The pseudogap persists as material superconducts

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For nearly a century, scientists have been trying to unravel the many mysteries of superconductivity, where materials conduct electricity with zero resistance.

Among the many questions: the existence of the pseudogap, a phase that up until now was found in materials as they were cooled to temperatures above the superconducting temperature - the phase where materials superconduct.

An international research team led by Boston College Physicist Vidya Madhavan reports the pseudogap doesn't give way to superconductivity, but persists and co-exists - possibly even competes - with it, they report in the journal *Physical Review Letters*.

"There is a need to understand the connection between superconductivity and the pseudogap," says Madhavan, an assistant professor of physics. "Is the pseudogap helpful or hurtful? Does it compliment superconductivity or does it compete with it? These are the questions researchers have been asking."

The pseudogap has been closely associated with superconductivity, the point where typically un-joinable electrons match up in perfect pairs; and has been documented to exist at temperatures just above those that give rise to superconductivity. What happens after temperatures drop further and electricity conducts without resistance has been a mystery.

A more in-depth understanding of the pseudogap could explain why some materials superconduct better than others at high temperatures - temperatures above absolute zero, or zero degrees Kelvin, according to researchers. The question has been whether this gap was a precursor to or a competitor with superconductivity.

Madhavan and her colleagues combined two investigative techniques that are typically used independently. Scanning tunneling microscopy - or STM - allows researchers to make images and study the electronic properties of materials at the scale of single atoms. Angle-resolved photoemission spectroscopy - or ARPES - also allows for the study of particles, but in relation to their momentum.

The dual profiles these techniques created of a ceramic high-temperature superconductor known as Bi 2201, a copper oxide, documented that the pseudogap doesn't just precede superconductivity. It continues to co-exist once the material superconducts.

"Researchers have thought that the pseudogap disappeared," said Madhavan, who collaborated with researchers at Tohoku University, in Japan, and the Institute of Physics and National Laboratory for Condensed Matter Physics in Beijing, China. "But both STM and ARPES show us (the pseudogap) in the superconductor state. It co-exists along with superconductivity and we think it is competing with superconductivity,"

The notion of competition implies that the pseudogap's mere presence draws electrons away from the superconductor gap. The exact nature of these competing states poses the next challenge for researchers.

"That we've shown the pseudogap co-exists raises a number of questions," said Madhavan. "If we didn't have the pseudogap, maybe the temperature at which materials superconduct could be higher?"

Finding materials that superconduct at higher temperatures could bring the promise of superconductivity that much closer to practical applications now prohibited by the high cost of super-cooling materials in a lab.

Source: Boston College