# Scanning Tunneling Spectroscopy Studies of High-Temperature Cuprate Superconductors

Thesis by

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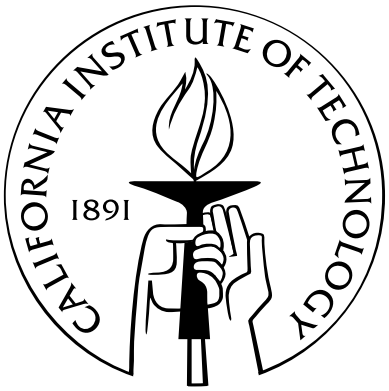


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*To my parents*

*for their unconditional love and support*

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# Abstract

This thesis presents the scanning tunneling spectroscopic studies of the non-universal electronic properties among electron- and hole-doped cuprates. Tunneling spectra of the electron-doped $Sr_{0.9}La_{0.1}CuO_2$ and the hole-doped $YBa_2Cu_3O_{6+\delta}$ reveal distinctly different behavior in the pairing symmetries, pseudogap phenomena, satellite features, and low-energy excitations. While underdoped and optimally doped $YBa_2Cu_3O_{6+\delta}$ exhibits $d$-wave and overdoped Ca-doped $YBa_2Cu_3O_{6+\delta}$ $(d+s)$-wave pairing symmetry, the electron-doped $Sr_{0.9}La_{0.1}CuO_2$ shows fully gapped $s$-wave pairing symmetry. The absence of the satellite features and pseudogap in tunneling spectra of electron-doped cuprates sharply contrasts with their general presence in hole-doped cuprates. Furthermore, the subgap low-energy spectral characteristics of $Sr_{0.9}La_{0.1}CuO_2$ deviate substantially from the mean-field Bardeen-Cooper-Schrieffer theory, while those of $YBa_2Cu_3O_{6+\delta}$ can be fully accounted for by the mean-field generalized Blonder-Tinkham-Klapwijk formalism.

Despite the aforementioned disparities, several experimental results reveal important connections between the two types of cuprates. For instance, the coexistence of the pseudogap and superconducting spectra in hole-doped cuprates and the observations of the current- and field-induced pseudogap in electron-doped cuprates suggest that competing orders, manifested as the pseudogap, coexist with superconductivity in both types of cuprates. In addition, by comparing the tunneling spectra with the high-field vortex dynamics measurements, we find that the quasiparticle spectral characteristics of $Sr_{0.9}La_{0.1}CuO_2$ and $YBa_2Cu_3O_{6+\delta}$ correlate with the degree of field-induced quantum phase fluctuations of the two compounds.

Based on these findings, we propose a simple model of coexisting density waves with superconductivity to unify the apparent non-universal phenomena among cuprate superconductors. By

incorporating quantum phase fluctuations and adopting realistic band structures, numerical simulations of the quasiparticle tunneling spectra demonstrate excess subgap low-energy excitations, which is consistent with the empirical observations in $Sr_{0.9}La_{0.1}CuO_2$. Furthermore, by tuning the ratio of the density waves to superconductivity, the theoretical calculations reproduce the absence of pseudogap phenomena in electron-doped cuprates and the general presence of he pseudogap in hole-doped cuprates. Thereby, we conclude that the competing orders that coexist with superconductivity in cuprate superconductors contribute to the rich cuprate phenomenology.

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