Researching niobium gilding in bid for better beams

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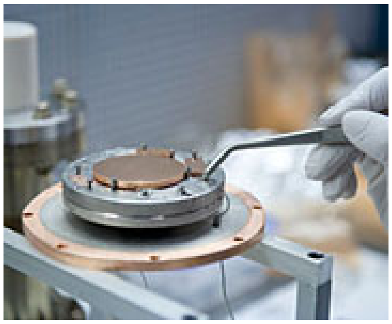

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For thousands of years, craftsmen have applied gilding, a thin layer of gold, to objects to enhance their value. Now, researchers at DOE's Jefferson Lab are using this same idea to enhance materials for accelerator science.

As the number of uses for accelerators grows, scientists are faced with the challenge of building low-cost accelerators that offer high performance. And to meet that challenge, scientists at Jefferson Lab are combining a bit of the old with the new.

Jefferson Lab SRF Institute Research Scientist Anne-Marie Valente and her colleagues are exploring the application of a thin film of niobium to other materials, such as copper, to make better accelerator components.

"We want to replace, in certain projects, the bulk niobium with niobium on copper. The niobium on copper has potential advantages over bulk niobium," she explains.

Jefferson Lab's Continuous Electron Beam Accelerator Facility accelerator depends on niobium, a rare metal, for more than 300 critical components. But during recent research and development efforts, JLab scientists reached the theoretical limit of niobium's performance, and it's still far short of what's needed for many proposed accelerator-based applications. In addition, niobium components are expensive, with individual units in CEBAF costing upwards of $30,000 each.

Anne-Marie Valente, an SRF Institute research scientist, and her colleagues are using a technique called energetic condensation by electron cyclotron resonance to produce and apply thin films of niobium to copper, aluminum and other test metals in the ECR Plasma Deposition Lab.

Early linear accelerators used accelerating components made of copper. The metal was a good conductor of the energy, but copper accelerators have their limits. They are capable of handling continuously high fields to accelerate particles but can only be used for short periods without overheating.

To get beyond these limitations, accelerator scientists turned to niobium. When chilled to near absolute zero, niobium becomes superconducting, losing its resistance to the flow of energy through it. This allows niobium accelerators to continuously accelerate particles at greater energies without overheating.

However, niobium also has its limits. It is susceptible to developing "hot spots" on its surface when pushed to higher efficiencies. These hot spots are the result of impurities embedded in the niobium or defects on the component surface.

"Because of the thermal properties of the niobium, you are not going to dissipate that energy, and you end up getting thermal breakdown," Valente explains. "With copper, you have a better chance of dissipating that energy, and that local heating is not going to be as critical or it's going to allow you to go further before you get to breakdown."

Other laboratories have explored thin-film niobium on copper and other materials as an alternative to pure niobium components.

"In some projects already, the niobium on copper has already been a good competitor to bulk niobium," Valente says.

In the 1990s, for instance, accelerator scientists used a technique called sputtering to apply a thin film of niobium to copper accelerator components for the Large Electron-Positron Collider at CERN in Europe.

The components exhibited many of the positive characteristics of bulk niobium components and were used at single-digit temperatures. But the thin-film-niobium-copper components in LEP did not reach the greater efficiencies needed for future accelerators.

"The sputtering technique used for LEP generated a lot of defects in the film, and these can affect performance when you try to reach higher fields," Valente explains.

LEP did demonstrate that thin-film-niobium-copper components can offer many of the benefits that bulk niobium components have over those made of copper. Valente aims to build on that work to optimize thin-film-niobium-copper component technology.

Valente and her colleagues are using a technique called energetic condensation by electron cyclotron resonance to produce and apply thin films of niobium to copper, aluminum and other test metals in JLab's ECR Plasma Deposition Lab. In this technique, bulk niobium pellets are vaporized, and a cloud of electrons whipped into cycloidal motion by the effect of powerful magnets associated with an electrical field is used to ionize the niobium vapor. The niobium ions are than deposited on a copper sample. Altering the plasma or the energy of the niobium ions arriving on the sample affects the thickness and other properties of the thin film.

Once the copper has been coated with niobium, the sample is analyzed. Analyses conducted on the sample, including Electron Backscatter Diffraction, X-ray diffraction, Transmission Electron Microscopy and Auger Electron Spectroscopy, are used to characterize the structure and surface of the film. Then, the samples are subjected to tests that predict their ability to accelerate particles. This is important should the samples be reproduced as accelerator components called cavities.

"That's one of the things that we're trying to work on: producing films that we can apply to the surface of a cavity," Valente explains. "The objective is not just to create good films, but to optimize the SRF performance of the films."

Once she and her colleagues have several good thin-film recipes for cavities, they aim to move beyond sample production to producing full cavities to test their performance in Jefferson Lab's cavity production facilities.

Valente and her colleagues are also testing the feasibility of multiple layers of different films to enhance performance. By layering, they hope to get better performance out of accelerator components, while operating them at higher temperatures than the current limit of single-digit temperatures above absolute zero.

"You have a superconductor over an insulator over a superconductor. You're basically getting the qualities of the higher operating temperature material to enhance the performance of the niobium," Valente says.

She says that while using less niobium in cavity production offers savings during construction of new accelerators, reducing the amount of refrigeration needed to run those accelerators can drastically reduce the ongoing operation costs over the lifetime of a machine.

"If you operate at liquid helium temperatures, you wouldn't need such an expensive refrigerating system." Valente confirms.

In the meantime, Valente and her colleagues are busy in the lab, pushing the boundaries of the science behind these ideas for producing ever more efficient, cheaper accelerators for a wide range of beneficial applications.

Provided by Jefferson Lab

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