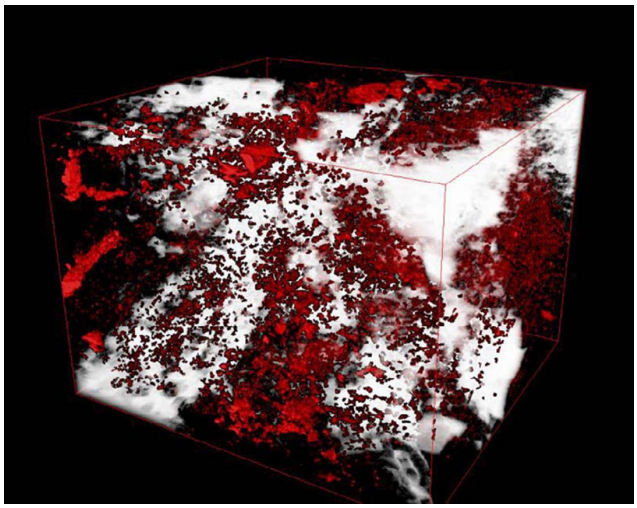
A scanning electron microscope backscatter electron image of commercial purity titanium made by International Titanium Powder using the Armstrong Process.

Research Generates Interest within Titanium Community

—NETL researchers have formulated a numerical model that predicts the compacted density of titanium powders (and perhaps other powders) as a function of pressure much better than previous efforts. An improved understanding of how compaction pressure affects density will permit better control of residual porosity and avoid excessive pressures that can

accelerate die wear in powder-metallurgy processes. Described in *Metallurgical Transactions A* (Vol. 42 (2011), No. 5, pp. 1325-1333), the model was applied to a new International Titanium Powder process that has the potential for greatly reducing the cost of manufacturing titanium components. The model has already received considerable interest from General Electric Co. and Boeing Co.

Contacts: Paul Jablonski, 541-967-5982 and Steve Gerdeman, 541-967-5964



Large connected pore network shown in white and unconnected pores in red. (Volume size 1.54 X 1.40 x 1.12 mm)

New Technique Characterizes Real-Time Movement of CO_2 Underground

—Collaborative research between NETL and the University of Pittsburgh, a participant in the NETL–Regional University Alliance, has produced a technique for characterizing CO_2 movement underground using seismic surveys. The field survey tool is an outcome of correlating the velocities of sonic compression and shear waves in reservoir rocks with their chemical/geomechanical properties following exposure to varying fluid compositional changes. The reservoir rocks examined were obtained from the Scurry Area Canyon Reef Operators Committee field located in north central Texas—the oldest U.S. CO_2-enhanced oil recovery site where more than 86.2 million tons of CO_2 have been purchased as of 2010. The technique is described in the Elsevier e-only product, *Energy Procedia* (Vol. 4 (2011), pp. 3676-3683).

Contact: T. Robert McLendon, 412-386-5749

NETL Researcher Named Associate Editor for New Nanomaterials Publication

—NETL's role in advancing the use of nanomaterials for improving energy technologies was recently recognized when Dr. Christopher Matranga was named Associate Editor of a new journal, *Nanomaterials and Energy*, to be published by the Institution of Civil Engineers beginning in 2012. Dr. Matranga will work with Editor-in-Chief, Dr. Nitin Chopra of the University of Alabama, to establish the journal as an internationally recognized publication covering all aspects of nanotechnology and its use in the energy sciences. Other members of the editorial board include researchers from Virginia Tech University, Oak Ridge National Laboratory, the University of Pennsylvania, Siemens, and other internationally recognized universities and research organizations.

Contact: Christopher Matranga, 412-386-4114

Richard Smosna (NETL) examines Marcellus Shale outcrop near Bedford, Pennsylvania.

New Report Compares Barnett and Marcellus Shales

—The Energy Information Administration (EIA) projects that 827 trillion cubic feet (Tcf) of natural gas is currently recoverable from U.S. shales using existing technology. The United States now consumes about 23 trillion cubic feet (Tcf) per year. Of that total, the United States produces about 20 Tcf and imports the rest, so the shale gas resource alone represents about 36 years at the current rate of consumption. One Tcf of natural gas is enough to heat 15 million homes for 1 year, generate 100 billion kilowatt-hours of electricity, or fuel 12 million natural-gas-fired vehicles for 1 year.

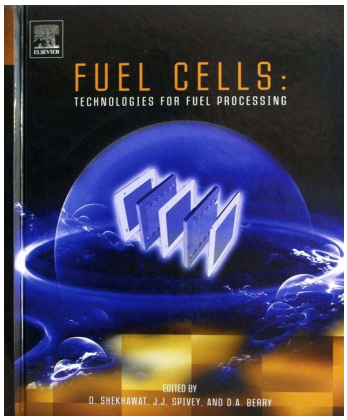
Shale gas production continues to increase. In 2009 it amounted to more than 8 Bcf per day, or about 14 percent of the total volume of dry natural gas produced in the United States and about 12 percent of the natural gas consumed in the United States.

NETL has released a new report that compares the geology and gas production characteristics of the Barnett and Marcellus gas shales. The Barnett Shale has higher total organic carbon content, but the Marcellus Shale has higher thermal maturity, and is thus more gas-prone. Permeability, porosity, and water saturation of the two shale formations are similar. Both rock units are quartz-rich, calcareous, and brittle, making them susceptible to hydraulic fracturing.

The Marcellus Shale has better initial production on horizontal wells, but the cost is higher due to greater depth. The Barnett Shale is thicker than the Marcellus, but the Marcellus play covers a much larger land area. Production from the Barnett Shale has leveled off, but volumes of gas from the Marcellus, Haynesville, Fayetteville, and Woodford shales are growing as more wells are drilled in these plays and as other emerging plays are developed.

The EIA forecasts that the shale gas share of U.S. natural gas production will continue to grow, reaching 45 percent of the total volume of gas produced in the United States by 2035.

Contact: Daniel J. Soeder, 304-285-5258



NETL Researchers Publish Book on Fuel Processing for Fuel Cells

—NETL researchers Dushyant Shekhawat and David Berry, along with Prof. James Spivey from Louisiana State University, have edited a book, "Fuel Cells: Technologies for Fuel Processing." The book, published by Elsevier in April 2011, is available in hardcover and a Kindle version. Several of the chapter authors are affiliated with NETL while others are well-known global contributors from industry, academia, government research laboratories, and foreign institutes. Despite the increasing technical and commercial importance of fuel cells, few books have addressed the critical subject of fuel reforming technology in a comprehensive fashion. This book provides an overview of the most important aspects

of fuel reforming to the generally interested reader, researcher, technologist, teacher, student, or engineer. The coverage includes all aspects of fuel reforming: fundamental chemistry, modes of reforming, catalyst types, catalyst deactivation, fuel desulfurization, reaction engineering, thermodynamics, heat and mass transfer, system design, and recent research and development.

This is an excellent self-instruction book for those new to fuel cells or as a comprehensive resource for experts in the area of fuel processing. The material is presented in such a way that it can also serve as a reference for graduate level courses, fuel cell developers, and fuel cell researchers.

Contact: Dushyant Shekhawat, 304-285-4634

The NETL team involved in this carbon capture process technology.

Team Receives Award for Carbon Capture Process

—The Federal Laboratory Consortium (FLC) recognized NETL with its 2011 Award for Excellence in Technology Transfer. This award is presented annually for outstanding work in facilitating the transfer of technology from the federal laboratory to the commercial marketplace.

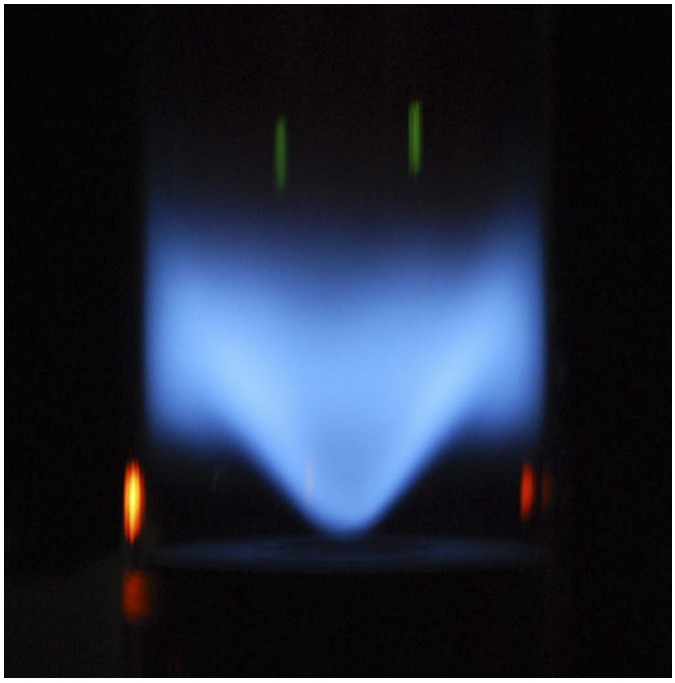
The "Basic Immobilized Amine Sorbent (BIAS) Process for CO_2 Capture" advances the capture of CO_2 from power plants, preventing its release into the air--a potential cause of global warming. The captured CO_2 can then be permanently stored in a carbon sequestration scenario. The BIAS process will use regenerable, solid CO_2 sorbents in large-scale fossil fuel-burning power plants. The sorbent selectively reacts with CO_2 to extract it from the flue gas and is then heated to release the CO_2 for storage, thereby regenerating the sorbent for reuse.

Technology transfer actions related to this process include:

- patenting and licensing various aspects of the sorbent development;
- assembling a consortium of interested collaborators including federal and industrial parties that can use the process technology and fabricate large quantities of the sorbent; and
- publicizing the technique through a solicitation.

All of these led to a Cooperative Research and Development Agreement with a company eager to commercialize this technology. The award was presented at a ceremony held May 5, 2011, at the FLC National Meeting in Nashville, TN.

Contact: Henry Pennline, 412-386-6013 and McMahan Gray, 412-386-4826.



Swirl-stabilized, premixed flames are used in modern gas turbine designs to reduce emissions, but are susceptible to thermoacoustic instabilities.

Researchers Develop Novel Approach to Combustion Modeling

—Combustion dynamics represent an ongoing obstacle to practical gas turbine combustion systems. Several modern combustion design considerations, such as fuel flexibility and the use of exhaust gas recirculation to enhance carbon capture and storage, place increased emphasis on the importance of dynamics due to the influential role played by variable reactant composition.

Postdoctoral researcher Dr. Joseph Ranalli, Dr. Donald Ferguson of NETL, and Dr. Christopher Martin of Virginia Tech have developed a novel modeling approach, termed convective disturbance modeling, for analysis of flame dynamic behaviors to aid in the prediction of thermoacoustic instabilities. Traditional approaches to flame dynamic modeling attempt to track the flame surface as it responds to local fluctuations in the velocity field. The convective disturbance approach generalizes this behavior, modeling the global flame response by considering the interaction of localized disturbances throughout the steady flame heat release rate distribution. This allows greater flexibility in the model constraints and allows easy input of either experimental data or results from steady-state computational flame models.

Validation studies are currently underway at NETL to investigate how this approach may enhance reliable operation of fuel-flexible gas turbine combustors. Preliminary results from this work were presented at the 7th U.S. National Meeting of the Combustion Institute in Atlanta, GA.

Contact: Joe Ranalli, 304-285-5287

Journal Details DOE Method for Estimating Geologic Storage Potential of CO_2

—A detailed description of the U.S. Department of Energy method for estimating carbon dioxide (CO_2) storage resource potential is now available through the peer-reviewed International *Journal of Greenhouse Gas Control.* It includes the methods used to determine CO_2 storage resource estimates for three types of geologic formations: oil/gas reservoirs, saline formations, and unmineable coal seams. These CO_2 storage resource estimates are based on physically accessible CO_2 storage pore volume in formations and on the assumption that the in situ fluids will either be displaced from the injection zone or managed. Economic and regulatory constraints are not considered.

CO_2 storage efficiency needed for CO_2 storage resource estimates are calculated using a Log Odds Method when applied with Monte Carlo Sampling. This methodology is intended to produce high-level CO_2 resource estimates of potential geologic storage at the regional and national scale and will be used by the Regional Carbon Sequestration Partnerships, future project developers, and governmental entities for high-level assessments of potential CO_2 storage reservoirs in the United States and Canada. However, the methodology is general enough that it could be applied for initial screening assessments in other locations. A summary version of this methodology is also available in the *2010 Carbon Sequestration Atlas of the United States and Canada (Atlas III)*.

Contact: Angela Goodman, 412-386-4962

Quantitative Particle Morphology Characterization Technique Developed

—A technique has been developed to quantify the roughness of granular materials. It involves analyzing hundreds of thousands to millions of two-dimensional shadowgraphs of individual particles. Currently, data is gathered on NETL's QICPIC, but any video or image stack that is thresholded to give black and white images of the particles would work. Once the data are collected, the perimeter of each particle is identified and parameterized so that each particle can be analyzed.

Recent tests have shown that this can all be done in less than an hour and that it can quantify subtle changes in surface roughness that may occur during attrition, whereas other traditional morphology techniques can only identify changes in particle size. This capability may be very important to various solid/fluid energy processes being supported at NETL or other related research initiatives. The technique can be used to track attrition performance of sorbents in various mechanical systems as well as quantify individual material performance in standardized tests. It can also be used to predict/correlate performance of dry feed systems that are highly dependent on granular particle characteristics for proper flow. Further testing and development are underway.

Contact: Dirk Van Essendelft, 304-285-5231

Recent NETL Publications

1.	Ai, W.G., and Kuhlman, J.M. 2011. Simulation of Coal Ash Particle Deposition Experiments. *Energy & Fuels* 25(2)708–718.
2.	Baltrus, J.P., Granite, E.J., Rupp, E.C., et al. 2011. Effect of Palladium Dispersion on the Capture of Toxic Components from *Fuel* Gas by Palladium-Alumina Sorbents. Fuel 90(5):1992–1998.
3.	Bhattacharyya, D., Turton, R., and Zitney, S. 2011. Steady-State Simulation and Optimization of an Integrated Gasification Combined Cycle Power Plant with CO_2 Capture. *Industrial & Engineering Chemistry Research* 50(3):1674–1690.
4.	Bosko, M.L., Miller, J.B., Lombardo, E.A., et al. 2011. Surface Characterization of Pd-Ag Composite Membranes After Annealing at Various Temperatures. *Journal of Membrane Science* 369(1–2):267–276.
5.	Cheong, W.Y., and Gellman, A.J. 2011. Energetics of Chiral Imprinting of Cu(100) by Lysine. *Journal of Physical Chemistry C* 115(4):1031–1035.
6.	Collett, T.S., Lee, M.W., Agena, W.F., et al. 2011. Permafrost-Associated Natural Gas Hydrate Occurrences on the Alaska North Slope. *Marine And Petroleum Geology* 28(2):279–294.
7.	Cummings, S., Trickett, K., Enick, R., and Eastoe, J. 2011. CO_2: A Wild Solvent, Tamed. *Physical Chemistry Chemical Physics* 13(4):1276–1289.
8.	Deng X.Y., Lee J., Wang, C.J., et al. 2011. In Situ Observation of Water Dissociation with Lattice Incorporation at FeO Particle Edges Using Scanning Tunneling Microscopy and X-ray Photoelectron Spectroscopy. *Langmuir* 27(6):2146–2149.
9.	Ding, D., Gong, M.Y., Xu, C.C., et al. 2011. Electrochemical Characteristics of Samaria-Doped Ceria Infiltrated Strontium-Doped LaMnO3 Cathodes with Varied Thickness for Yttria-Stabilized Zirconia Electrolytes. *Journal of Power Sources* 196(5):2551–2557.
10.	Debangsu Bhattacharyya, Richard Turton, and Stephen E. Zitney, "Steady-State Simulation and Optimization of an Integrated Gasification Combined Cycle Power Plant with CO_2 Capture," *Industrial & Engineering Chemistry Research*, 2011, 50 (3), pp 1674–1690; DOI: 10.1021/ie101502d.
11.	Ding, M.N., Tang, Y.F., Gou, P.P., et al. 2011. Chemical Sensing with Polyaniline Coated Single-Walled Carbon Nanotubes. *Advanced Materials* 23(4):536–540.
12.	Dressel, B., Deel D., Rodosta T., et al. 2011. CCS Activities Being Performed by the U.S. DOE. *International Journal of Environmental Research and Public Health* 8(2):300–320.
13.	Hakala, J.A., Stanchina, W., Soong Y., and Hedges, S. 2011. Influence of Frequency, Grade, Moisture and Temperature on Green River Oil Shale Dielectric Properties and Electromagnetic Heating Processes. *Fuel Processing Technology* 92(1):1–12.

14.	Hunter, R.B., Collett, T.S., Boswell, R., et al. 2011. Mount Elbert Gas Hydrate Stratigraphic Test Well, Alaska North Slope: Overview of Scientific and Technical Program. *Marine and Petroleum Geology* 28(2)295–310.
15.	Kauffman, K.L., Culp, J.T., Goodman, A., and Matranga, C. 2011. FT-IR Study of CO_2 Adsorption in a Dynamic Copper(II) Benzoate-Pyrazine Host with CO_2-CO Interactions in the Adsorbed State. *Journal of Physical Chemistry C* 115(5):1857–1866.
16.	Kneafsey, T.J., Seol, Y., Gupta, A., and Tomutsa, L. 2011. Permeability of Laboratory-Formed Methane-Hydrate-Bearing Sand: Measurements and Observations Using X-ray Computed Tomography. *SPE Journal* 16(1):78–94.
17.	Li, B.Y., Jiang, B.B., Fauth, D.J., et al. 2011. Innovative Nano-Layered Solid Sorbents for CO_2 Capture. *Chemical Communications* 47(6):1719–1721.
18.	Li, Y.H., Jiang Y.L., Wu. J.W., et al. 2011. Corrosion Behavior of Ebrite and SS430 in Coal Syngas with Loaded Current. *International Journal of Applied Ceramic Technology* 8(1):60–67.
19.	Mahalatkar, K., Kuhlman, J., Huckaby, E.D., and O'Brien, T. 2011. Computational Fluid Dynamic Simulations of Chemical Looping Fuel Reactors Utilizing Gaseous Fuels. *Chemical Engineering Science* 66(3):469–479.
20.	Massoudi, M., and Mehrabadi, M.M. 2011. Implicit Constitutive Relations in Thermoelasticity. *International Journal of Non-Linear Mechanics* 46(1):286¬–290.
21.	Monazam, E.R., and Shadle, L.J. 2011. Method and Prediction of Transition Velocities in a Circulating Fluidized Bed's Riser. *Industrial & Engineering Chemistry Research* 50(4):1921–1927.
22.	Moridis, G.J., Collett, T.S., Pooladi-Darvish, M. et al. 2011. Challenges, Uncertainties, and Issues Facing Gas Production From Gas-Hydrate Deposits. *SPE Reservoir Evaluation & Engineering* 14(1):76–112.
23.	Ogura, K., and Salazar-Villalpando, M.D. 2011. CO_2 Electrochemical Reduction via Adsorbed Halide Anions. *JOM* 63(1):35–38.
24.	Orlovskaya, N., Chen, Y., Miller, N., et al. 2011. Glycine-Nitrate Synthesis of Sr Doped $La_2Zr_2O_7$ Pyrochlore Powder. *Advances in Applied Ceramics* 110(1):54–57.
25.	Phuoc, T.X, Massoudi, M., and Chen, R.H. 2011. Viscosity and Thermal Conductivity of Nanofluids Containing Multi-Walled Carbon Nanotubes Stabilized by Chitosan. International *Journal of Thermal Sciences* 50(1):12–18.
26.	Phuoc, T.X., and Chen, R.H. 2011. Synthesis of Cation-Exchanged Laponite Suspensions by Laser Ablation of Microsized-Metal Particles in Liquid. *Optics And Lasers In Engineering* 49(3):396–402.

27.	Rose, K.K., Boswell, R., and Collett T.S. 2011. Mount Elbert Gas Hydrate Stratigraphic Test Well, Alaska North Slope: Coring Operations, Core Sedimentology, and Lithostratigraphy. *Marine and Petroleum Geology* 28(2)311–331.
28.	Salazar-Villalpando, M.D., and Miller, A.C. 2011. Hydrogen Production by Methane Decomposition and Catalytic Partial Oxidation of Methane over Pt/$Ce_xGd_{1-x}O_2$ and Pt/$Ce_xZr_{1-x}O_2$. *Chemical Engineering Journal* 166(2):738–743.
29.	Scherer, G.W., Kutchko, B., Thaulow, N., et al. 2011. Characterization of Cement From a Well at Teapot Dome Oil Field: Implications For Geological Sequestration. *International Journal of Greenhouse Gas Control* 5(1):115–124.
30.	Shukla, N., Nigra, M.M., Bartel, M.A., et al. 2011. Fe_2O_3 Shell Growth on Pt *Nanoparticles. Journal of Nanoscience and Technology* 11(3):2480–2485.
31.	Raja, K.S., Smith, Y.R., Kondamudi, N., et al. 2011. CO_2 Photoreduction in the Liquid Phase over Pd-Supported on TiO_2 Nanotube and Bismuth Titanate Photocatalysts. *Electrochemical and Solid State Letters* 14(5):F5–F8.
32.	Solunke, R.D., and Veser, G. 2011. Integrating Desulfurization with CO_2-Capture In Chemical-Looping Combustion. *Fuel* (90)2:608–617.
33.	Sorescu, D.C. 2011. Adsorption and Activation of CO Coadsorbed with K on Fe(100) Surface: A Plane-Wave DFT study. *Surface Science* 605(3–4):401–414.
34.	Torres, M.E., Collett, T.S., Rose, K.K., et al. 2011. Pore Fluid Geochemistry from the Mount Elbert Gas Hydrate Stratigraphic Test Well, Alaska North Slope. *Marine and Petroleum Geology* 28(2):332–342.
35.	Vasireddy, S., Morreale, B., Cugini, A., et al. 2011. Clean Liquid Fuels from Direct Coal Liquefaction: Chemistry, Catalysis, Technological Status and Challenges. *Energy & Environmental Science* 4(2):311–345.
36.	Weiland, N., Chen, R.H., and Strakey, P. 2011. Effects of Coaxial Air on Nitrogen-Diluted Hydrogen Jet Diffusion Flame Length and NOx Emission. *Proceedings of the Combustion Institute*, 33(2):2983–2989.
37.	Xie, H.B., Johnson, J.K., Perry, R.J., et al. 2011. A Computational Study of the Heats of Reaction of Substituted Monoethanolamine with CO_2. *Journal of Physical Chemistry A* 115(3):342–350.
38.	Zhi, M.J., Mariani, N., Gemmen, R., et al. Nanofiber Scaffold for Cathode of Solid Oxide Fuel Cell. 2011. *Energy & Environmental Science* 4(2):417–420.
39.	Zhi, M.J., Zhou, G.W., Hong, Z.L., et al. 2011. Single Crystalline $La_{0.5}Sr_{0.5}MnO_3$ Microcubes as Cathode of Solid Oxide Fuel Cell. *Energy & Environmental Science* 4(1):139–144.
40.	Zhu, J.X., Diaz, L.M.F., Holcomb, G.R., et al. 2011. An Electron Microscopy Investigation of the Transient Stage Oxidation Products in an Fe-22Cr Alloy with Ce and La Additions Exposed to Dry Air at 1073 K (800 °C). *Metallurgical and Materials Transactions A*. 42(1):121–137.

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