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Andreev nanoprobe of half-metallic CrO_2 films using superconducting cuprate tips

C. S. Turel,[1] I. J. Guilaran,[2] P. Xiong,[3] and J. Y. T. Wei[1,4,a)]

[1]*Department of Physics, University of Toronto, 60 St. George Street, Toronto, Ontario M5S1A7, Canada*
[2]*Department of Physics, Union University, Jackson, Tennessee 38305, USA*
[3]*Department of Physics, Florida State University, Tallahassee, Florida 32306, USA*
[4]*Canadian Institute for Advanced Research, Toronto, Ontario M5G1Z8, Canada*

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Superconducting tips of $YBa_2Cu_3O_{7-x}$ were used to perform point-contact Andreev reflection spectroscopy on half-metallic CrO_2 thin films. At 4.2 K, strong suppression of the *d*-wave Andreev reflection characteristics was observed, consistent with the high spin polarization of CrO_2. Our technique was validated by comparison with data taken on non-magnetic Au films and with data taken by superconducting Pb tips. The point contacts were estimated to be $\lesssim$10 nm in size, attesting to their ballistic and microscopic nature. Our results demonstrate the feasibility of using superconducting cuprate tips as spin-sensitive nanoprobes of ferromagnets. © *2011 American Institute of Physics*. [doi:10.1063/1.3659411]

Andreev reflection:normal/d-wave

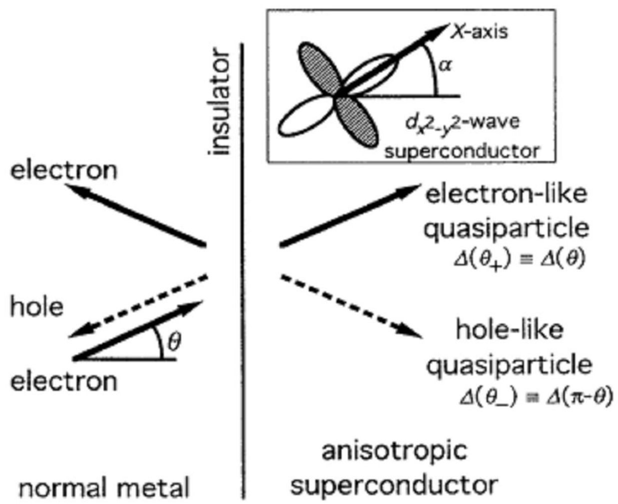

FIG. 1. Schematic illustration of the reflection and transmi sion processes at the interface. In this figure the quantities and α express the injection angle of the electron and the ang between the normal vector of the interface and the x axis of t $d_{x^2-y^2}$-wave superconductor, respectively.

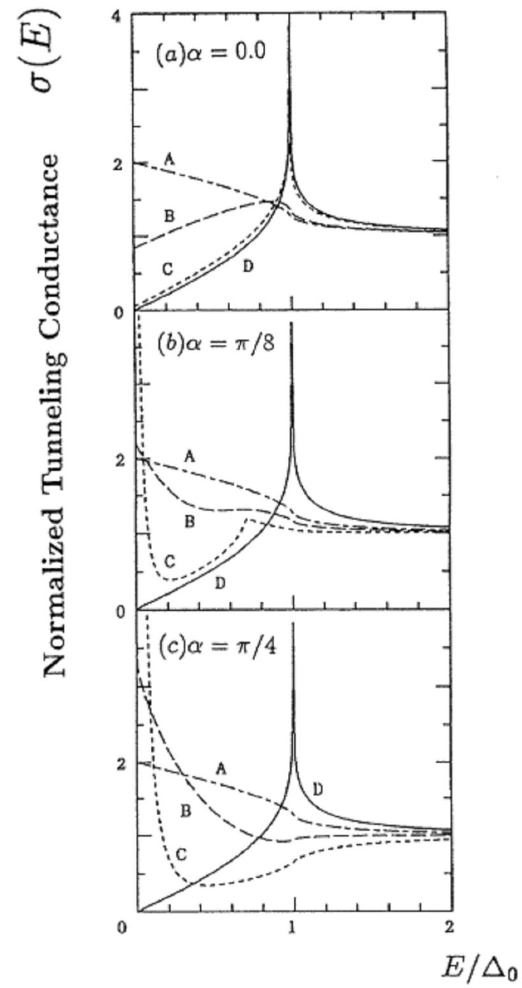

FIG. 2. Normalized tunneling conductance $\sigma(E)$ plotted as a function of E/Δ_0 for a normal metal–insulator–$d_{x^2-y^2}$-wave superconductor junction with the transmitted quasiparticles in the crystal ab plane: (a) $\alpha = 0$, (b) $\alpha = \pi/8$, and (c) $\alpha = \pi/4$. $A: Z = 0$, $B: Z = 1$, $C: Z = 5$, and $D: \sigma_0(E)$.

*Y. Tanaka et al., PRL, **74**, 3451 (1995)*

Test measurements: Pb tip – CrO_2 (normalize to dI/dV bigger than Δ)
Test measurements 2: YBCO tip – Au (10-500Ohm)
Zero Bias Peak observed

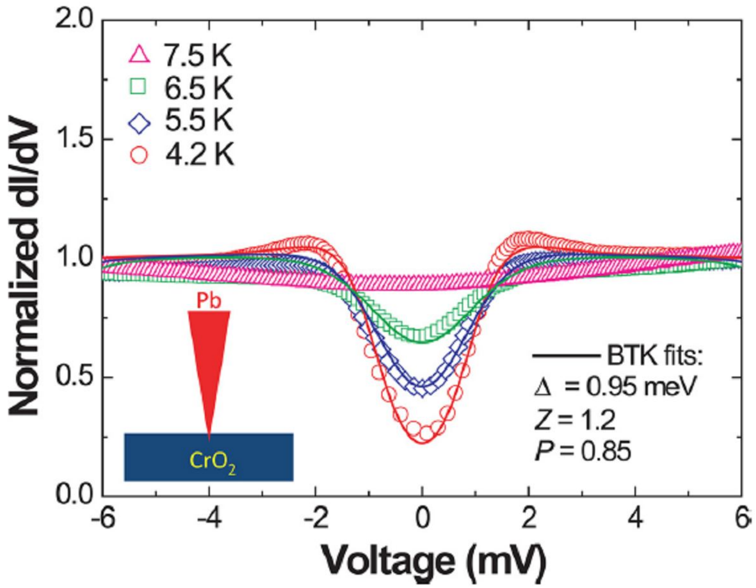

FIG. 1. (Color online) Normalized differential conductance versus bias voltage spectrum taken on a Pb/CrO_2 point-contact junction at different temperatures. Open symbols correspond to the spectral data, and solid lines are fits using the BTK model.

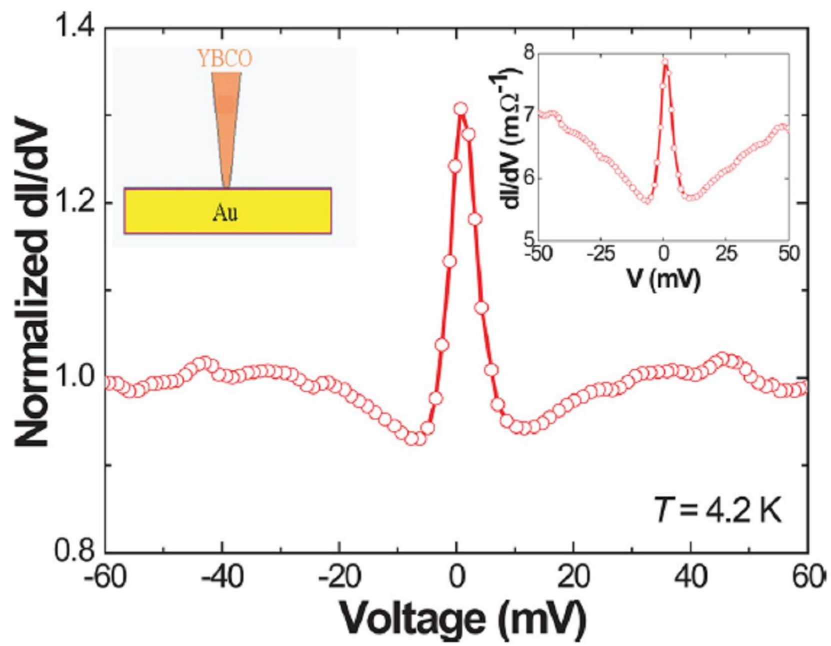

FIG. 2. (Color online) Normalized conductance spectrum measured on a Au film using a YBCO tip at 4.2 K. Right inset is a plot of the unnormalized spectrum showing the linear background which is characteristic of YBCO.

-Zero Bias Dip, kinks az 22mV
-Measure above Tc, can be nicely fit (polynomial fits)
-100-4000Ohm →Wexler formula: radius ~0.7-6 nm (ballistic)
spectra calculated using the spin-dependent d-wave BTK model

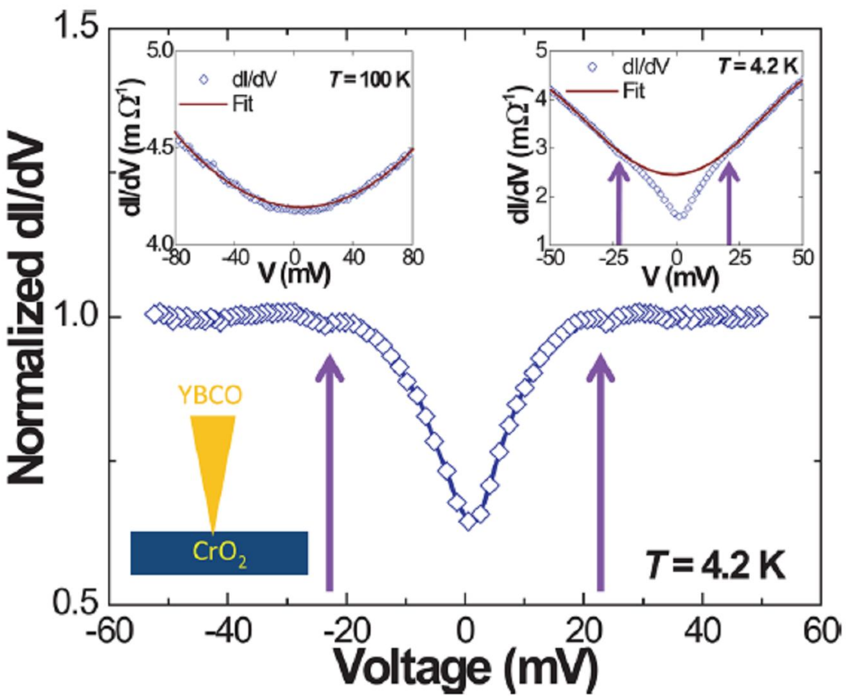

FIG. 3. (Color online) Normalized conductance spectrum measured on a CrO_2 film using a YBCO tip at 4.2 K. Insets show the unnormalized differential conductance spectra taken at 4.2 K (right) and at 100 K (left). Open symbols represent the data while solid lines are a polynomial fit to the background. Arrows indicate spectral kinks, whose locations are consistent with the superconducting gap maximum for YBCO.

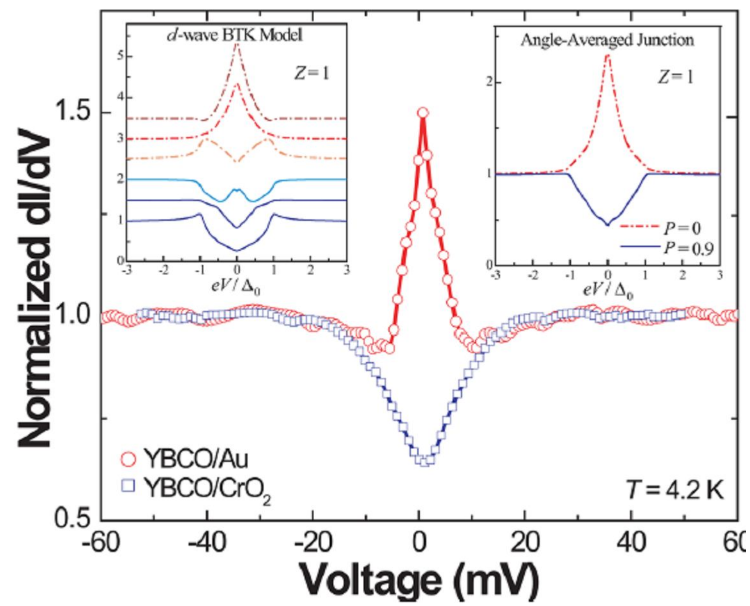

FIG. 4. (Color online) Comparison of the normalized conductance spectr taken on YBCO/Au (circles) and YBCO/CrO_2 (squares) at 4.2 K. Left inse shows various spectra calculated using the spin-dependent d-wave BTI model, for three junctions oriented normal to the ab-plane at $Z = 1$: uppe three curves are for $P = 0$, with the junction normal rotated by 0, $\pi/12$ an $\pi/4$ (top to bottom) from the d-wave node axis; the lower three curves ar for $P = 0.9$ at the same three junction angles. Right inset shows two angle averaged spectra ($P = 0$ for upper, $P = 0.9$ for lower), each averaged withi a Gaussian envelope of width $\pi/6$ about the d-wave node axis, to simulat our nominally-oriented (110) YBCO tip junctions.