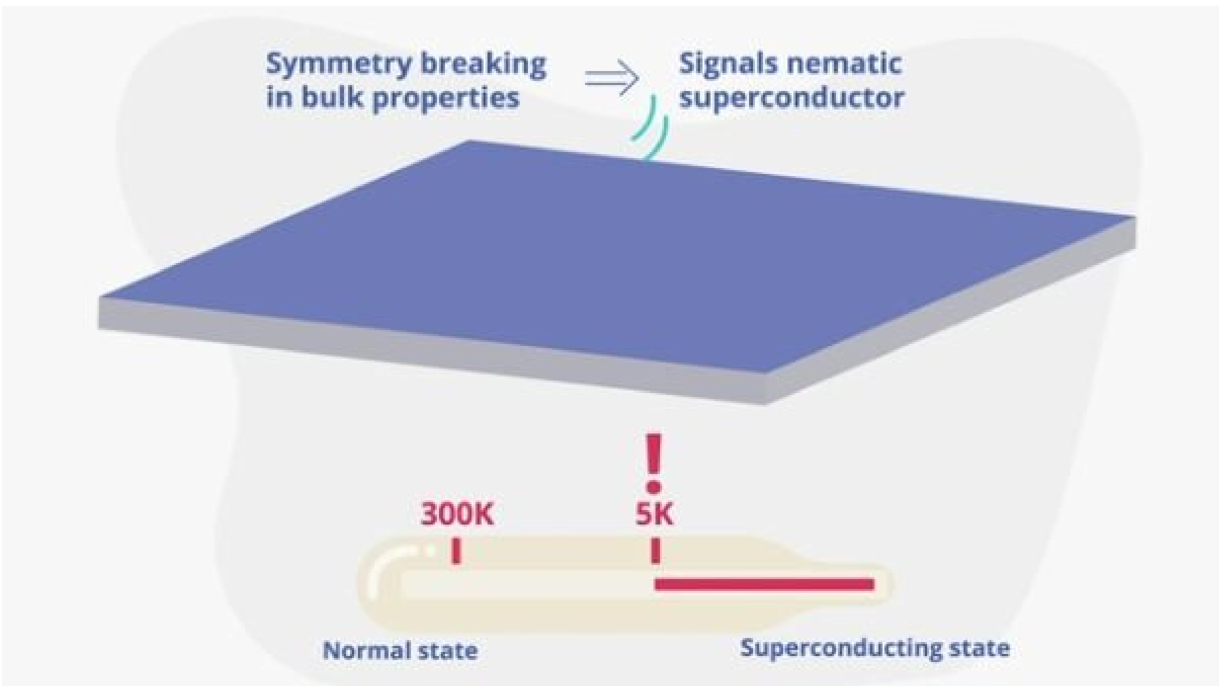
Unexpected properties uncovered in recently discovered superconductor

April 15 2019



Researchers from Tokyo Metropolitan University have found that crystals of a recently discovered superconducting material, a layered bismuth chalcogenide with a four-fold symmetric structure, shows only two-fold symmetry in its superconductivity. The origin of superconductivity in these structures is not yet well understood; this finding suggests a connection with an enigmatic class of materials known as nematic superconductors and the extraordinary mechanisms by which superconductivity can emerge at easier-to-reach temperatures.

Superconductors are materials with zero electrical resistance. They have already seen numerous applications to powerful electromagnets, particularly in medical magnetic resonance imaging (MRI) units, where they are used to generate the strong magnetic fields required for high resolution non-invasive imaging. However, significant barriers exist which prevent more widespread usage e.g. for power transmission over long distances. The most notable is that conventional superconductivity only arises at extremely low temperatures. The first "high-temperature" superconductors were only found in the latter half of the 1980s, and the mechanisms behind how they work are still hotly debated.

In 2012, Prof Yoshikazu Mizuguchi of Tokyo Metropolitan University succeeded in engineering layered bismuth chalcogenide materials with alternating insulating and superconducting layers for the first time. (Chalcogenides are materials containing elements from group 16 of the periodic table.) Now, the same team have taken measurements on single crystals of the material and found that the rotational symmetry characteristics of the crystalline structure are not replicated in how the superconductivity changes with orientation.

The material the group studied consisted of superconducting layers made of bismuth, sulfur and selenium, and insulating layers made of lanthanum, fluorine and oxygen. Importantly, the chalcogenide layers had four-fold rotational (or tetragonal) symmetry i.e. the same when rotated by 90 degrees. However, when the team measured the magnetoresistance of the material at different orientations, they only found two-fold symmetry i.e. the same when rotated by 180 degrees. Further analyses at different temperatures did not suggest any changes to the structure; they concluded that this breakage of symmetry must arise from the arrangement of the electrons in the layer.

The concept of nematic phases comes from liquid crystals, in which disordered, amorphous arrays of rod-like particles can point in the same direction, breaking rotational symmetry while remaining randomly distributed over space. Very recently, it has been hypothesized that something similar in the electronic structure of materials, electronic nematicity, may be behind the emergence of superconductivity in high temperature superconductors. This finding clearly links this highly customizable system to high temperature superconductors like copper and iron-based materials. The team hope that further investigation will reveal critical insights into how otherwise widely different materials give rise to similar behavior, and how they work.

More information: Kazuhisa Hoshi et al, Two-Fold-Symmetric Magnetoresistance in Single Crystals of Tetragonal $BiCh_2$-Based Superconductor LaO0.5F0.5BiSSe, *Journal of the Physical Society of Japan* (2019). DOI: 10.7566/JPSJ.88.033704

Provided by Tokyo Metropolitan University