

Particle Spray (sculpting gel, acrylic, gold leaf on canvas): Based on the particle spray resulting from the reaction of $^{32}\text{S} + ^{197}\text{Au}$ at 6.4 TeV (Stable sulfur isotope with 16 neutrons incident on a heavy and stable gold nucleus with a comparable 118 neutrons). Painted by Kathryn Metzger and included in her undergraduate thesis.

IUP Fellow Dr. Kathryn Metzger: The Art of Engineering

by Eric Williams for DOE's Nuclear Energy University Program

When the physics majors at the University of South Carolina (UofSC) handed in their honors theses in 2009, one stood out.

"I think our professor intended for them to be research papers," Kathryn "Kallie" Metzger recently recalled. "But I noticed my friends in the arts were having more fun than we were." As a result, her thesis included 13 of her original paintings, ranging from the helix nebula (oil on canvas) to a particle spray (sculpting gel, acrylic, and gold leaf on canvas).

Today Metzger is the advanced fuels development lead for Westinghouse Electric Company, bringing a broad-spectrum, creative approach to the field. "There is a nice parallel between painting a new image and making a new product," she said. "If you're developing a new material, in the commercial world, research and development is an iterative process, the same as painting on canvas."

Since her undergrad days at UofSC, Metzger has developed strong technical chops by excelling in the academic, national laboratory, and private-sector worlds. A South Carolina native, she earned her masters and PhD in nuclear engineering from

UofSC; as an Integrated University Program (IUP) Fellow, her doctoral work focused on accident tolerant fuels (ATF) and cladding systems, including material testing, characterization, and fuel performance modeling and simulation.

"If I hadn't had the fellowship, I don't know if I would have had the opportunity to go from a master's to a PhD," she said. "I do know I wouldn't have been able to go to conferences and attend other meetings that help build strong relationships in the nuclear community." Those ties, in turn, are invaluable when working across multiple public and private platforms.

After her schooling, Metzger worked in nuclear materials at both Savannah River National Laboratory and Idaho National Laboratory, deepening her expertise in irradiation testing, microstructural characterization, and fuel performance modeling. She has also carved out time to volunteer, having served on the Advanced Test Reactor-National Scientific User Organization's executive committee, and currently as chair of the American Nuclear Society's Materials Science and Technology Division. In addition, she represents Westinghouse on the Nuclear Energy Advanced Modeling and Simulation

(NEAMS) Light Water Reactor and Advanced Reactor Industry Councils.

“My focus is the pellets inside the fuel rod,” she said recently. “I have an appreciation for all materials within the fuel cycle, but I get nerdy about the fuel pellets.”

Indeed, Metzger relishes getting nerdy when delving into the benefits of advanced fuel materials like uranium nitride (UN) and uranium silicide (U_3Si_2). In 2016, for example, she completed her doctoral thesis, *Analysis Of Pellet Cladding Interaction and Creep of U_3Si_2 Fuel for Use in Light Water Reactors*, under advisors Travis Knight and Elwyn Roberts.



Above left to right: Jeff Leong (Westinghouse), Adrian Wagner (Idaho National Laboratory), Tom Morello (Exelon), and Kallie Metzger (Westinghouse). Westinghouse and its partners have developed EnCore® Fuel as part of the U.S. Department of Energy’s (DOE) Accident Tolerant Fuel Program. The Westinghouse-Exelon EnCore® Fuel Lead Test Rod (LTR) Program marked the first insertion of EnCore® Fuel rod assemblies into a commercial nuclear power plant. These two lead test assemblies contain chromium-coated zirconium cladding for enhanced oxidation and corrosion resistance, higher density ADOPT™ pellets for improved fuel economics, and uranium silicide pellets. Photograph shows inspection of U_3Si_2 pellets prior to loading in segmented rod.

Below: Image shows U_3Si_2 rodlet loaded in Byron Unit 2 as part of EnCore® LTR program. Two ATF LTRs were inserted in April 2019. LTRs contained chromium-coated cladding, ADOPT™ doped UO_2 pellets, and U_3Si_2 . U_3Si_2 was inserted in the form ~12 inch rodlets as shown in figure below. First cycle ATF materials are due to be removed in fall 2020. Photo courtesy of Westinghouse Electric Company, LLC.



X-ray image of U_3Si_2 fuel segment

“Too often physics is dismissed as complex, intimidating, or even boring. The aim of my senior art exhibit was to dispel these misconceptions through art. An interdisciplinary art exhibition allowed individuals from all walks of life to experience and learn about physics in a lecture-free format. Brochures were available at the art exhibit to clarify physics terminology and to enhance the viewer’s understanding of the relationship between physics and art.”

“The Bubble Chamber and Particle Series is inspired by actual bubble chamber images. I selected a transparent cyanic blue for many of the bubble chamber images because it reminded me of Cherenkov radiation and emphasized the liquid background of the bubble chamber traces. The colors in the Bubble Chamber series are bright and vibrant to suggest the energy movement and activity of particles in a detector. The galaxy and nebula series is an investigation into the origins of cosmic rays using images from the Hubble telescope. Cosmic rays are energetic particles from outer space that rain down on the Earth’s atmosphere and can be observed through a variety of particle detectors. The relationship between the far reaches of the galaxy and particle traces observed in man-made bubble chambers was something I attempted to portray through the artwork. In total, 15 pieces of art were shown.”

Dr. Kathryn Metzger
undergraduate honors thesis



Metzger's dissertation noted advanced and high density fuel pellets offer "a number of advantageous thermophysical properties, including high density, high thermal conductivity at room temperature, and a high melting point." These properties support goals of accident tolerance while higher uranium density is capable of supporting uprates to the Light Water Reactor (LWR) fleet.

Energy density is one of the attributes she finds especially important. And she has a way of merging her understanding of the complex with her ability to frame things in simple terms. "If you have more uranium atoms in there, that ultimately dictates how much power you'll get from the fuel pellet – it's an economic benefit to the plant," she said, adding "Everyone recognizes we have a need for reliable, energy dense, power. We already have it in nuclear. As developing countries grow and commercialize and want the amenities afforded by electricity, nuclear is a critical part of the solution."

In an abbreviated description of its ATF fuel products, Westinghouse says "chromia (Cr_2O_3) and alumina (Al_2O_3) doped UO_2 pellet, known as our ADOPT™ pellet, will be enhanced for the first phase of the EnCore® Fuel Program. The improved ADOPT™ pellet design achieves greater uranium efficiency" through attributes such as a higher creep rate, higher thermal stability and, of course, density. Higher density fuels like nitrides and silicides provide the opportunity for significant improvements to uranium density and fuel cycle economics.

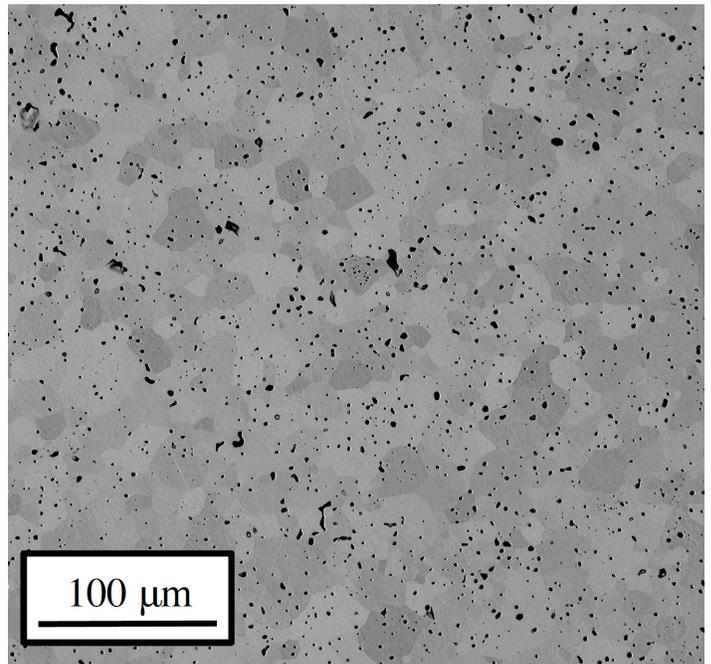


Image shows high density microstructure of Uranium Nitride fuel pellet, produced by Los Alamos National Laboratory (LANL). Image provided courtesy of Josh White, LANL. Dr. White is leading both UN fuel fabrication and thermal mechanical testing in support of the Westinghouse ATF program.

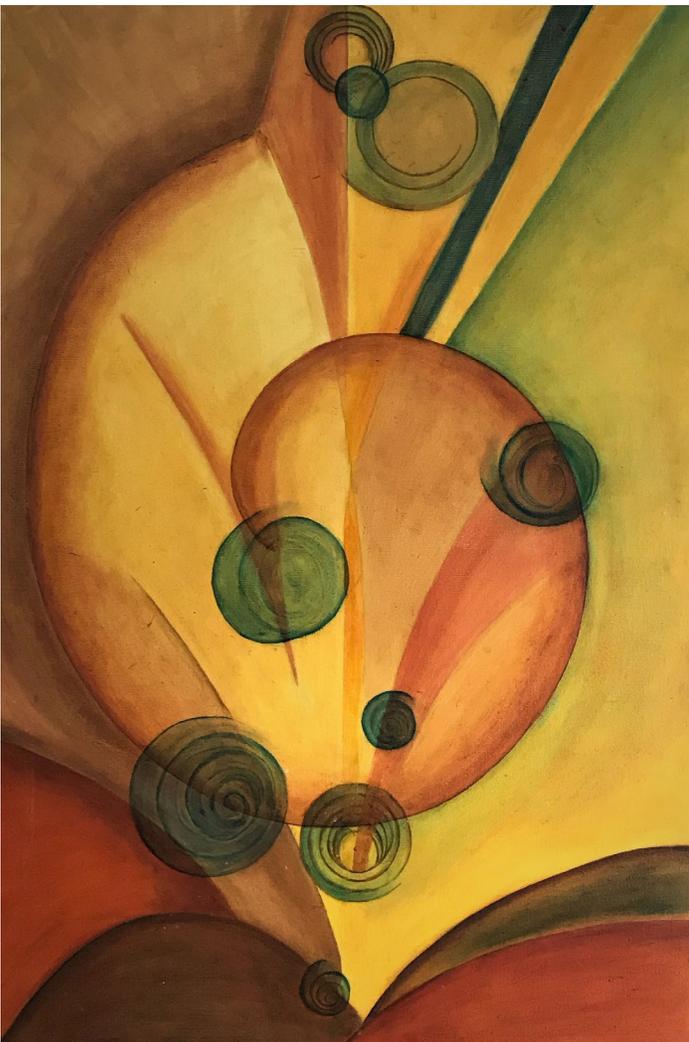
Two lead test fuel assemblies from Westinghouse-Exelon EnCore® Fuel Lead Test Rod (LTR) Program. The assemblies contained chromium-coated zirconium cladding for enhanced oxidation and corrosion resistance, higher density ADOPT™ pellets for improved fuel economics, and uranium silicide pellets. Photo courtesy of Westinghouse Electric Company, LLC.



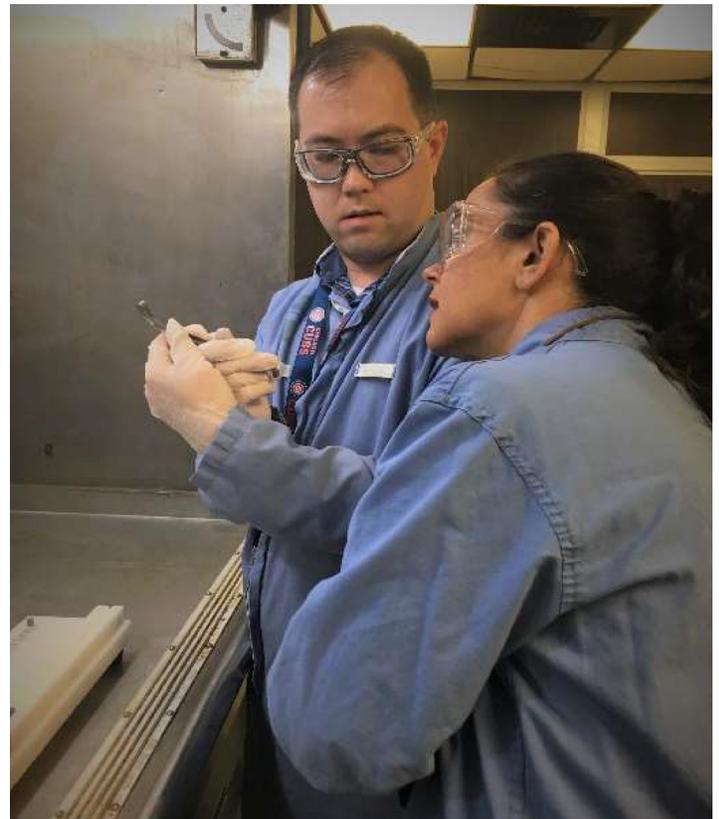
Image taken from panel discussion on Accelerated Fuel Qualification (AFQ), as part of Atomic Wings Lunch and Learn Series. Left to right: Kallie Metzger (Westinghouse), Chris Stanek, (Los Alamos National Laboratory) Adam DeMella (Professional Staff Senate Appropriations Committee), Ron Faibish, (General Atomics), U.S. Representative Chuck Fleischmann (House Appropriations Committee), Andy Griffith (DOE-NE), Michelle Harstine (DOE), and John Monninger (NRC).

Westinghouse fuels benefits from a number of collaborations with universities and national laboratories via the DOE Accident Tolerant Fuel Program. In December of 2018, Idaho National Laboratory (INL) announced U_3Si_2 pellets had been manufactured in the lab, noting “The new pellets use a mixture of uranium and silicon instead of uranium and oxygen, to achieve a higher density of uranium atoms per pellet – leading to longer operation times, increased power outputs and higher burnups.”

Today Kallie plays a key role on the Westinghouse team advancing fuels, including leading the uranium nitride development and testing. “We’re among the first to look at the uranium nitride potential for LWRs. We’re asking, ‘How will it perform in a reactor?’” Working with our collaborators, we are able to make slight changes to the fuel microstructure and composition with the end goal of improving uranium nitride performance and behavior. Such advancements ensure that the fuel remains suitable and compatible with its environment during both normal operation and off-normal events.”



Bubble Chamber II (oil on canvas): Based on particle traces produced in CERN’s first liquid hydrogen bubble chamber. Painted by Kathryn Metzger and included in her undergraduate thesis.



Left to right: Jeff Leong and Kallie Metzger (Westinghouse). Westinghouse and its partners have developed EnCore® Fuel as part of the U.S. Department of Energy’s (DOE) Accident Tolerant Fuel Program. The Westinghouse-Exelon EnCore® Fuel Lead Test Rod (LTR) Program marked the first insertion of EnCore® Fuel rod assemblies into a commercial nuclear power plant. These two lead test assemblies contain chromium-coated zirconium cladding for enhanced oxidation and corrosion resistance, higher density ADOPT™ pellets for improved fuel economics, and uranium silicide pellets. Photograph shows inspection of U_3Si_2 pellets prior to loading in segmented rod. Photo courtesy of Westinghouse Electric Company, LLC.

Finding suitability and compatibility is at the core of science and engineering, in nuclear power and myriad other fields. Viewing things from an atypical perspective is an inborn trait for Metzger.

"I admit I approach problems abstractly," she said. "I'm ok asking the weird questions and thinking outside the box."

Kallie is a strong believer in the benefit of non-traditional approaches. One might not think to put experimentalists and modelers in a room and get them talking but it makes natural sense to her. She is a strong champion of integrated

experiments and modeling-simulation. "When we use a continuous loop of modeling-informed experimentation, we accelerate our material development and commercialization timelines. This process, referred to as Accelerated Fuel Qualification (AFQ), aims to reduce lengthy fuel development and licensing timelines."

One might conclude that her jam-packed schedule today would preclude Metzger from creating new art, but that's not the case. "I still paint," she said. "Just smaller and usually watercolor. These allow me to complete a small doodle in an afternoon."



Kallie Metzger, PhD (Advanced Fuels Development Lead, Accident Tolerant Fuels, Westinghouse), and Chris Stanek, PhD (Joint Modeling and Simulation Program National Technical Directory, Los Alamos National Laboratory). Photo taken during Atomic Wings Lunch and Learn Series on 'Accelerating Qualification of New Nuclear Fuel'. Stanek and Metzger were panelists supporting the combined use of advanced experimental techniques and modeling and simulation.

DOE-NE's Integrated University Program Student Series

This profile of Dr. Kathryn Metzger is one in a series of stories highlighting recipients of support from the Department of Energy, Office of Nuclear Energy (DOE-NE). In 2009 DOE-NE established the Nuclear Energy University Program (NEUP), which funds nuclear energy research and equipment upgrades at U.S. colleges and universities and provides educational support to students. In addition to NEUP, DOE-NE administers the Integrated University Program (IUP), which works to attract qualified nuclear science and engineering (NS&E) students to nuclear energy professions. Through IUP and NEUP, DOE-NE has supported hundreds of undergraduate and graduate level students in obtaining science, technology, engineering, or math (STEM) degrees.

"The IUP Scholarship and Fellowship program of the DOE Office of Nuclear Energy has been attracting the top students in the U.S. into the nuclear energy field since 2009. It has been the most successful and largest program of its kind, ever. Many former students have attained leadership positions in the academic, industry, and government realms of nuclear energy." - NEUP Program Director, Dr. John Gilligan



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