Technology Innovation Program

2017

Oak Ridge National Laboratory

U.S. Department of Energy

The Technology Innovation Program

Delivering new technologies and solutions to industry to help increase the nation's economic competitiveness is an important part of Oak Ridge National Laboratory's mission. The Technology Innovation Program (TIP) was created to accelerate the commercial adoption of promising ORNL technologies by making targeted investments to increase the technologies' commercial readiness and raise their visibility to prospective partners. TIP is funded by royalties from previously licensed ORNL technologies.

Each year, ORNL scientists and engineers compete to participate in TIP. A panel of laboratory managers and commercial experts select 4-5 of the most compelling technologies for a year of research and development investment and increased outreach to prospective partners. Toward the end of the year, prospective industry partners are invited to submit applications to commercialize the TIP technologies, and the companies with the most compelling commercialization plans are offered licenses. A portion of TIP teams whose technologies are successfully licensed are competitively awarded additional funding for further research and development to be performed at ORNL in partnership with the licensing companies.

The 2017 cohort of TIP technologies includes a novel high temperature alloy for 3D printing, a new precursor material for improved carbon fiber, an improved catalyst for vehicle pollution control systems, a low-cost true random number generator, and a system to convert carbon dioxide to ethanol. Each of these technologies is believed to be an important breakthrough with significant commercial potential.

Since 2013, ORNL has invested nearly $6M in 26 TIP projects, resulting in 18 commercial licenses and options with partners ranging from Fortune 100 companies to early stage startups. This brochure provides brief descriptions of the 2017 TIP technologies, introductions to the inventors behind the innovations, and contact information for the technology transfer managers responsible for licensing. ORNL will accept license applications for each technology in the fourth quarter of calendar year 2017, with a goal of entering license agreements by the end of the year.

About Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is the largest US Department of Energy science and energy laboratory, conducting basic and applied research to deliver transformative solutions to compelling problems in energy and security. With an annual budget of $1.4 billion, ORNL is home to 4,750 research and mission support staff, including 1,100 staff scientists and engineers.

ORNL's diverse capabilities span a broad range of scientific and engineering disciplines, enabling the Laboratory to explore fundamental science challenges and to carry out the research needed to accelerate the delivery of solutions to the marketplace. ORNL supports DOE's national missions of scientific discovery, clean energy, and national security through leadership in four major areas of science and technology: neutrons, computing, materials, and nuclear technologies.

Over the past decade, ORNL researchers have produced a portfolio of nearly 700 US patents, and the laboratory currently has more than 150 active technology licenses.

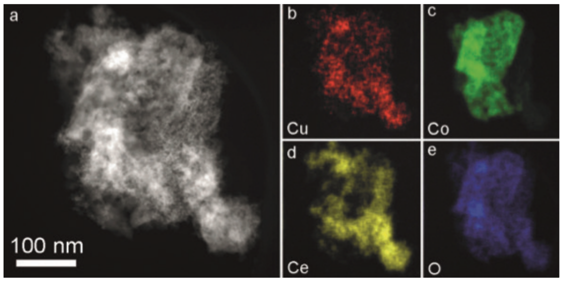
For more information please visit our webpage at www.ornl.gov.

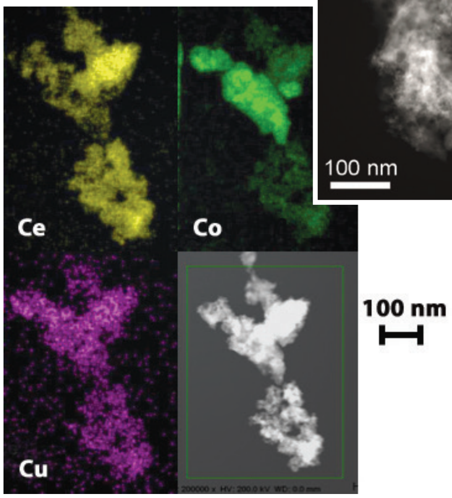
Meeting More Restrictive Emission Standards: A New, Low-Temperature Oxidation Catalyst

The current standard for controlling pollutants in automotive exhaust incorporates Platinum Group Metal (PGM) catalysts. These catalysts are unfortunately very expensive, and they struggle with oxidation of carbon monoxide (CO) and hydrocarbon pollutants at lower temperatures. As engine fuel efficiency improves, less energy is wasted as heat in the exhaust resulting in lower exhaust temperatures, and catalysts have more difficulty achieving the necessary efficiency for pollution control. Therefore, engines require more advanced catalysts that are capable of operating at lower temperatures to meet newer, and stricter, emission regulations. Researchers at ORNL have developed a low-temperature oxidation catalyst that can meet these new industry needs. ORNL's catalyst is composed of cerium, cobalt, and copper, in addition to traditional components of PGM catalysts. This catalyst offers improved low-temperature oxidation at a lower cost than traditional PGM catalysts. ORNL's catalyst offers performance advantages for engines today as well as for new fuel-efficient engine technologies of the future, including hybrid vehicles.

This project was accepted into TIP with the goals of scaling up cerium, cobalt, and copper (CCC) material to >1kg batch size, coating CCC material and PGMs on a cordierite substrate monolith for engine study, and comparing the full-scale CCC catalyst with state-of-the-art commercial catalysts. Since the project began, Dr. Parks' team has developed a procedure for making large batches of active catalysts with even better reactivity than predicted, and they have transferred the technique to a company to produce 10 kg batches of active catalyst powder. Once the full-scale catalyst is produced, engine studies will be conducted at ORNL's National Transportation Research Center engine dynamometer laboratories.

The biggest advantage of this technology is that it can oxidize pollutants at lower temperatures than ever before with lower overall cost. In addition to automotive and trucking applications, the catalyst offers similar advantages for power generation from stationary sources such as gas turbines.





Publications

- Andrew J. Binder, Todd J. Toops, Raymond R. Unocic, James E. Parks II, Sheng Dai, "Low Temperature CO Oxidation over Ternary Oxide with High Resistance to Hydrocarbon Inhibition", *Angewandte Chemie International Edition.*

James Parks II, PhD
Energy and Environmental Sciences Directorate

Dr. Jim Parks leads the Emissions and Catalysis Research Group at the National Transportation Research Center at Oak Ridge National Laboratory. He received his B.S. in physics from North Carolina State University in 1989 and his PhD in physics from the University of Tennessee in 1995. Prior to joining Oak Ridge National Laboratory, Dr. Parks worked in the private sector at EmeraChem LLC. Dr. Parks also has numerous publications in peer-reviewed journals. His current research interests are emission control for lean burn and advanced combustion engines as well as catalysis for biomass-to-fuel processes.

Technology

Low Temperature Oxidation Catalyst
Non-provisional US Patent
Application 15/134,449

Invention Disclosure No. 201403345

Inventors

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Adam Rondinone, PhD
Physical Sciences Directorate

Dr. Adam Rondinone is a senior staff scientist at the Oak Ridge National Laboratory's Center for Nanophase Materials Sciences. He received his PhD in chemistry from the Georgia Institute of Technology in 2001 and immediately joined Oak Ridge as a prestigious Wigner Fellow. He is an expert on materials chemistry at the nanoscale, and his research is focused on developing novel means to create functional nanomaterials for energy applications. More recently Dr. Rondinone has explored nanostructured electrochemical catalysts for the conversion of waste to useful products. He has served on various committees in service to ORNL, including 2 years as a Legislative Fellow in the office of Senator Lamar Alexander working on energy and technology issues. He is also the outreach coordinator for the Center for Nanophase Materials Sciences.

Technology

Converting CO_2 to Ethanol

Provisional US Patent Application 15/143,651

Invention Disclosure No. 201403439

Inventors

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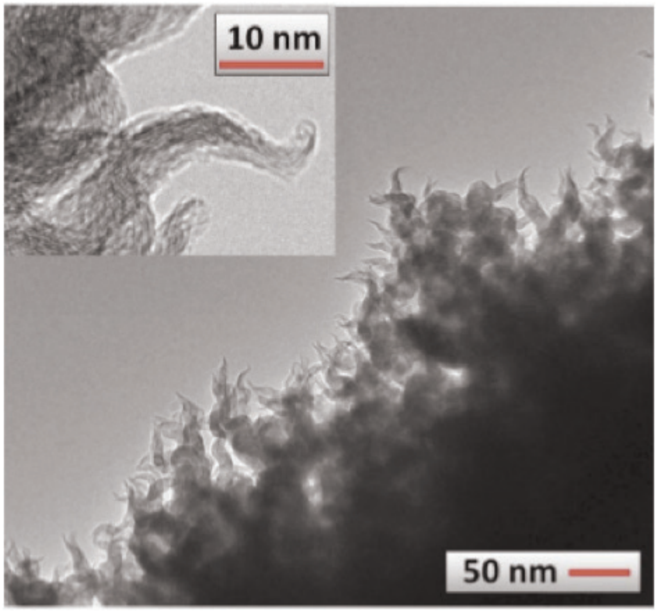
Reusing CO_2 as Fuel: Converting Carbon Dioxide to Ethanol

An inherent problem with renewable energy sources is that the amount of energy produced is variable. When too much energy is produced, it must be used or it will be wasted, and when too little energy is produced a secondary source is required. What is needed is a process that can be turned on and off as surplus energy permits and that can produce a useful product. Researchers at ORNL have developed a process for converting CO_2 to ethanol by introducing CO_2 onto a bed of carbon nanospikes and copper nanoparticles that react electrochemically with the CO_2 in the form of bicarbonate, producing ethanol. The process can be terminated and reinitiated at any point, and the yield is greater than the average yield of cellulosic-based ethanol production. This conversion process can be powered by the excess energy produced by renewable sources to reduce both the need for extra infrastructure and the introduction of CO_2 into the atmosphere.

This project was accepted into TIP with two overarching project goals: evaluate the catalyst for performance in the context of typical industrial concerns of lifetime, durability, poisoning, and scale-up; then use that information to estimate the economic viability of the process as a source of fuel ethanol. Additionally, Dr. Rondinone's team is conducting studies to understand efficiency limits and potential improvements.

Applications of this technology are primarily in the areas of fuel production and emergency energy production. Additionally, this method has the potential to be an economically viable alternative to the use of seed crops as precursors to ethanol production.



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- Song, Y.; Peng, R.; Hensley, D. K.; Bonnesen, P. V.; Liang, L.; Wu, Z.; Meyer, H. M.; Chi, M.; Ma, C.; Sumpter, B. G.; Rondinone, A. J., "High-Selectivity Electrochemical Conversion of CO2 to Ethanol using a Copper Nanoparticle/N-Doped Graphene Electrode," *ChemistrySelect* (2016), *1* (19), 6055-6061.
- Sheridan, L.B.; Hensley, D.K.; Lavrik, N.V.; Smith, S.C.; Schwartz, V.; Liang, C.; Wu, Z.; Meyer, H.M.; Rondinone, A.J., "Growth and Electrochemical Characterization of Carbon Nanospike Thin Film Electrodes," *Journal of Electrochemical Society* (2014).

Expanding 3D Printing Capabilities: Thermally Stable Aluminum-Cerium Alloys

ORNL has recently developed novel cerium-containing aluminum alloys that offer weight, strength and temperature performance characteristics close to those of titanium-based alloys at a fraction of the cost. The high strength / high temperature characteristics of the alloys are due to the formation of ultra-fine nanostructures in the material when the alloy melt is rapidly cooled. Because additively manufactured (i.e. 3D printed) components are created by locally melting and rapidly cooling layers of material, the performance of these alloys is optimized in additive manufacturing processes. Furthermore, because the cooling rate of the alloy can be controlled during the additive manufacturing process, the strength / temperature characteristics of the material can be optimized locally within components as they are fabricated.

This project was accepted into TIP with the goal of enabling the adoption of low-cost, lightweight additively manufactured components in the automotive and aerospace industries where high strength at high temperatures is required. The increased strength of the alloy may allow the material to replace steel in some applications, and the combination of strength and thermal stability may allow the material to replace titanium in other applications.

Near term opportunities for the alloy include automotive heat exchangers and turbo charger impellers where the added design flexibility of additive manufacturing (*e.g.* complex internal cooling features impossible to manufacturing by traditional methods) may provide performance characteristics unavailable with traditional manufacturing processes.

Publications

- R.R. Dehoff, M.M. Kirka, W.J. Sames, H. Bilheux, A.S. Tremsin, L.E. Lowe, S.S. Babu, "Site specific control of crystallographic grain orientation through electron beam additive manufacturing". *Materials Science and Technology.*
- R.R. Dehoff, M.M. Kirka, F.A. List, K.A. Unocic, W.J. Sames. "Crystallographic texture engineering through novel melt strategies via electron beam melting". *Materials Science and Technology.*

Ryan Dehoff, PhD
Physical Sciences Directorate

Dr. Ryan Dehoff is the Deposition Science and Technology Group Leader for Oak Ridge National Laboratory. He is developing processing techniques and exploring new materials via additive manufacturing to improve energy efficiency during component production, decrease material waste, and improve material performance. Projects include near net shape fabrication of titanium-and nickel-based super alloy components using low-cost feedstock materials and developing laser processing techniques for forming nanocomposite coatings and bulk components utilizing amorphous based powder materials.

Patent

High Temperature Al Alloys for Additive Manufacturing
Provisional US Patent Application 62/396,490
Invention Disclosure No. 201603698

Inventors

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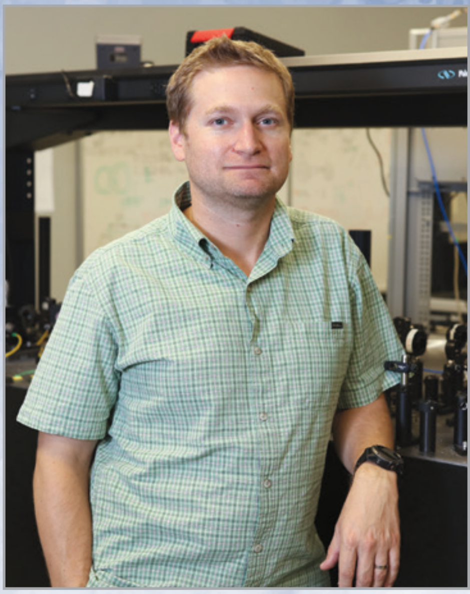

Raphael Pooser, PhD
Computing and Computational Sciences Directorate

Dr. Raphael Pooser is an expert in continuous variable quantum optics. He has over 15 years of quantum optics experience, having led the Quantum Sensing Program at ORNL over the past 7 years. Dr. Pooser has published multiple refereed papers in high-impact journals, including in *Science*, *Nature*, and *Physical Review Letters*. He previously worked as a postdoctoral fellow in the Laser Cooling and Trapping Group at NIST after receiving his PhD in engineering physics from the University of Virginia. He received a B.S. in physics from New York University, graduating cum laude on an accelerated schedule.

Technology

Quantum Random Number Generator
US Patents 9,436,436 and 9,335,973
Invention Disclosure Nos. 201102727, 201202833, and 201703949

Inventors

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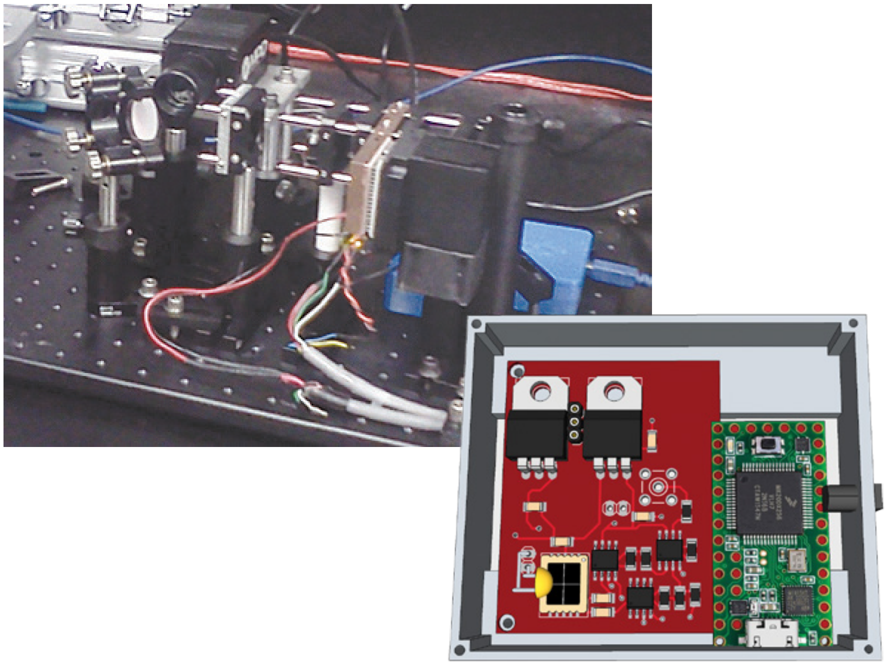
Creating Truly Random Numbers: The Self-Correcting Random Number Generator

Truly random numbers are incredibly difficult to produce. Pseudo-random number generators, typically used in computational applications, are not truly random because they are based on computations and require a seed from some source, typically the system time. This basis in computation can be potentially reverse engineered, making the numbers predictable, and that is dangerous for cyber security. Quantum random number generators (QRNGs) are different because they rely on the truly random nature of quantum mechanics to guarantee the unpredictability of their numbers. However, while the quantum mechanics guarantees theoretical randomness, there are ambient effects that can affect the results. Additionally, QRNGs are notoriously slow in putting out numbers and are renowned for being expensive. Researchers at ORNL have developed a self-correcting quantum random number generator. The device generates a field of photons and measures the quantum statistics after passing them through a beam splitter. By creating a beam of many photons instead of a single one, ORNL's device is able to generate random numbers at a significantly higher rate, and the device itself is several orders of magnitude less expensive. In addition, the device is capable of recognizing and accounting for its own bias, making the produced numbers truly random.

Overall, the goal of this project is to demonstrate that a QRNG which corrects and removes its own biases can be integrated into a small package and that the total cost of such a device can be under $100. A secondary goal is to demonstrate the ability to generate random numbers at a rate greater than 20 Gbps.

The key applications of this device are in the fields of cryptography, high performance computing, authentication, and digital/online gambling. These fields would all benefit from large amounts of cheap, truly random numbers.



Publications

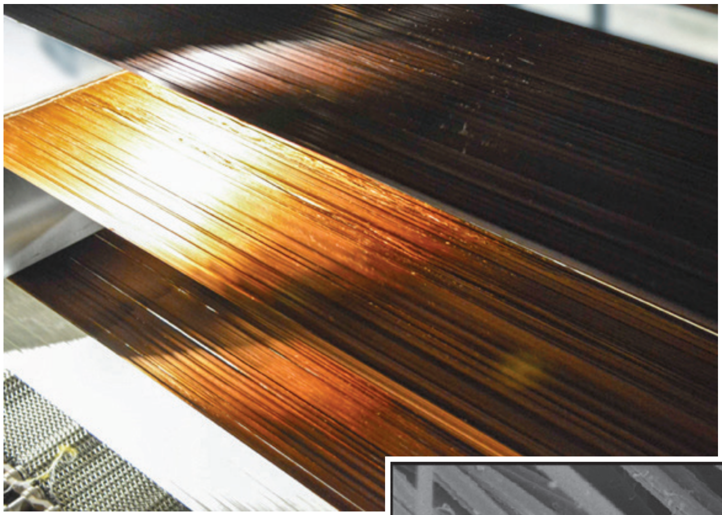
- R.C. Pooser and B.J. Lawrie, "Plasmonic trace sensing below the photon shot noise limit", *ACS Photonics* 3, 8 (2016).
- R.C. Pooser, "Practical Quantum Sensing at Ultra Trace Levels with Squeezed States of Light", *SPIE Photonics West* (2017).

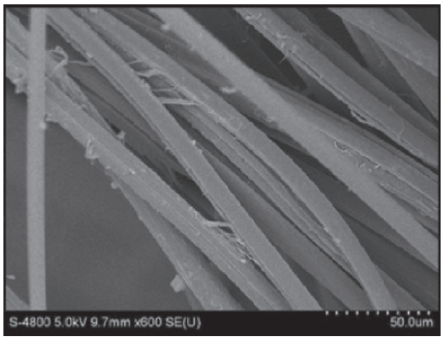
Improving Carbon Fiber Production: A Better Textile PAN Precursor

Recently, ORNL has developed a new process for converting textile-grade polyacrylonitrile (PAN) precursor to low-cost carbon fibers. This process has the advantage of significantly reducing the cost of carbon fiber production, but to date the performance of the resultant carbon fiber is limited to industrial applications. In addition, the chemistry of the precursor, its original production method, and its stabilization kinetic parameters cause a lack of molecular order. To address these challenges, ORNL has developed a method that can be introduced into traditional PAN precursor production processes with minimal impact and that has the potential to significantly improve the economics and performance of the resulting carbon fiber. While this technology is still in the early development stage, if successful it will enable much broader adoption of carbon fiber formed using precursors produced in textile PAN manufacturing facilities.

This project was accepted into TIP with the goal of providing a minor modification to traditional textile PAN production lines that enhances molecular order in the precursor, thereby improving the performance of the resulting carbonized filaments.

The ability to improve and retain the molecular order in precursor fibers during stabilization favors carbon fiber quality and performance. If successful, this technology could enable the adoption of carbon fiber produced from textile PAN precursors in more demanding applications, possibly including aerospace.





Publications

- E. Morris, M.C. Weisenberger, M.G. Abdallah, F. Vautard, H.A. Grappe, S. Ozcan, F.L. Paulauskas, C. Eberle, D.C. Jackson, S.J. Mecham, A.K. Naskar. "High performance carbon fibers from very high molecular weight polyacrylonitrile precursors". *Carbon, 101(C)* (2016).

Amit Naskar, PhD
Physical Sciences Directorate

Dr. Amit Naskar is a senior research staff member and leader of the Carbon and Composites Group in ORNL's Materials Science and Technology Division. He is the lead inventor of ORNL's technology for conversion of polyolefin fibers into carbon fibers, sustainable polymer formulations for composites, and tailored carbon morphology for energy storage. Dr. Naskar earned his PhD in rubber technology from the Indian Institute of Technology (IIT), Kharagpur, India. Prior to joining ORNL, he worked as a post-doctoral researcher at Clemson University in South Carolina. He has published 35 articles in refereed journals and books.

Technology

Enhancing Textile Grade PAN Carbon Fiber Precursors

Invention Disclosure No. 201603816

Provisional Patent Application in Preparation

Inventors

Amit K. Naskar, and Kelly M. Meek

ORNL Materials Science and Technology Division, Carbon and Composites Group

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