Abstract: The pairing of electrons underlies the formation of a superconducting state with zero electrical resistance. After more than twenty years of work, the mechanism of pairing and the temperature at which Cooper pairs first form in high-temperature copper-oxide superconductors are still hotly debated. Do pairs form at the critical temperature like conventional superconductors? Is pairing mediated by a bosonic excitation, as in conventional BCS superconductors, or is pairing with d-wave symmetry an unavoidable consequence of strong Coulomb repulsion in these compounds? In search of experimental answers to these important questions, we have develop several new techniques, based on the scanning tunneling microscope (STM), to visualize the process of pair formation on the atomic scale [1] and to probe what controls the strength of pairing in these compounds with high precision.[2] In general the techniques we have developed, such as the ability to perform spectroscopy at a specific atomic site while varying temperature (from 4K up to over 100K), provide unique opportunities to examine phase transition phenomena in a heterogeneous material system.

In this talk, I will describe how these new experiments are providing evidence that pairing in these exotic superconductors occur above the bulk transition temperature and in nanoscale regions with sizes of 1-3nm. The high-temperature nucleation and proliferation of these nanoscale puddles have a strong connection to the temperature-doping phase diagram of these superconductors. Moreover, these variations of the pairing strength within the puddles can be examined to find microscopic clues of the mechanism of pairing. Specifically, we have found evidence that suggests that strong electronic correlation, as oppose coupling of electrons to bosons, is responsible for the pairing mechanism in the cuprates. Surprisingly, we have found that nanoscale measurements of electronic correlations in the normal state (at temperatures as high as twice T_c) can be used to predict the strength their pairing interaction at low temperatures. Overall, these measurements are providing important ways to examine the nanoscale nucleation of superconductivity in these exotic materials and its underlying mechanism.

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References:

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