Cuprate Twistronics for a New Generation of Macroscopic Quantum Hardwares

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Recent technological advancements have enabled the preservation of near-perfect superconductivity and lattice structure in isolated, atomically thin $Bi_2Sr_2CuCa_2O_{8+\delta}$ (Bi-2212) crystals, facilitating the development of Bi-2212-based junctions [1,2]. These advancements focus on controlling the diffusion of oxygen interstitials, a key factor causing disorder in Bi-2212 cuprates. While intrinsic local lattice distortions in pristine cuprates [3] may contribute minimally without affecting the d-wave nature of the dominant order parameter, lattice distortions due to oxygen interstitials diffusion above 200 K [4,5] are detrimental. To counter this, a cryogenic stacking protocol has been developed, freezing oxygen interstitial motion at temperatures well below 200 K and rapidly establishing the interface in an ultra-low moisture environment [6-8]. This method has led to the creation of artificial intrinsic Josephson junctions, which show a strong dependence of Josephson energy on the twist angle, exhibiting unique properties at a 45° twist [6-8]. Notably, these junctions display fractional Shapiro steps and Fraunhofer patterns, indicating two degenerate Josephson ground states with time-reversal symmetry (TRS). The ability to control the junction current bias sequence to selectively break TRS allows the junction to enter either ground state. This discovery has prompted the proposal of a novel capacitively shunted qubit, termed 'flowermon,' characterized by its d-wave order parameter that offers inherent protection against charge-noise-induced relaxation and quasiparticle-induced dissipation [9]. The flowermon signifies a step towards high-coherence, hybrid superconducting quantum devices using unconventional superconductors. To fabricate complex circuits like those needed for the flowermon, a new technique involving cryogenic dry transfer of printable circuits embedded in a silicon nitride membrane has been developed [10]. This technique separates the circuit fabrication process, which involves chemical and physical stresses, from the creation of thin superconducting structures, thereby providing electrical contacts in a single step and protecting the superconducting surface from environmental damage.

References

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