Correlation between superfluid density and transition temperature in infinite-layer nickelate superconductor $Nd_{1-x}Sr_xNiO_2$

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INTRODUCTION

A strong correlation between zero-temperature superfluid density (ρ_{s0}) and transition temperature (T_c) is considered as a hallmark of unconventional superconductivity. However, their relationship has yet to be unveiled in nickelates due to sample inhomogeneity. Here we perform local susceptometry on an infinite-layer nickelate superconductor $Nd_{0.8}Sr_{0.2}NiO_2$ (NSNO). The sample shows inhomogeneous superfluid density and T_c on micron-scale. The spatial statistics for different scan areas reveal a linear dependence of local T_c on ρ_{s0} for $T_c > 8$ K and a sub-linear one for $T_c < 8$ K. Remarkably, the overall relationship is reminiscent of that reported in overdoped cuprate superconductors, hinting at a close connection between them.

RESULTS

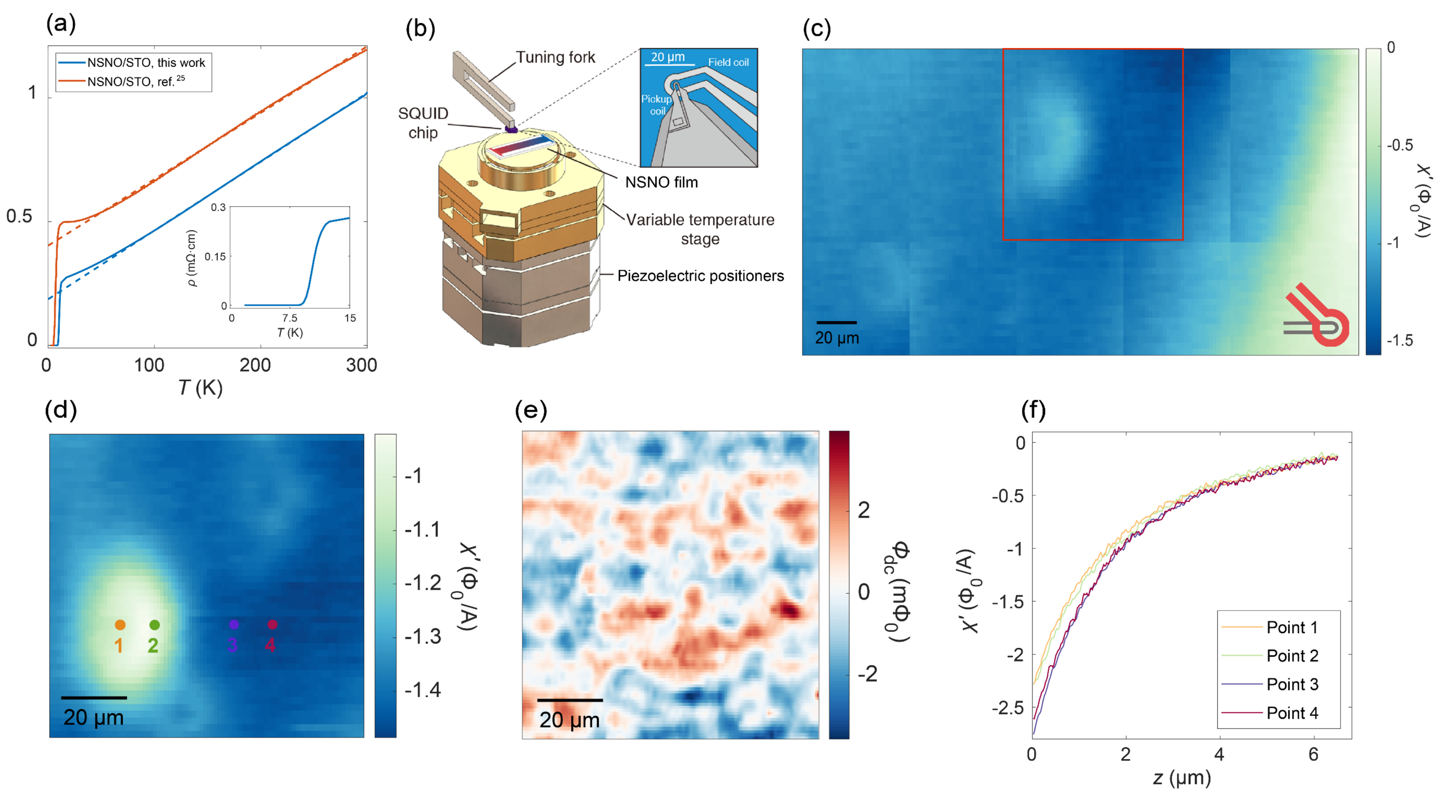

FIG. 1 Characterization of superconducting properties of the $Nd_{0.8}Sr_{0.2}NiO_2$ (NSNO) film. All data are acquired at T_{base} = 5.00 K except specified otherwise. (a) Temperature-dependent resistivities of NSNO films. (b) Illustration of the scanning superconducting quantum interference device (sSQUID) system installed in a 4 K cryostat. (c) In-phase susceptibility imaging of a 280 × 150 μm² region. Negative χ' (blue color) indicates diamagnetism. Multiple weakly diamagnetic rings (WDRs) are visible. The red square depicts the scan area in panel (d) and Fig. 2. The inset shows the configuration and orientation of the pickup loop (gray) and the field coil (red) of the SQUID sensor. (d) In-phase susceptibility imaging of the main WDR in panel (c). Smaller WDRs are visible. (e) DC magnetic flux imaging of the same region as in (d). (f) Susceptibility approach curves $\chi'(z)$ of the selected points marked in panel (d).

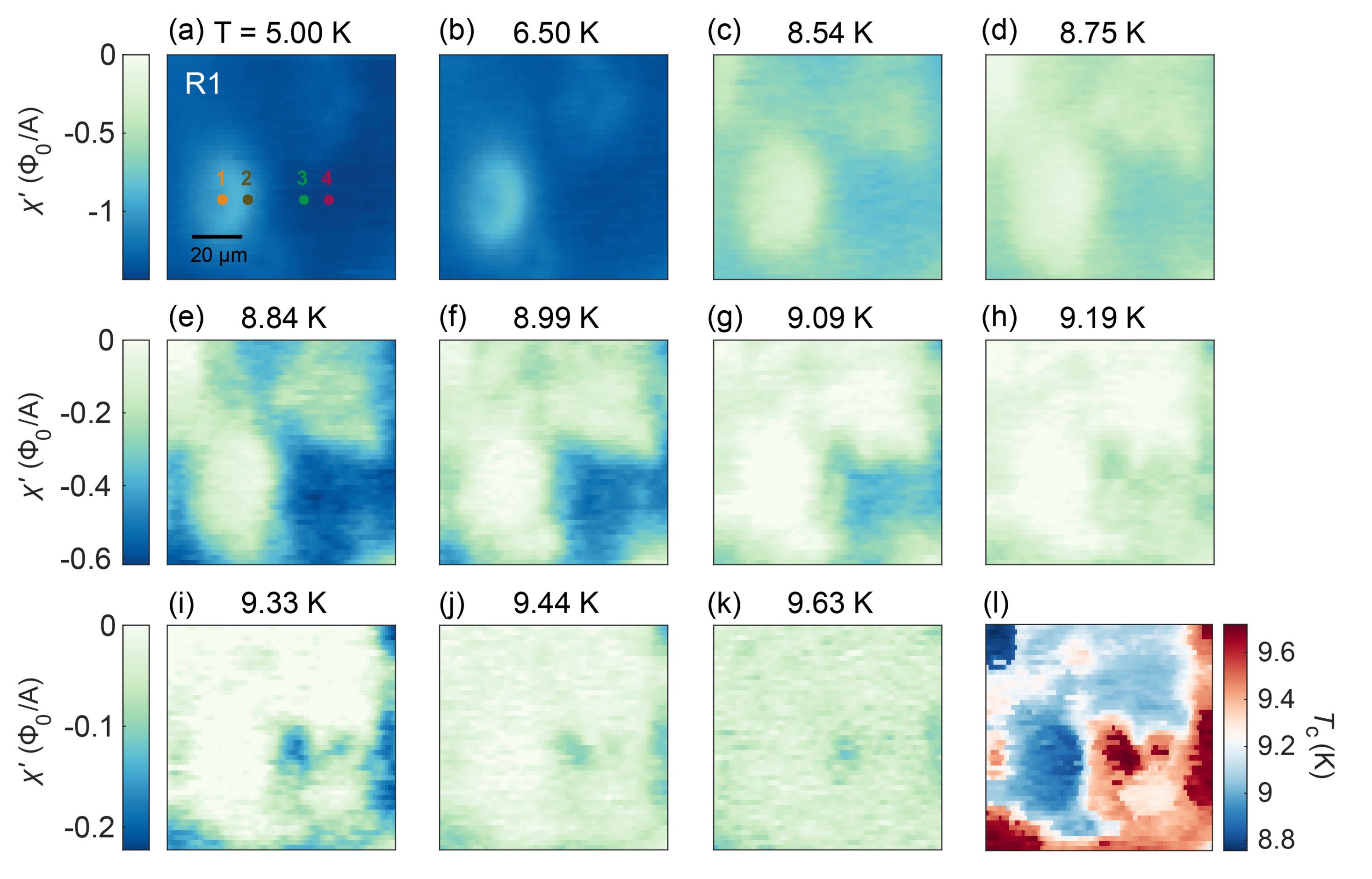

FIG. 2 Temperature evolution of the superconducting diamagnetism and the map of local superconducting transition temperature. The scan area, labeled as R1, is the same area as in Fig. 1(c). For (a)-(k), every panel in a row shares the same color scale. At $T <$ bulk T_c = 8.6 K, the scan area exhibits diamagnetism with significant inhomogeneity [(a)-(c)]. At bulk $T_c < T \leq 9.63$ K, WDRs and adjacent regions lose diamagnetism quickly with increasing temperature. Beyond 9.63 K, the diamagnetism of the full scan area vanishes (not shown in the figure). Panel (l) is the map of local T_c, which is determined as the onset temperature of superconducting diamagnetism.

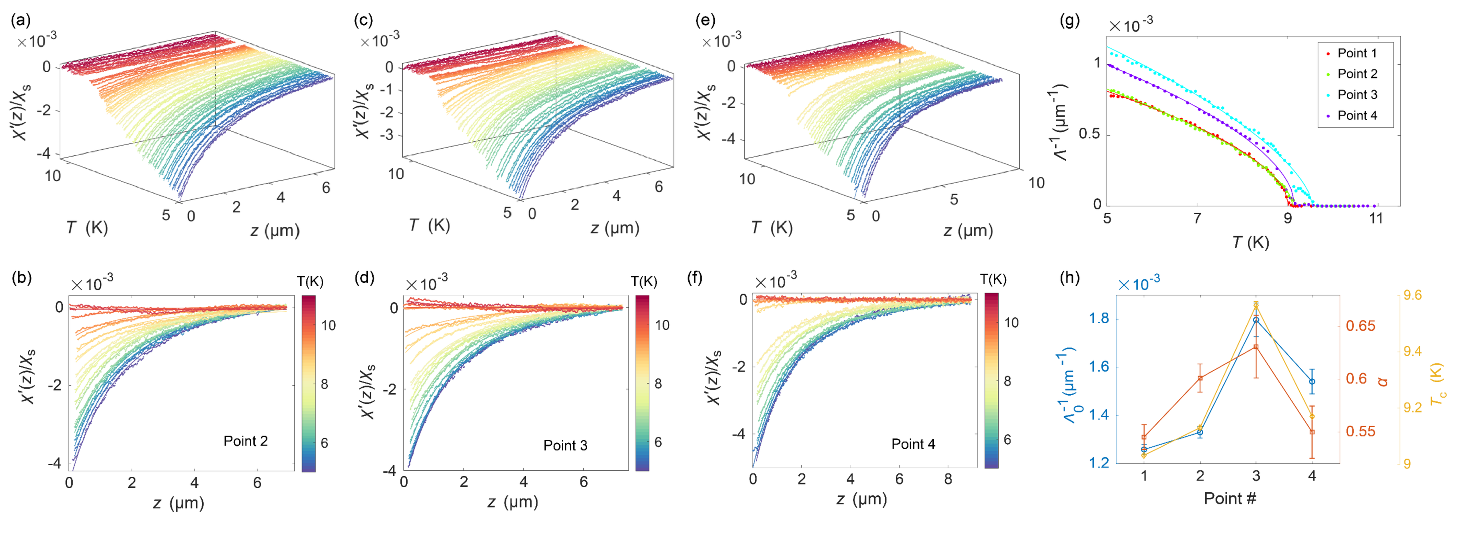

FIG. 3 Temperature evolution of susceptibility approach curves and superfluid density at different points. Panels (a)-(f) show the susceptibility approach data measured at the points labelled in Fig. 1(c): (a)-(b) correspond to point 2, (c)-(d) point 3, and (e)-(f) point 4. The color of data points represents the temperature. The temperature increment is 0.1 K in (a), (c), (e) and 0.3 K in (b), (d), (f). The solid lines are fits of the data using Eq. (1). (g) Temperature-dependent $\Lambda^{-1}(T)$. Dots represent experimental data, and the curves are fittings of the experimental data to Eq. (2). The error bars of the fitting are smaller than the size of data points. (h) Fitting parameters of points 1-4. Left axis (blue): zero-temperature Λ_0^{-1}, which is proportional to the superfluid density at T = 0 K; right axis (inner, brown): α; right axis (outer, yellow): T_c.

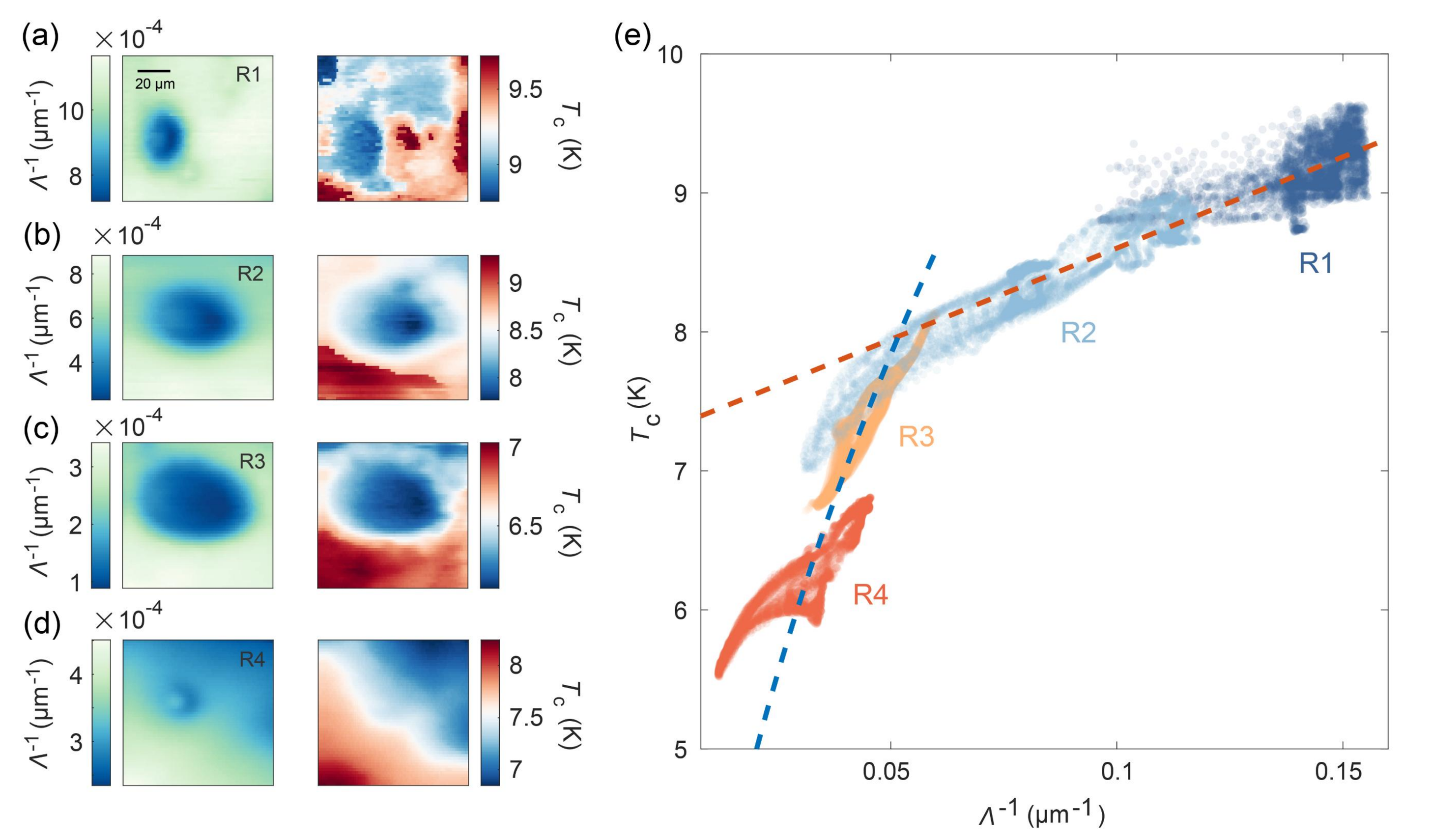

FIG. 4 Correlation between superfluid density and local superconducting transition temperature in NSNO. (a-d) Mappings of the inverse of Pearl length Λ^{-1} at base temperature T_{base} = 5 K (left column), and the local critical temperature T_c (right column) for regions R1-R4. (e) Scaling of T_c with Λ^{-1} extracted from (a-d). The color of the dots represents the scan area from which the data are extracted. Data points with $T_c > 8$ K can be fitted with a linear relation $T_c = T_0 + \alpha\Lambda^{-1}$ where T_0 = 7.29 K, α = 13.1 K·μm (the red dashed line), and those with $T_c < 8$ K can be fitted with a parabolic relation $T_c = \gamma\sqrt{\Lambda^{-1}}$ where γ = 35.0 K·μm$^{1/2}$ (the blue dashed line). Note that the dependence of T_c on Λ^{-1} ($T \to 0$ K), where Λ^{-1} ($T \to 0$ K) is the extrapolation of Λ^{-1} to T = 0 K using the expressions for nodeless-gap superconductors or nodal-gap superconductors, obeys similar scaling relations (Supplementary Material S6).

CONCLUSIONS

We perform local susceptometry on the infinite-layer NSNO/STO films and establish a quantitative relation between local superfluid density and T_c. We find that their relation is strikingly similar to that found in overdoped cuprate superconductors. Our findings suggest the unconventional pairing beyond BCS paradigm in infinite-layer nickelates and its close ties with cuprates.

REFERENCES

1. **Z. Li**, K. Liang, M. Xu, et al. Correlation between superfluid density and transition temperature in infinite-layer nickelate superconductor $Nd_{1-x}Sr_xNiO_2$, *Natl. Sci. Rev.* 2026, nwag068.

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