

TECHNOLOGY INNOVATION PROGRAM ²⁰¹⁹

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 (ORNL) 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 selects 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 2019 cohort of TIP technologies includes:

- CellSight - Rapid, Native Single Cell Mass Spectrometry
- Nanocapsular Radiation Track Etch Indicator
- Rapid Regeneration of Recalcitrant Plant Species
- BEST: Biomacromolecule Engineering by Soft Chain Coupling
- Genetic Improvement of Salt and Drought Tolerance in Crop Plants

Each of these technologies is believed to be an important breakthrough with significant commercial potential.

Since 2013, ORNL has invested more than \$7M in 34 TIP projects, resulting in 26 commercial licenses and options with partners ranging from Fortune 100 companies to early-stage startups. This brochure provides brief descriptions of the 2019 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 beginning in the third quarter of calendar year 2019, with a goal of entering license agreements by the end of the year.

About 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.

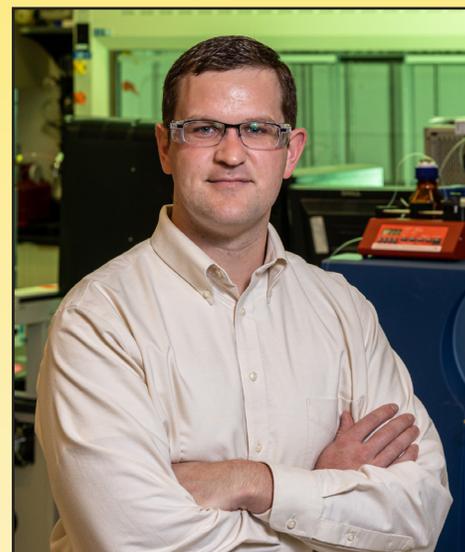
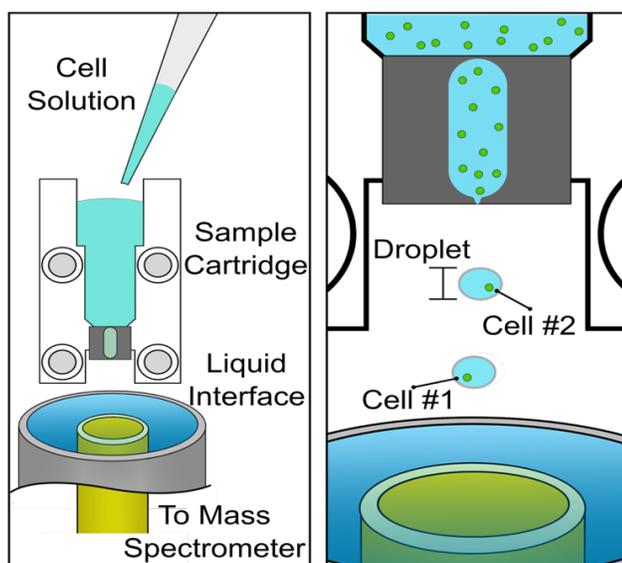
For more information, please visit our webpage at www.ornl.gov.

CellSight — Rapid, Native Single Cell Mass Spectrometry

Problem: Cells are naturally heterogeneous, exhibiting differences in chemistry due to their history, age, and microenvironment, among other factors. Tumors, for example, are heterogeneous mixtures that include epithelial, mesenchymal, stromal, and immune cells. Even when they start from a single genetic precursor, natural stochastic cellular processes create variation in cell chemistries over time. Conventional measurements of cell chemistry fail to identify cellular variations by providing only an average picture of the cell. New technologies that offer single cell resolution are needed to understand cellular heterogeneity.

Solution: CellSight enables untargeted chemical analysis of cell suspensions with single-cell resolution. The system utilizes single-cell droplet ejection and liquid extraction mass spectrometry to measure cellular chemistry quantitatively, with high throughput, in an untargeted manner and without any sample preparation or molecular staining required. Droplet ejection isolates individual cells that are captured in a continuously flowing liquid solvent via an extraction–mass spectrometry technology pioneered and patented at ORNL. Upon being exposed to the solvent, the cell ruptures due to the change in osmotic pressure. The analyte molecules are then measured using mass spectrometry in an untargeted or targeted manner. The CellSight system measures cellular chemistry quickly (1 s/cell) and can process thousands of molecules simultaneously. These unprecedented capabilities will provide critical insights into cell chemistry.

Impact: Knowledge of the chemical constituents in single cells, including lipids, metabolites, and proteins, is valuable for applications such as determining cellular function, understanding molecular mechanisms inside cells, and designing targeted therapies. Most studies measure cellular chemistry in aggregate, and, thus, information on cellular variations is lost and understanding of cellular function impeded. Research related to disease treatment, pharmaceutical drug development, cell signaling, and cell function will be aided by rapid characterization and quantitation of a cell's molecular components, with detail provided by resolving single cells.



John "Jack" F. Cahill, PhD
Chemical Sciences Directorate

Dr. Cahill is an associate research scientist in the Chemical Sciences Directorate at ORNL. His research focuses on the development and application of novel surface sampling and high-throughput mass spectrometry techniques to chemically characterize tissues, plant systems, bacterial colonies, and materials at small spatial scales. Dr. Cahill's work on elucidating metabolic chemistry with cellular resolution led to the CellSight system.

Intellectual Property

CellSight—Rapid, Native Single Cell Mass Spectrometry, ID-201804255

Publications

- J. F. Cahill, J. Riba, and V. Kertesz, "Rapid, Untargeted Chemical Profiling of Single Cells in Their Native Environment," *Anal. Chem.* 2019; 91 (9): 6118–5126. DOI: 10.1021/acs.analchem.9b00680.

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Timothy McKnight Energy and Environmental Sciences Directorate

Timothy McKnight is a research staff member in the Electrical and Electronics Systems Research Division's Sensors and Embedded Systems Group. He holds engineering science degrees from the University of Michigan and University of Tennessee. His research interests include chemical, biological, and radiological nano- and microstructured systems. His work has resulted in over 65 publications and 18 patents. In 2014, he was recognized as a Battelle Distinguished Inventor.

Intellectual Property

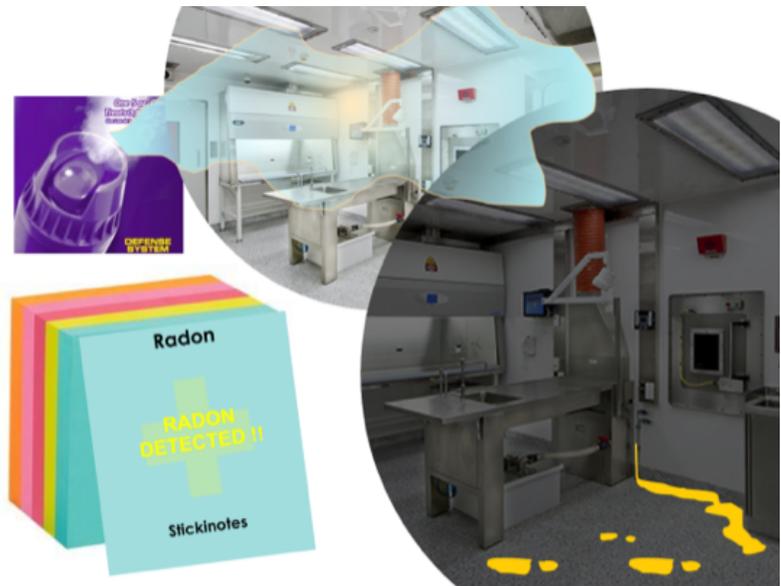
Radiation Contamination Visualizer;
ID-201804293, DOE S-138,964

Nanocapsular Radiation Track Etch Indicator

Problem: Radioactive contamination from phenomena such as spills of radioactive materials and accumulation of radon gas within homes can be colorless, odorless, and essentially invisible without proper detection equipment. These characteristics result in a significant risk of harmful interaction with radioactive contamination and the uncontrolled spread of these materials. Conventional track etch materials, used for detection of radioactive materials, must be processed under laboratory conditions using caustic chemical etching, increasing risk and reducing flexibility.

Solution: ORNL is developing a nanocapsular track etch material that delivers a visible indication following exposure to alpha-particle radiation. Unlike conventional track etch materials, the new capsules feature a biodegradable etch mechanism that provides feedback to users without laboratory processing. The technology may be implemented on small, fixed surfaces such as wipes and sticky notes to provide low-cost single-point test strips or may be aerosol dispersed to larger surfaces, including entire laboratories, to facilitate safe and effective cleanup following radiological spill events.

Impact: Low-cost, passive indication of local areas of alpha-emitting radioactive contamination will significantly improve the health and safety of radiological technicians, contamination remediation personnel, and the public by reducing the time workers are exposed to potentially harmful materials and the uncontrolled spread of these materials during remediation operations. The technology, formulated as low-cost test strips, will also significantly impact in-home testing of radon, a hard-to-detect radioactive substance that causes approximately 21,000 lung cancer deaths each year in the United States.



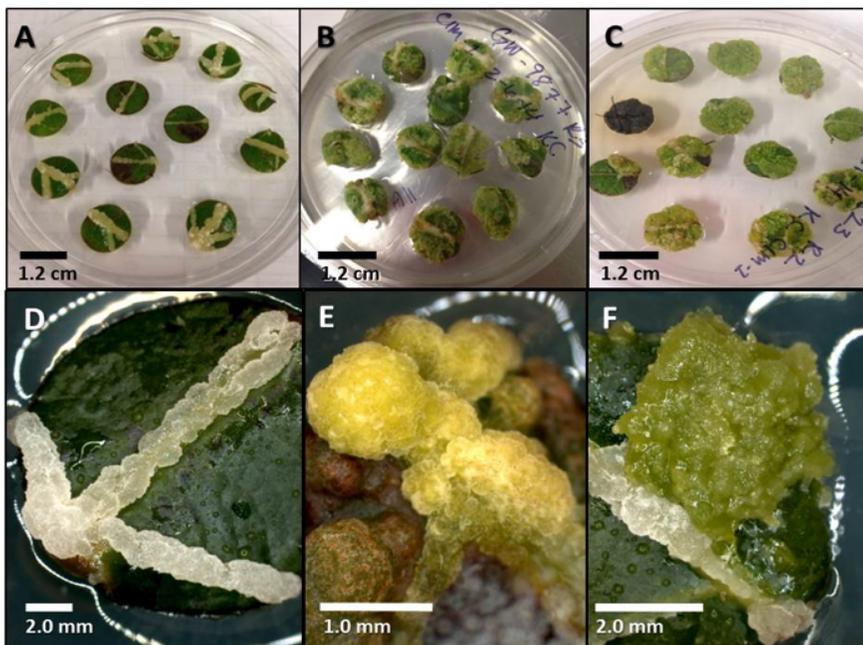
ORNL's nanocapsular radiation track etch indicators can visualize the spatial extent of contamination within a facility via aerosol dispersal or may be immobilized onto paper and fabric substrates to provide low-cost single-point test strips.

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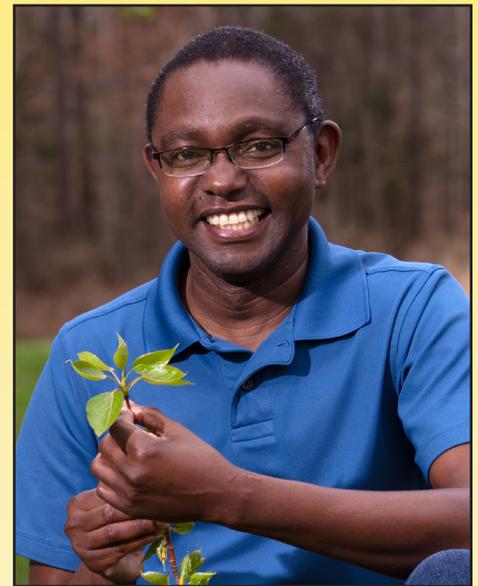
Rapid Regeneration of Recalcitrant Plant Species

Problem: Despite rapid advances in development of genome-editing tools such as CRISPR-Cas9, regenerating viable plants during transgenesis remains a major barrier to cost-effective deployment of these tools in the biotechnology field to enhance plant performance.

Solution: Enhancing regeneration of inherently recalcitrant plant species can be achieved by utilizing four major regulators of DNA replication and cell division that are highly conserved across eukaryotes. Developments in this area would broaden the portfolio of genome-editable plant species. A four-gene construct carrying 2-RNAi-mediated gene-silencing cassettes as well as 2-overexpression cassettes will simultaneously inhibit cell division suppressors (i.e., SOK1 kinase and Histone Deacetylase RPD) and enhance the activity of cell division inducers (i.e., mitogen-activated protein kinase and targeting protein for XKLP2).



Impact: This genetic technology leverages materials and methods to improve the transformation efficiency of plant cells, particularly for those commercially important species that have been difficult to genetically engineer or where transformation efficiencies are low. The simple, easy-to-use approach enhances the efficiency of callus regeneration to enable the creation of intact fertile plants bearing desired genetic improvements.



Wellington Muchero, PhD Energy and Environmental Sciences Directorate

Dr. Wellington Muchero is a quantitative geneticist in the Biosciences Division at ORNL. He holds joint appointments in the Plant Sciences Department and the Bredesen Center for Interdisciplinary Research and Graduate Education at the University of Tennessee–Knoxville. Dr. Muchero received a PhD in plant pathology from the University of California, Riverside, and an undergraduate degree in crop science from California State Polytechnic University, Pomona. He is a 2016 recipient of the US Department of Energy's Early Career Research award. He holds three issued patents, three technology licensing agreements, and numerous invention disclosures related to plant biotechnology.

Intellectual Property

Genes regulating plant regeneration; ID-201804190

Genes regulating plant regeneration; 16/525,724
and PCT/US2019/044048

Publications

- G. A. Tuskan, et al. Defining the Genetic Components of Callus Formation: A GWAS Approach." *PLOS ONE*, 2018; 13.8: e0202519.

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Soydan Ozcan, PhD Energy and Environmental Sciences Directorate

Dr. Soydan Ozcan is a senior scientist in ORNL's Energy and Environmental Sciences Directorate and joint associate professor in the Mechanical, Aerospace and Biomedical Engineering Department at the University of Tennessee–Knoxville. He also serves as the thrust lead for development of bioderived polymer composites for additive manufacturing at ORNL. His research addresses the broad and vital issue of identifying novel, high-value biomaterials from biomass, along with viable processes for preparing biomaterials for composite and additive manufacturing applications. Dr. Ozcan is developing manufacturing techniques and exploring new materials to improve energy efficiency during composite manufacturing, decrease material waste, and improve material performance. He has actively initiated new programs and has been the principal investigator for over 30 R&D projects including research in the areas of fiber and composite manufacturing, composite recycling, and bioderived-materials additive manufacturing. Dr. Ozcan's team engages over 30 industrial partners and delivers research with direct applications to society. He has published nearly 80 papers; holds 18 issued and pending patents; has published 7 book chapters; and is an active speaker, having delivered more than 100 presentations and short courses on manufacturing of fibers and composites topics and research.

Intellectual Property

Silane-Modified Polyester Blends and Methods of Preparation; 16/110,138

Biomacromolecule Engineering by Soft Chain Coupling Technology, ID-201904306

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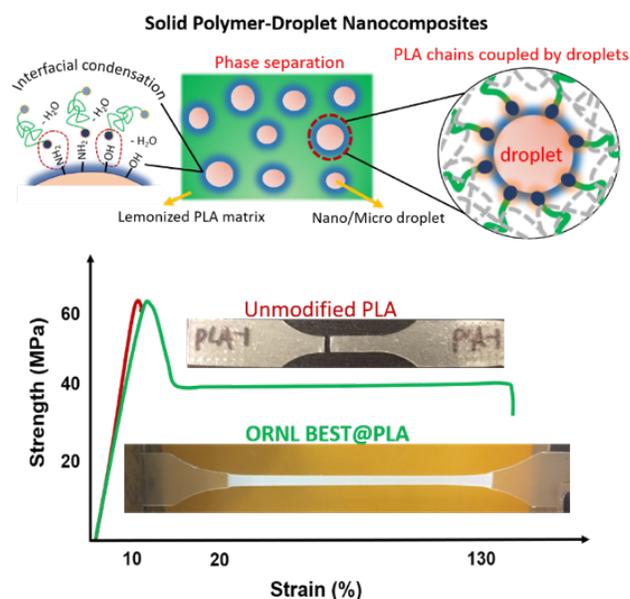
BEST: Biomacromolecule Engineering by Soft Chain Coupling Technology

Problem: Poly(lactic acid) (PLA) is the most widely used bioplastic today. Its biodegradability, biocompatibility, high strength, and stiffness as a commodity polymer make PLA one of the most promising bioplastics under development. Its many application areas include but are not limited to biomedical devices, biodegradable films and packages, and 3D printing. However, PLA's brittle nature is a major barrier to its adoption in much wider application areas.

Solution: The BEST approach dramatically improves the ductility and toughness of PLA via a novel industry-friendly soft-coupling technology based on small droplets and chain end/tail modification. This technology is realized by a scalable, environmentally friendly process that uses only nontoxic additives and a melt-phase process to achieve the desired droplet-in-polymer microstructures, referred to as polymer–droplet composite. The droplets work as a unique topological modifier to manage the topological defects of chain entanglement networks. As a result, with minimal loading of modifiers (<1.5 wt%), the modified PLA offers significant improvements in toughness as well as processability without sacrificing the material's mechanical strength.

Impact: The production capacity of the biobased-polymer industry is projected to triple, from 3.5 million tons in 2011 to nearly 12 million tons in 2020. As the fastest-growing segment of this market, PLA is expected to account for over \$6.5 billion because of its use in packaging, biomedical devices, composites, additive manufacturing, and other areas. Overcoming the issue of brittleness without sacrificing other valuable mechanical properties would revolutionize the already rapidly growing PLA industry. Improvements in mechanical performance would not only extend existing markets, but also enable

new applications such as films and packages and penetration into new polymer markets. The new materials derived using the BEST approach exhibit outstanding mechanical toughness and processability, which are of great value for its broad applications.



Publications

- X. T. Meng, N. A. Nguyen, H. Tekinalp, E. Lara-Curzio, and S. Ozcan, "Supertough PLA-Silane Nanohybrids by In Situ Condensation and Grafting," *ACS Sustain. Chem. Eng.*, 2018; 6 (1): 1289–1298.

Genetic Improvement of Salt and Drought Tolerance in Crop Plants

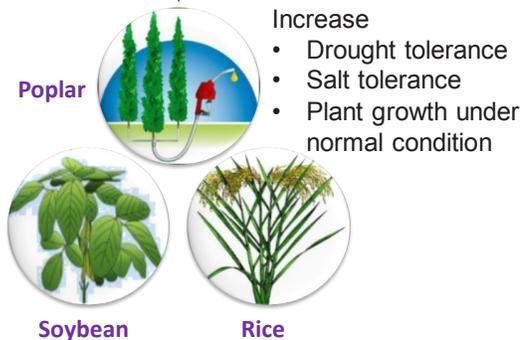
Problem: Drought and salt stresses impose big challenges on crop production. To keep American farmers competitive, developments that increase crop tolerance to seasonal drought and salt stresses—and enhance growth under normal conditions—are urgently needed. However, it has been very challenging to simultaneously improve growth, drought tolerance, and salt tolerance in plants, and it is very difficult to find a single solution that achieves improvements in all three areas.

Solution: Crassulacean acid metabolism (CAM), a natural water-use efficiency mechanism that facilitates plant adaptation to water-limited and salinized environments, employs a key CAM gene from the desert-dwelling plant *Agave* to



Desert-living plant
Agave
(*Agave americana*)

Transferring a key gene
in CAM pathway



simultaneously increase biomass yield under normal conditions and resistance to both drought and salt stresses. This technology has been successfully established in model plant tobacco, and it is currently being extended to food crops (e.g., rice, soybean) and bioenergy feedstocks (e.g., poplar). Overexpression of this key gene enhances the expression of multiple genes relevant to CO₂ fixation, consequently improving photosynthetic efficiency and biomass yield, and increases the accumulation of proline, a key player in plant tolerance to drought and salt stresses.

Impact: This technology facilitates the sustainable production of food and bioenergy on marginal lands or under seasonal drought conditions, with potential to generate significant positive impact on the food, bioenergy, landscape, and timber industries, which together represent a combined market opportunity of hundreds of billions of dollars each year. Such markets are essential for our national food, energy, and economic security. In an average year, the world experiences a 50–80% yield loss of crops due primarily to drought and high soil salinity. Application of this technology will help meet the increasing demand for food, biofuel, and animal feed while increasing the competitiveness of the US agricultural industry in an environmentally friendly way.



Xiaohan Yang, PhD Energy and Environmental Sciences Directorate

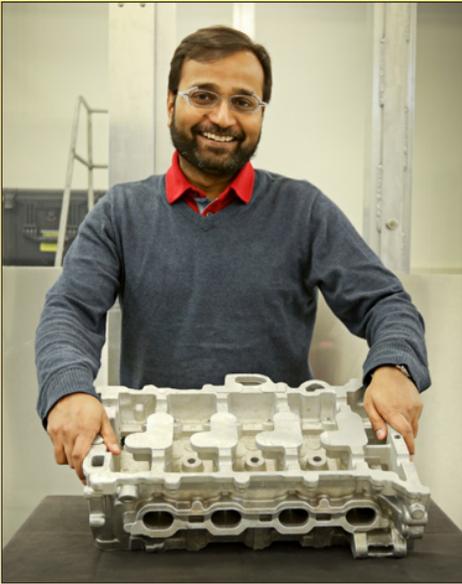
Dr. Xiaohan Yang is a senior research staff member in the Biosciences Division at ORNL. He obtained his PhD in horticulture, plant molecular biology, and plant breeding from Cornell University. He has expertise in plant genomics, bioinformatics, and plant synthetic biology. Dr. Yang's research focuses on molecular signaling, plant-gene editing, and plant biosystem design in relation to bioenergy research and plant-microbe interactions. He has published more than 80 journal articles. His research garnered a 2018 R&D 100 award, which is considered the "Oscars" of research and innovation toward commercialization.

Intellectual Property

Gene for enhancing salt and drought tolerance in plants; ID -201804140

BESC-Gene for Enhancing Salt and Drought Tolerance in Plants; 62/797,452

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Amit Shyam, PhD Physical Sciences Directorate

Dr. Amit Shyam is a senior research staff member in the Alloy Behavior and Design group in the Materials at ORNL. He has an undergraduate degree in materials and metallurgical engineering from the Indian Institute of Technology at Kanpur (1997) and a Ph.D. in materials science and engineering from Michigan Technological University (2002). His research interests include materials for automotive propulsion and lightweighting applications and design of alloys for structural applications. He has over 60 publications in addition to two issued US patents.

Intellectual Property

Cast Aluminum Alloys with Improved Microstructural Stability and Strength at 350°C; ID-3569; 15/160,926

Aluminum Alloy Compositions and Methods of Making and Using the Same; ID-3804; 15/594,434

ID-3963: Heat Treatments for High Temperature Cast Aluminum Alloys and Components Fabricated from Them, 16/171,201

ID- 4221: High temperature cast aluminum alloys with improved ductility at lower temperatures, 62/774,468

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Commercialization of AlCuMnZr (ACMZ) Alloys

Problem: Realization of design opportunities for higher engine efficiencies in the global automotive industry demands new cast aluminum (Al) cylinder head alloys with higher strengths at higher temperatures (up to 300°C). However, despite decades of intense study, present commercial aluminum alloys for automotive engine applications are viable for temperatures only up to 250°C.

Solution: ACMZ alloys are a remarkable new family of cast aluminum alloys that combine unprecedented levels of cost competitiveness, castability, and mechanical property superiority at temperatures previously unattainable for lower cost Al alloys. At ORNL, a suite of atomic-level characterization and computation tools were applied to rapidly develop breakthrough alloys with unmatched yield strength and thermomechanical fatigue resistance at 300°C. In addition, the ACMZ alloys also possess superior hot tear cracking resistance, a problem common to all existing higher-temperature-capable aluminum alloys.

Impact: Cast ACMZ alloys provide an immediate upgrade over all existing commercially available cylinder head alloys by providing a >100°C increase in temperature capability, as well as substantial strength improvements. The primary industry that will be targeted for commercialization will be the automotive industry, including light- and heavy-duty engine manufacturers, casting suppliers, and original equipment manufacturers (OEMs).



Publications

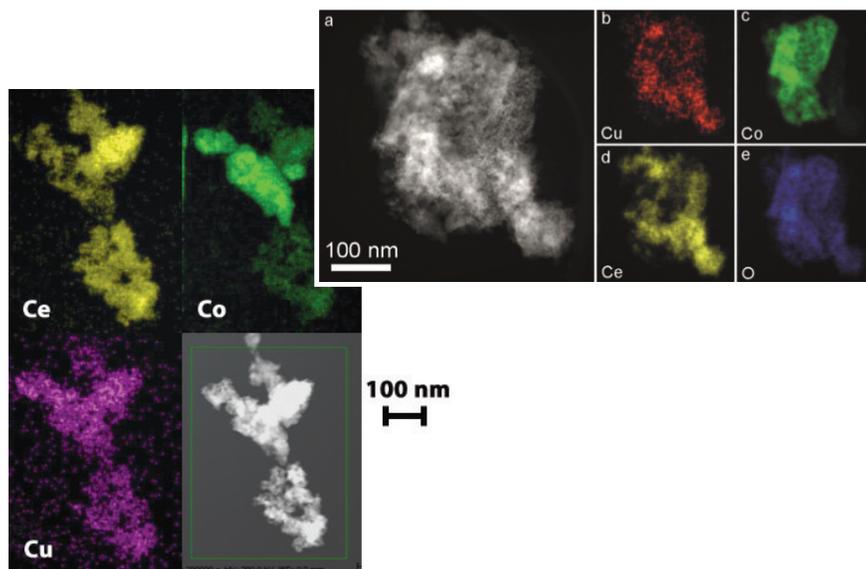
- S. Roy, L. F. Allard, A. Rodriguez, T. R. Watkins, and A. Shyam, "Comparative evaluation of cast aluminum alloys for automotive cylinder heads: Part I - Microstructure evolution," *Metallurgical and Materials Transactions A*, Volume 48, Issue 5, pp 2529–2542, May 2017.
- S. Roy, L. F. Allard, A. Rodriguez, W. D. Porter, and A. Shyam, "Comparative evaluation of cast aluminum alloys for automotive cylinder heads: Part II: Mechanical and thermal properties," *Metallurgical and Materials Transactions A*, Volume 48, Issue 5, pp 2543–2562, May 2017.

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.



James Parks II, PhD Energy and Environmental Sciences Directorate

Dr. Jim Parks leads the Applied Catalysis and Emissions 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.

Intellectual Property

Low Temperature Oxidation Catalyst

Non-provisional US Patent

Application 15/134,449

Invention Disclosure No. 201403345

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*.

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Matt Garrett

Commercialization Manager

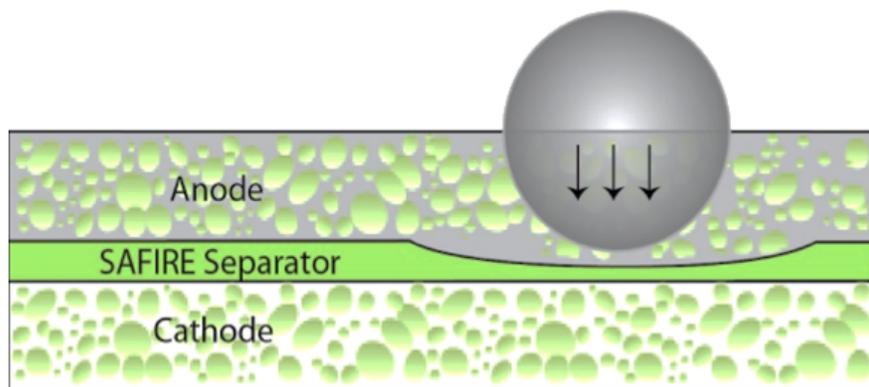
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Safe Impact Resistant Electrolytes (SAFIRE)

Problem: Images of electric vehicles and personal electronics on fire demonstrate the problematic reality of lithium-ion batteries. The electrolyte in a lithium-ion battery is traditionally built from highly flammable organic solvents that present a fire hazard in the event of an internal short circuit—contact between positive and negative electrodes.

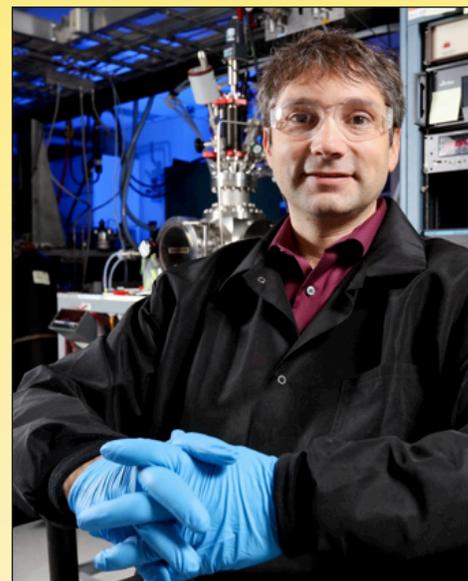
Solution: This project focuses on the scale-up and safety demonstration of ORNL's shear thickening electrolytes for advanced battery applications. The Safe Impact Resistant Electrolyte (SAFIRE) transformative design results in the electrolyte functioning as a safety feature of the battery and eliminating the risk of thermal runaway. The SAFIRE electrolyte is a liquid under normal operating conditions, allowing solvents to wet all the electrode surfaces just like a traditional battery electrolyte. However, upon impact, as caused by a car crash or some other mechanical impact event, the additive causes the electrolyte to undergo an immediate and massive rheological shift to become a solid. The solid barrier prevents the positive and negative electrodes from coming into contact and short circuiting. By preventing the electrodes from touching, none of the energy stored in the battery components is released.



Impact: Emerging technology markets, such as those within the automotive industry, depend on safe electrical energy storage. The SAFIRE electrolyte challenges previous notions regarding battery safety/engineering and will turn the electrolyte into an intrinsic part of the battery safety envelope. Beyond the safety aspects of this electrolyte, the value added from this technology enables the redesign of battery packaging and battery placement to introduce design flexibility to end users. Additional SAFIRE market impact is in US military applications, specifically batteries that double as body armor and/or safer portable drone batteries.

Publications

- Brian H. Shen, Gabriel M. Veith, Beth L. Armstrong, Wyatt E. Tenhaeff, and Robert L. Sacci, "Predictive design of shear-thickening electrolytes for safety considerations," *Journal of the Electrochemical Society*, 164(12), A2547–A2551 (2017).
- Gabriel M. Veith, Beth L. Armstrong, Hsin Wang, Sergiy Kalnaus, Wyatt Tenhaeff, and Mary Patterson, "Shear Thickening Electrolytes for High Impact Resistant Batteries," *ACS Energy Letters* 2(9), 2084–2088 (2017).
- Brian Shen, Beth L. Armstrong, Mathieu Doucet, Luke Heroux, James F. Browning, Michael Agamalian, Wyatt E. Tenhaeff, and Gabriel M. Veith, "Shear Thickening Electrolyte Built from Sterically Stabilized Colloidal Particles" *ACS Materials and Interfaces* In Press (2018).



Gabriel M. Veith, PhD Physical Sciences Directorate

Dr. Gabriel Veith is a senior research staff member and team lead for the Thin Film and Fundamental Electrochemistry group within the Materials Science and Technology Division at ORNL. His research focuses on the development of new materials and processes related to energy storage/conversion applications as well as fundamental studies of liquid-solid interfaces. He has 176 published papers, four patents, six patents submitted, and two R&D 100 awards.

Intellectual Property

- Impact Resistant Electrolyte; US20160093917 A1
- Shear Activated Impact Resistant Electrolyte; US20170104236A1
- Stabilized Shear Thickening Electrolyte; ID-3814
- Fabrication of Films and Coatings Using Shear Thickening, Impact Resistant Electrolytes; ID-3634
- ID-3025 Impact Resistant Electrolyte; US9590274B2
- ID-3633 Shear Activated Impact Resistant Electrolyte, US 10,347,934 B2
- ID-3634 Fabrication of Films and Coatings Using Shear Thickening Impact Resistant Electrolytes; 15/958,448
- ID-3814 Stabilized Shear Thickening Electrolyte; US 10,347,945 B2

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