First ever niobium single crystal single cell accelerating cavity

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Jefferson Lab's Institute for Superconducting Radiofrequency Science & Technology has, for the first time, successfully fabricated and tested a single cell accelerating cavity made from a single crystal of niobium. Preliminary tests reveal this new fabrication process could simplify manufacturing and reduce cost and assembly time of future accelerator cavities, while delivering a product with high quality performance.

Many particle accelerators require accelerating cavities made of niobium operating at temperatures between -271 and -269 degrees centigrade, when niobium becomes superconducting with close to zero electrical resistance. Jefferson Lab's accelerator uses superconducting niobium cavities to accelerate electrons to energies approaching six billion electron-volts for nuclear physics experiments in its three experimental halls. These cavities were fabricated from sheets of fine-grain niobium that were forged and rolled from a niobium ingot. In addition to the benefits, this fabrication process poses some disadvantages.

"Intermediate annealing steps are necessary to remove stresses in the material and re-crystallize it. These manufacturing steps have the inherent risk of introducing unwanted impurities in the material," says Peter Kneisel, senior staff scientist on the project. But these steps are required to yield a high-quality cavity from fine-grain niobium metal.

Recently, a Jefferson Lab team, led by senior scientists Peter Kneisel and Ganapati Myneni, procured regular ingots of large-grain and single crystal niobium through an industrial partnership with Tadeu Carneiro, spokesperson and manager of Reference Metals. The team fabricated four niobium single cell cavities from the ingots. Like salt crystals, niobium crystals, or grains, can be grown in either larger or smaller sizes, so large-grain niobium consists of larger niobium crystals. Large-grain niobium sheets were obtained by simply slicing them off an ingot.

"It's just like slicing up a sausage," Kneisel says. The team used some of these slices to manufacture a single cell cavity in the same shape as the low-loss design proposed as an improvement to the baseline for the International Linear Collider (ILC). The cavity, though a scaled-down version of what the ILC would require, was made out of a single crystal of niobium.

"So the only difference between what we are doing now and typically what everybody else does, is that we have a different kind of material -- not fine-grain material, but large-grain or single crystal material," Kneisel explains.

In preliminary tests conducted at -271 degrees centigrade, the cavity's accelerating gradient (its ability to transfer energy into particles per unit of cavity length) exceeded the ILC specification of 28 MV/m and eventual goal of 35 MV/m. After a brief, low-temperature bake, the cavity achieved an accelerating gradient of 45 MV/m, equal to Cornell's current world record of 46 MV/m, when measurement uncertainty is taken into account.

This new fabrication process, which eliminates the rolling procedure and related steps, could simplify the manufacturing process while reducing cost and assembly time. For instance, it's estimated that the new procedure could cut the cost of producing cavities by as much as 35%. The new fabrication process also provides cavities with smoother interior surfaces after only chemical surface treatment, better mechanical performance and less time-consuming quality assurance procedures.

The Jefferson Lab team fabricated two of the single cell cavities in Jefferson Lab's own 12 GeV Upgrade design from large-grain niobium. Two more single cell cavities were built from single niobium crystals, one in the ILC design and the other in the 12 GeV design. Kneisel says all the cavities performed well in early tests. Kneisel presented these results in a poster session of the 2005 Particle Accelerator Conference in Knoxville, Tenn., on Tuesday, May 17.

The team who built the cavities and conducted the tests includes: Peter Kneisel, Ganapati Myneni, Gianluigi Ciovati, Jacek Sekutowicz (DESY), Larry Turlington, Robert Manus, Gary Slack, Steve Manning and Pete Kushnick. This work was performed under the auspices of the Institute of Superconducting Radio Frequency Science and Technology, headed by Warren Funk, in Jefferson Lab's Accelerator Division under Associate Director Swapan Chattopadhyay.

Source: Thomas Jefferson National Accelerator Facility

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