Twisted cuprate van der Waals heterostructures with controlled Josephson coupling

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Twisted van der Waals heterostructures comprising high temperature cuprate superconductors offer a unique platform for engineering the efficient Josephson coupling between cuprate crystals harboring nodal superconducting order parameter. Preparing Josephson junctions with an atomically sharp twisted interface between cuprate crystals is however extremely challenging, and special attention during the fabrication must be given to the role of the oxygen and lattice reconstructions.
Our work addresses properties of the interface superconductivity and Josephson coupling in twisted interfaces between stacked cuprate $Bi_2Sr_2CuCa_2O_{8+d}$ crystals. We realize these Josephson junctions using the recently established cryogenic dry transfer technique, and we additionally encapsulate the interfaces with a protecting insulating layer to eliminate effects of disorder during the fabrication process. We demonstrate in these heterostructures a strong twisting angle and temperature dependence of the Josephson critical current compatible with the d-wave symmetry of the superconducting order parameter. We find that the critical current has its maximum value comparable to that of the bulk intrinsic junctions at small twisting angles, and that it reduced by almost by two orders of magnitudes at twisting angles close to 45 degrees, due to the mismatch between the superconducting d-wave order parameters that suppresses direct Cooper pairs tunneling.

Figures

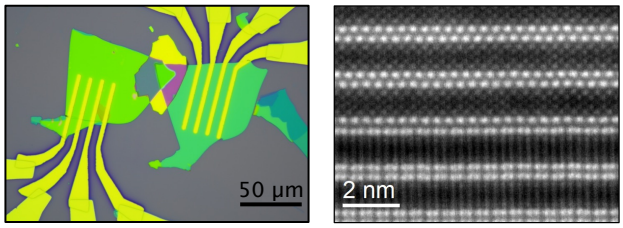

Figure 1: Left) Optical micrograph of a representative device. Right) TEM image displaying the cross section of a twisted junction

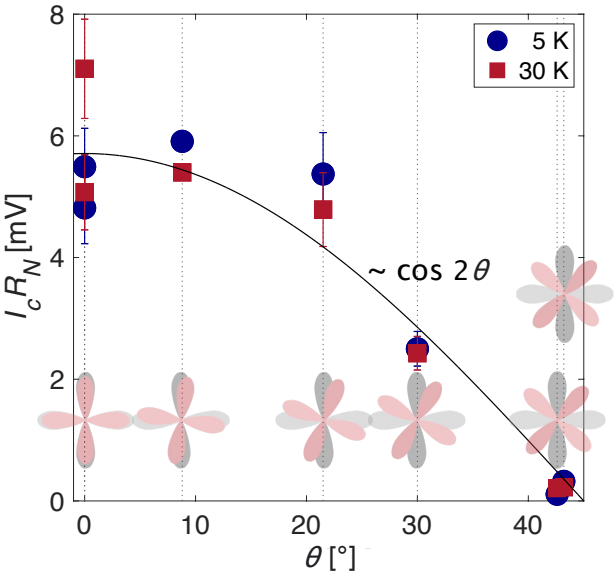

Figure 2: Josephson coupling (critical current times normal resistance) versus twist angle

References

[1] Y. Lee, M. Martini, *etal,* Adv. Mater, 2209135 (2023)
[2] M. Martini, Y. Lee, *etal,* under review Mat. Today