

Research predicts the high-temperature topological superconductivity of twisted double-layer copper oxides

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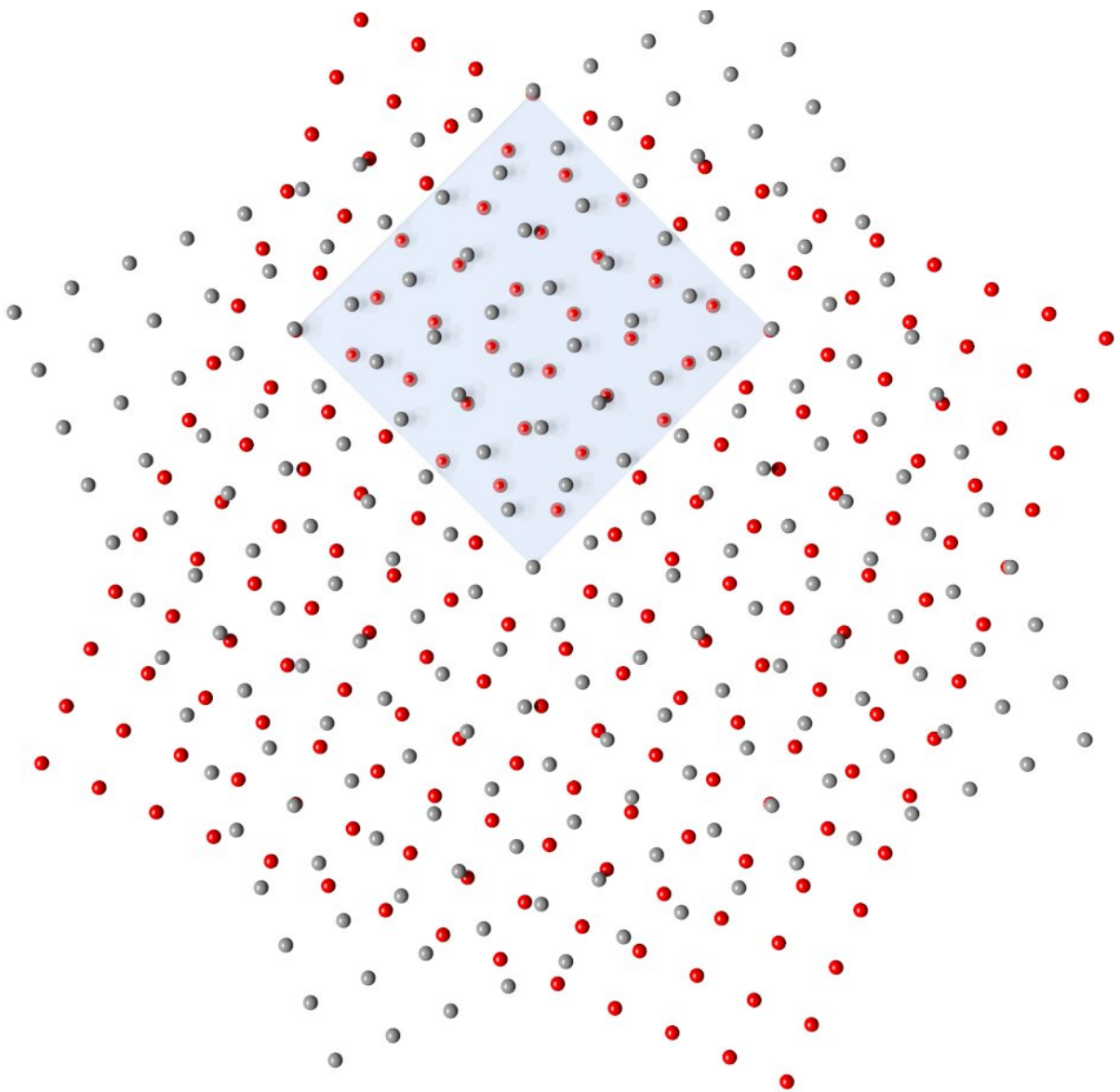


Illustration of a moire pattern obtained by superimposing two square lattices with a twist. For certain 'commensurate' angles, the resulting structure is periodic and can be generated by assembling shaded square regions next to one another like floor tiles. Credit: Can et al.

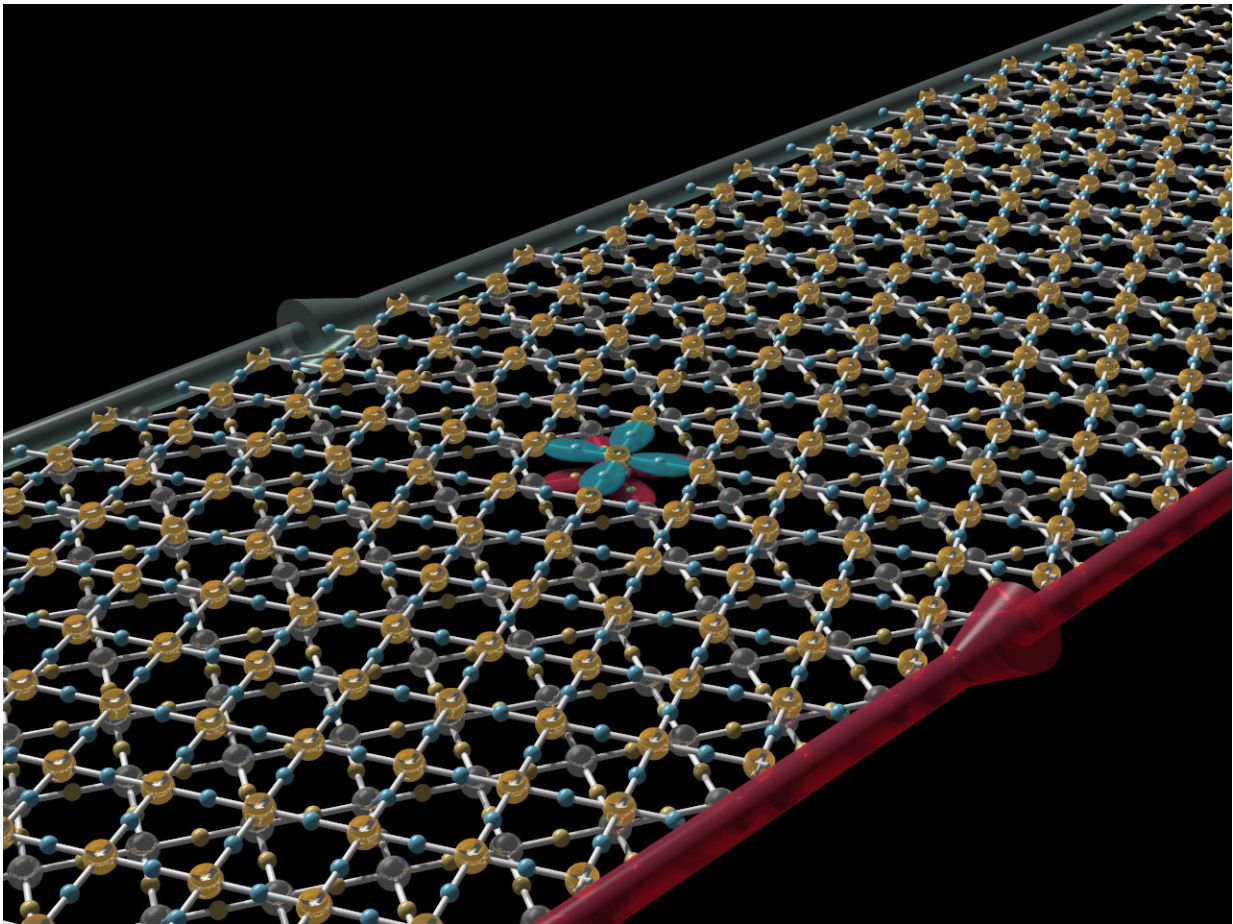
Two-dimensional (2D) materials, such as graphene or transition metal dichalcogenides, can sometimes be assembled into bilayers with a twist between individual layers. In recent years, many researchers have been investigating the properties of these twisted double-layer structures and their potential advantages for fabricating electronic devices.

A research group at the University of British Columbia in Vancouver recently carried out a study exploring the properties of twisted double-layer copper oxides. In their paper, published in *Nature Physics*, they predict that structures composed of two monolayer-thin d-wave [superconductors](#) will exhibit high-temperature topological superconductivity.

"Twisted [bilayer graphene](#) has been a big research topic over the past couple of years, and we were thinking about other 2D materials where twist-angle engineering could be applied," Marcel Franz, one of the researchers who carried out the study, told Phys.org. "The goal of our work, however, was to uncover some new physics, not just repeat what others have done in the context of graphene. After several false starts, we zeroed in on cuprate superconductors, which share some similarities with graphene, such as 2D basic structure and low-energy Dirac excitations, but are also in many aspects very different materials."

The most notable difference between graphene and cuprate-based superconductors is that they conduct electricity with no resistance at high

temperatures. This characteristic could make them arguably more suitable for fabricating [topological superconductors](#).



Simplified crystal structure of twisted Bi₂Sr₂CaCu₂O_{8+δ} bilyer. One important manifestation of topological superconductivity is the presence of topologically protected ‘edge modes’, represented as red and green arrows, that are present in any geometry with edges. Credit: Can et al.

In their study, Franz and his colleagues specifically focused on single monolayer cuprate materials, such as Bi₂Sr₂CaCu₂O_{8+δ}, which is known to be a so-called d-wave superconductor. This essentially means that its

order parameter changes sign upon a 90-degree rotation, just like a d orbital in chemistry.

"It is this superconducting property of cuprate, established more than 20 years ago, that underpins the emergence of topological superconductivity in a bilayer of such a material when assembled with a twist," Franz said. "We constructed simple mathematical models describing this situation and they show unambiguous evidence for robust topological phase when the twist angle is close to 45 degrees."

Topological superconductors are extremely rare, and researchers have so far only identified a handful of materials that could be classified as such. Moreover, most of the topological superconductor candidates identified so far only reach the topological state at very low temperatures (i.e., below 1 degree Kelvin).

Franz and his colleagues modeled twisted $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+\delta}$ bi-layer materials and found that it could reach the topological phase at temperatures as high as 80 Kelvin. The fact that it might enter this phase at higher temperatures could have notable advantages, as it could open up new possibilities for studying topological superconductivity, potentially enabling the development of the first true high-temperature topological superconductors.

"Several labs around the world, including researchers at my own Stewart Blusson Quantum Matter Institute, are currently preparing samples of twisted high temperature cuprates and are gearing up to be able to probe for signatures of the elusive topological phase," Franz said. "My group is engaged in a significant effort aimed at providing theoretical support to these experiments and it turns out that although the topological state should be robustly present in these samples, its signatures can be quite subtle. Through theoretical modeling, we are now working to predict characteristic behaviors of various experimentally measurable

quantities."

More information: High-temperature topological superconductivity in twisted double-layer copper oxides. *Nature Physics*(2021). [DOI: 10.1038/s41567-020-01142-7](https://doi.org/10.1038/s41567-020-01142-7).

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