2018 Technology Innovation Program

Oak Ridge National Laboratory | 75 Years

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 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 2018 cohort of TIP technologies includes:

- Heartbeat, which provides Cyber Anomaly Detection through Side-Channel Analysis of Periodic System Function Invocation
- Carbon Nanomaterial Enabled Ultra Conductive Metal Composites, a scalable assembly of Cu-CNT multilayer composites
- Low-Cost, High-Strength Ni-Fe-Cr Alloys, which have the potential to be used in next generation high-efficiency engines and exhaust valves
- ACMZ alloys, a remarkable new family of cast aluminum alloys
- SAFIRE, shear thickening electrolytes for advanced battery applications

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

Since 2013, ORNL has invested more than $7M in 29 TIP projects, resulting in 19 commercial licenses and options with partners ranging from Fortune 100 companies to early-stage startups. This brochure provides brief descriptions of the 2018 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 2018, 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.

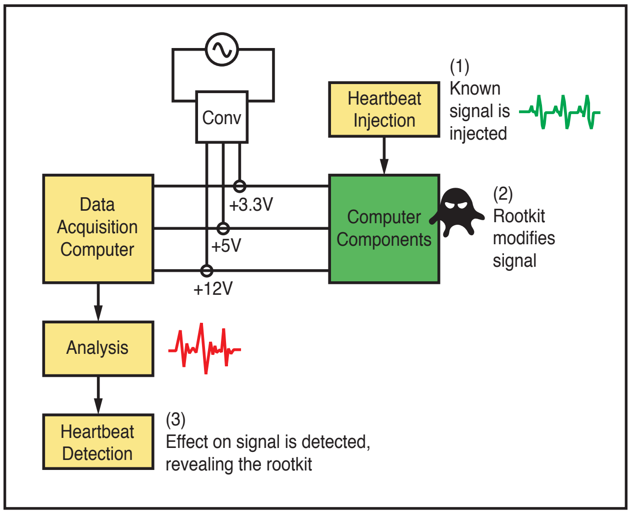
For more information, please visit our webpage at www.ornl.gov.

Heartbeat – Cyber Anomaly Detection through Side-Channel Analysis of Periodic System Function Invocation

Problem: Malware infections and cyberattacks are escalating in frequency, sophistication, and severity, creating an urgent demand for next generation sensor and analysis technologies. In response to this, the cyber security market reached $150 billion in 2017. However, legacy signature or heuristics-based solutions are unable to keep up with the flood of new polymorphic malware samples, or to address the powerful and stealthy tactics of kernel-level rootkits.

Solution: Heartbeat responds to this problem by focusing instead on the physical behavior of the device being protected, under the hypothesis that malware infection will produce a measureable change in the power consumption state of a device that can be picked up by an outside detector. All code execution uses power, so the execution of malware—especially polymorphic variants—will leave a trace on a power consumption record. The Heartbeat system collects power trace measurements directly from the hardware and so is invisible to malware and resilient to internet service interruption. By collecting power measurement data only during the periodic invocation of a single or of several system functions, Heartbeat will address several challenges that plague current anomaly-based intrusion detection systems and is operational-context agnostic.

Impact: Heartbeat will provide a significant market advantage to three main industries: threat intelligence, endpoint security, and unified threat management industries. First, Heartbeat will achieve efficiency, scalability, and flexibility by implementing a data collection process that has low computational requirements, is fast, and makes use of mechanisms—namely, system and API calls—that are present in almost all modern computing systems. Second, Heartbeat will achieve accuracy through execution-independent data collection and a flexible algorithm that is modular and analysis-agnostic, permitting different analysis techniques for different device classes. Finally, because the Heartbeat data collection will require minimal configuration and user knowledge, Heartbeat will achieve ease of use and user friendliness.



Stacy Prowell, PhD
Computing and Computational Sciences Directorate

Dr. Stacy Prowell serves as the chief cyber security research scientist in the Computing and Computational Sciences Directorate at ORNL and is the program manager for the lab's Cybersecurity for Energy Delivery Systems program. Dr. Prowell's research focuses on exploiting physical sensors and properties to detect and prevent intrusion, on deep semantic analysis of compiled software, and on the security of safety critical systems. Dr. Prowell's work on a system for deep analysis of compiled software led to the Hyperion system, which received a 2015 R&D 100 award and two awards for technology transfer. Previously, Dr. Prowell worked in the CERT Program of the Software Engineering Institute on automated analysis of malware.

Intellectual Property

Tampering Detection Heartbeat; 62/506,170

System and Method for Monitoring Power Consumption to Detect Malware; 62/506,114

An Anomaly Detection Ensemble for Time-Series Data; 62/608,750

Publications

- J. M. Hernández, R. A. Bridges, J. A. Nichols, K. Goseva-Popstojanova, and S. Prowell, "Towards a Malware Detection Framework Based on Power Consumption Monitoring," Proc. of the 12th Annual Cyber and Information Security Research (CISR) Conference, Oak Ridge, TN, April 4–6, 2017.
- J. M. Hernández, A. Ferber, S. Prowell, and L. Hively, "Phase-Space Detection of Cyber Events," Proc. of the 10th Annual Cyber and Information Security Research (CISR) Conference, Oak Ridge, TN, April 7–9, 2015.
- S. J. Prowell and C. Rathgeb, "Statistical Fingerprinting for Malware Detection and Classification," US Patent 9,135,440, filed July 31, 2013.

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Tolga Aytug, PhD
Physical Sciences Directorate

Dr. Tolga Aytug is a senior research staff member in the Chemical Sciences Division at ORNL. He received his PhD in physics from the University of Kansas. He is an expert in processing of advanced materials, using both physical and chemical vapor deposition, and chemical solution approaches, as well as advanced materials characterization and microstructure-property correlations for process optimization. He has published over 100 articles in referred journals and has written two book chapters. He holds 13 issued US patents.

Intellectual Property

Carbon Nanomaterial Enabled Novel Ultra Conductive Copper Composites; ID-3766

Carbon Nanomaterial Copper Composites; ID-3946

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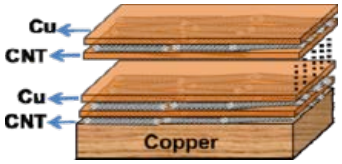
Carbon Nanomaterial Enabled Ultra Conductive Metal Composites (UCC)

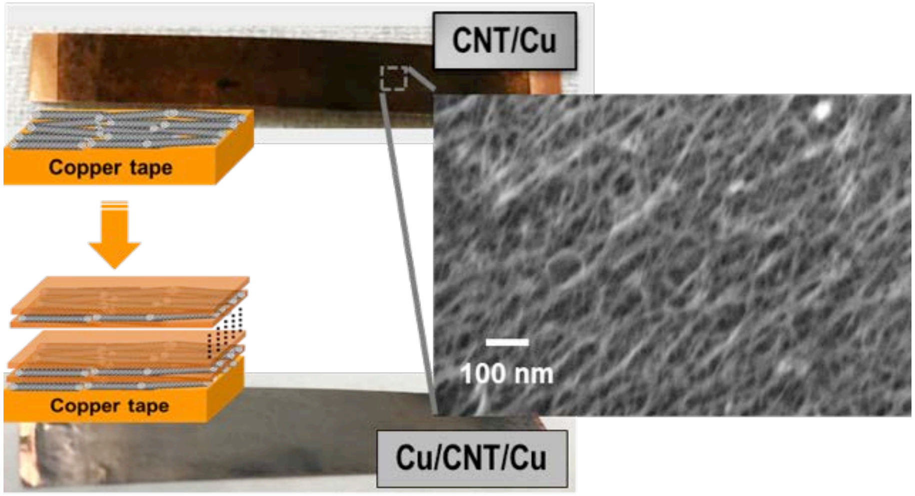
Problem: A growing demand for electrical energy and the increasing need for high-power grid systems necessitate development of new conductors that provide enhanced electrical and thermal conductivity. In preliminary work, ORNL has produced UCCs with conductivities 4-5% greater than that of pure copper. Conductivities are expected to continue to increase as the process matures. A new class of high-performance Cu (Al) conductors—ultra-conductive metal composites (UCC)—is needed to provide enhanced electrical and thermal conductivity.

Solution: Carbon nanomaterial enabled UCC metal composites combine ORNL's strength in nanomaterial research, electron microscopy, and scalable material processing together with novel methods to produce a scalable assembly of Cu-CNT multilayer composites. These composites enable higher electrical conductivities than that of pure Cu.



Using scalable, cost-effective, and commercially viable solution-based processing methods, our technological platform achieves a high degree of CNT alignment and coating stability, which demonstrates a novel technological platform to reproducibly produce carbon nanomaterial enabled ultra conductive conductors for a broad range of electrical systems and industrial applications.

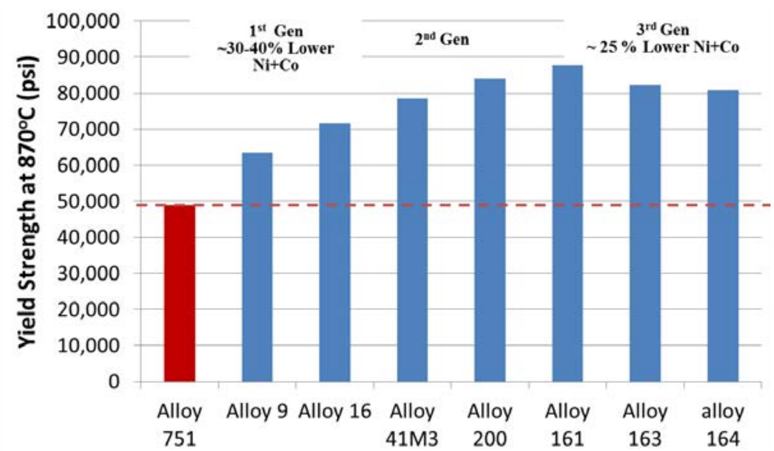
Impact: Commercialization of this technology will potentially result in immense technological and economic value across diverse energy sectors (e.g., electronic devices, electric machines/motors, grid applications) and will help to reduce greenhouse gas emissions while supporting the global competitiveness of clean energy products. The market potential of this technology is staggering. For instance, the projected global market for wire and cable, which is currently valued at $205 billion, is expected to reach $297.4 billion by 2019.



Low-Cost, High-Strength Ni-Fe-Cr Alloys for High-Temperature Applications

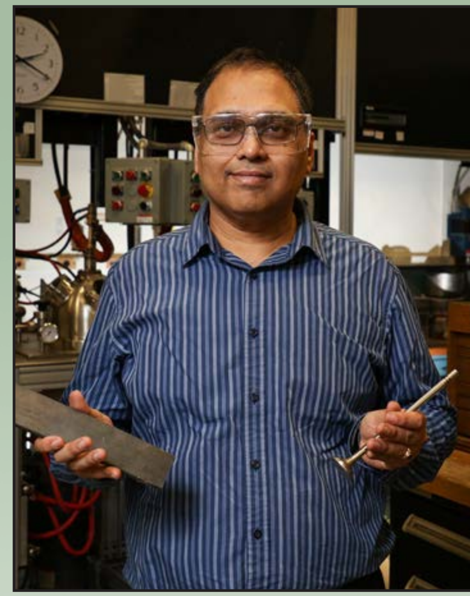
Problem: Exhaust gas temperatures in high-efficiency light-duty and heavy-duty engines are expected to increase steadily through 2025 and beyond. This has created a demand for new materials that can meet the performance and cost targets for components, such as exhaust valves, which are exposed to these higher exhaust gas temperatures. Currently Ni-based alloy 751, which contains about 71% nickel, is used in high-performance exhaust valve applications. Alloy 751 has strength and oxidation resistance up to about 800–850°C. However, above 850°C, this alloy rapidly loses its strength.

Solution: Using computation modeling techniques, ORNL researchers have developed several new low-cost, high-strength Ni-Fe-Cr alloys with yield strengths up to ~80% better than that of alloy 751. In addition, these alloys have been designed to contain 50% or less by weight of Ni+Co, which is about 25–40% lower than that of alloy 75, translating to material cost savings.



Yield strengths of new alloys are up to 80% greater than that of alloy 751, which is currently used as a valve material.

Impact: The low-cost, high-strength Ni-Fe-Cr alloys have the potential to be used for exhaust valves in the next generation high-efficiency engines. Additionally, high-temperature applications exist in the industrial manufacturing, chemical, gas turbine, power, and aerospace markets. For example, low-cost, high-strength Ni-Fe-Cr alloys could enable manufacturing of lighter heat-treating baskets and fixtures, radiant tubes, wire mesh furnace belts and basket liners, fluidized-bed components, muffles and retorts, and recuperators.



Govindarajan Muralidharan, PhD
Physical Sciences Directorate

Dr. G. Muralidharan is a senior research staff member in the Alloy Behavior and Design Group. He received his PhD in Materials Science and Engineering from the University of Illinois at Urbana-Champaign. He is a UT-Battelle Distinguished Inventor with more than 18 granted US patents and has won several R & D 100 awards for successful commercialization of various technologies. He is currently actively involved in the development and commercialization of high-temperature alloys for automotive, industrial, and nuclear applications.

Intellectual Property

Low-cost Fe-Ni-Cr alloys for High Temperature Valve Applications; US9605565 B2

Low-Cost, High-Strength Fe-Ni-Cr Alloys for High Temperature Exhaust Valve Applications; US9752468 B2

Publications

- R. N. Andrews, J. Serio, G. Muralidharan, and J. Ilavsky, "An in-situ USAXS-SAXS-WAXS study of precipitate size distribution evolution in a model Ni-based alloy," *J. Appl. Crystallogr.*, 2017 June 1; 50 (Pt. 3): 734–740.

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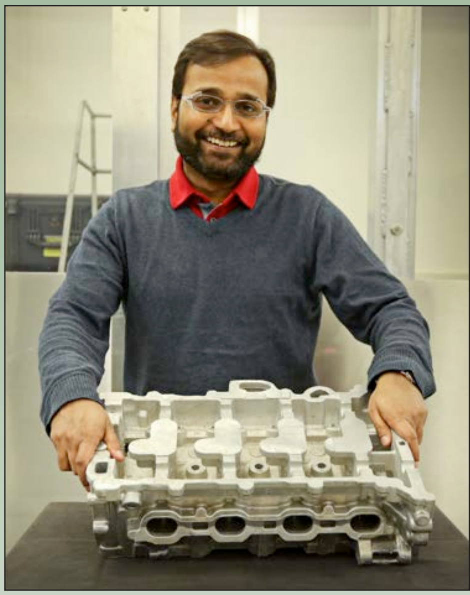

Amit Shyam, PhD
Physical Sciences Directorate

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

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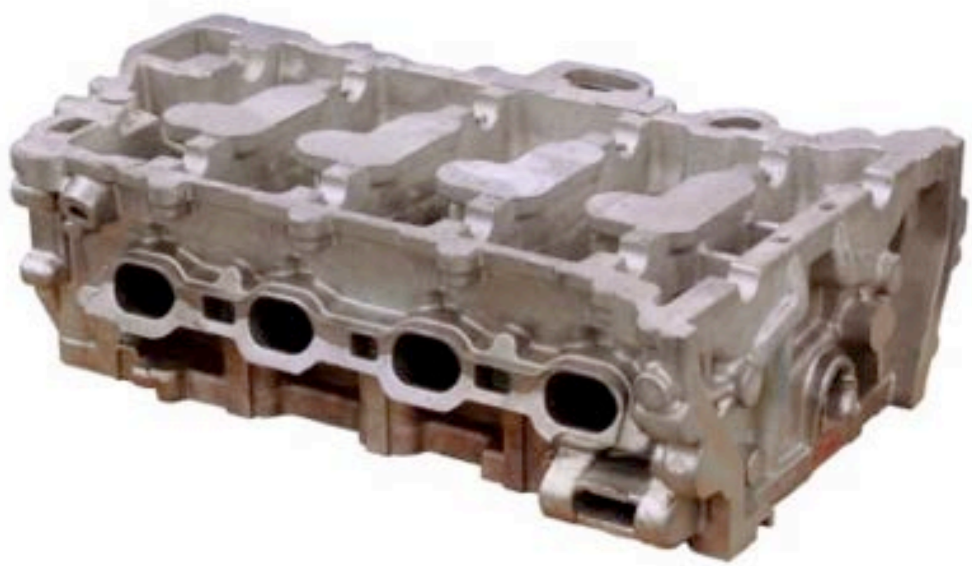
Commercialization of AlCuMnZr (ACMZ) Alloys

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).



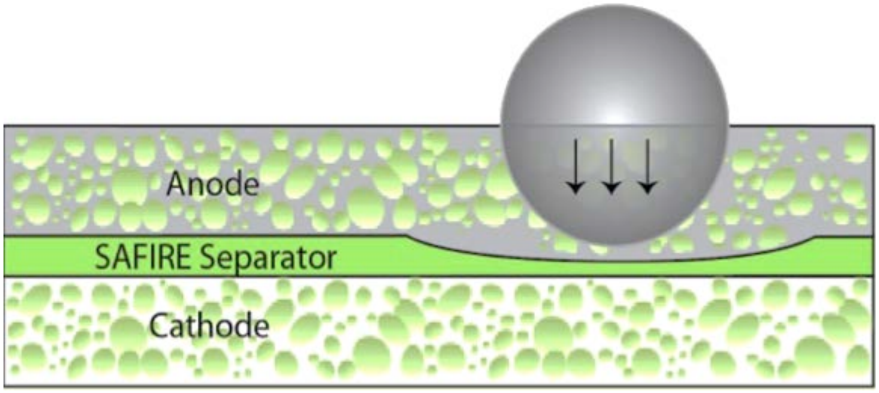
Publications

- 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.

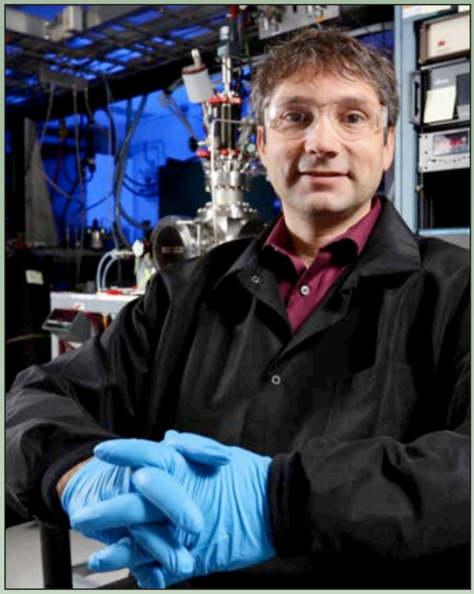
Safe Impact Resistant Electrolytes (SAFIRE)

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.



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

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).

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