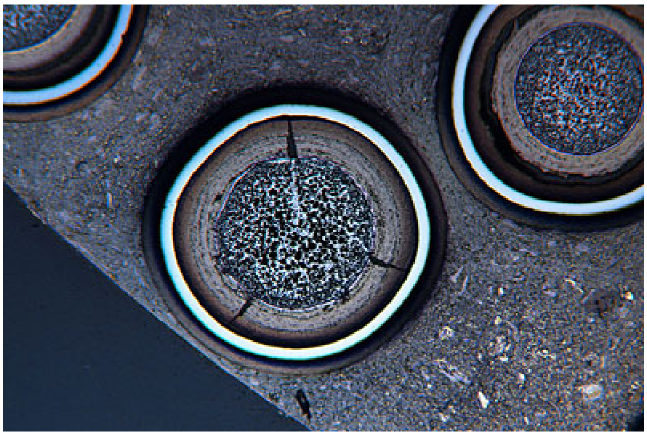


INL leads research efforts to test advanced TRISO nuclear fuel, which has several layers of carbon and carbide that serve as the primary containment for radioactive material.

Idaho scientists discover clue in the case of the missing silver

By Shannon Palus *for INL Communications & Governmental Affairs*

Some come to Idaho to travel the highways that lead to the Tetons, to Yellowstone, to small towns and big adventures. Idaho National Laboratory researcher Isabella van Rooyen came, all the way from South Africa, looking for a piece of silver 500,000 times smaller than a poppy seed.

Researchers Isabella Van Rooyen, Tom Lillo, and Yaqiao Wu working in the Materials and Characterization Suite in the Center for Advanced Energy Studies at INL.

The silver was somewhere inside irradiated tristructural-isotopic (TRISO) fuel particles — a safer, more efficient, next-generation nuclear fuel — the "poppy seed" in question. Break a TRISO fuel particle open and it looks like a jaw breaker on the inside. An outer shell of carbon coats a layer of silicon carbide, which coats the uranium center where the energy-releasing fission happens. These layers are meant to contain the radioactive products of fission, which includes little bits of silver. Containment of the radioactive material is built right into the fuel itself.

But it doesn't always work perfectly. Occasionally, in just one or two out of 100 particles, silver escapes the center. It moves around the particle, and potentially gets out. Since the 1970s, scientists have been wondering exactly how this happens.

"I find it absolutely fascinating," said Van Rooyen. She has been studying the TRISO-silver problem since 2006. "I have a natural tendency to know what is going on [inside the fuel]."

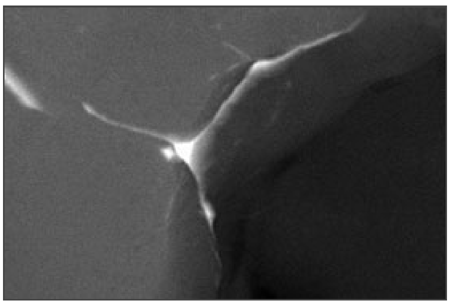
And it does take a sixth science-minded sense: The silver seems to jump the silicon carbide layer as though by magic. There is no obvious point of exit, or forcible silver-shaped hole, to be found. The transport mechanism that brings it from the inside out is a mystery that spans decades. It is a wrinkle in the plan to make TRISO the most efficient, and potentially the safest, fuel of the future.

In South Africa, Van Rooyen worked on a number of hypotheses for the TRISO problem. For example, did it piggyback out of the TRISO fuel particle attached to another element? Were there almost-too-tiny-to-see nanotubes forming in the silicon carbide layer?

One possibility seemed most probable to Van Rooyen. But to test it, to even begin to see if it was correct, she needed to be able to get a closer look. And she needed irradiated TRISO fuel.

Roads less traveled

There are roads in Idaho that will take you on long trips to lakes and mountains. But it was a different type of road that Van Rooyen came here to travel. Nanoroads describe the networks where each layer of the TRISO particle meets the next and where the grains that make up the layers themselves align with each other. These are the roads that Van Rooyen came to travel.



The bright white triangle is where researchers spotted silver fission

Could the nanoroads be the silver precipitate's path out of the TRISO fuel particle? They do offer a path of lesser resistance, a point of potential weakness in the silicon carbide. The first step would be to see if silver could be found along these roads.

Van Rooyen's method of investigation was a Scanning Transmission Electron Microscope operated by Yaqio Wu, a Boise State University research associate professor and instrument lead of the Materials and Characterization Suite at the Center for Advanced Energy Studies. Somewhere along one of the nanoroad grain boundaries, Van Rooyen and Wu, along with materials engineer Tom Lillo, might be able to spot the silver precipitate.

"We were really like private investigators," Van Rooyen said. The silver's presence on the nanoroads — if that's where it was — would be a lynchpin clue in the mystery.

products congregating in a TRISO fuel particle.

After a year of patience and administrative work, she finally got her hands on actual, irradiated samples.

Eureka moment

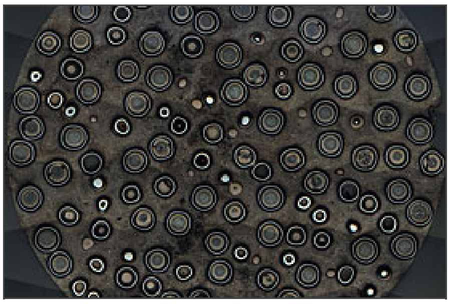
At a research briefing on the morning the team received the samples, they discussed the fact that they were looking for a needle in a haystack. For one, the bits of silver were so small. And not all TRISO particles emit silver. Would there even be silver in the specific sample they were looking at?

But what came that afternoon was one of the rare eureka moments — a discovery that seems to come into existence in an instant.

After years of exploring and discarding various hypotheses about the location of the silver, Van Rooyen and her team placed the irradiated TRISO particle under the electron microscope. This would be the closest, most careful look at the nanoroads in irradiated TRISO ever.

On that very afternoon, microscope operator Wu zoomed in and they found the silver precipitate. It was wedged at the intersection of two layers of TRISO coating, at the nanoroads between grains.

It was "an absolute wow moment," said Van Rooyen. "We made such a commotion that people from other labs were coming to have a look."



This cross-section of a TRISO fuel pellet shows TRISO fuel particles at the 10 mm scale.

The journey is far from over. Next, Van Rooyen and her team will observe the silver to see how far it moves through the silicon carbide and try to determine exactly how it is able to get out. Time and hard work will tell if the nanoroads hypothesis is correct.

For Van Rooyen, the search for the silver is just the beginning. This new section of the problem is the next adventure. "This is where the fun starts," she said.

In addition to her colleagues Lillo and Wu, Van Rooyen would like to acknowledge Jim Madden for focused ion beam sample preparation; Jason Harp for isotope calculations; Joanne Taylor (Idaho State University); and Kristi Moser-McIntire (ISU) from CAES for their organization and support in the licensing of the CAES facility, which enabled the team to bring irradiated samples to the microscope.

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Feature Archive