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Two-dimensional Superconductivity at a Cu-Cu_2O Interface

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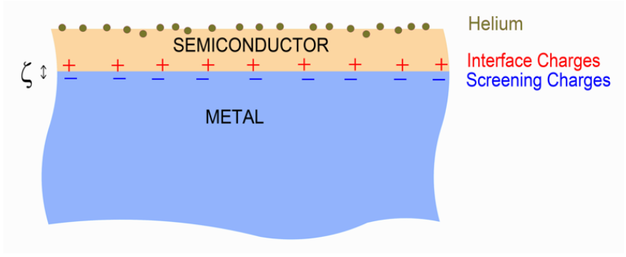


Superconductor Model Structure

Cu metal with **Cu_2O** semiconductor grown by ambient oxidatation.

Adsorbed ^{4}He at 4.2 K induces a double layer of interface and screening charges of areal density ***n*** and separation ζ.

2D Superconductivity in Cu_2O interface hole charges is mediated by Coulomb interactions with Cu screening charges.

Theory

$T_C = \beta\, n^{1/2}/\zeta$ **High-T_C superconductor**

β = 1247.4(3.7) K-Å^2 *Universal constant*

$n \propto \theta$ *^{4}He coverage*

Ambient Electric Field Model

for WF & LWF electron free fall experiment

$E = E_G + SE_T + E_A$

E *measured ambient electric field*

E_G *gravitational sag of e^- in Cu, –mg/e*

E_T *Cu tube patch and lattice compression*

E_A *applied current in the Cu tube*

S *shielding factor – Interface 2D conductor*

$T < T_C$ *– 2D superconducting fluctuations*

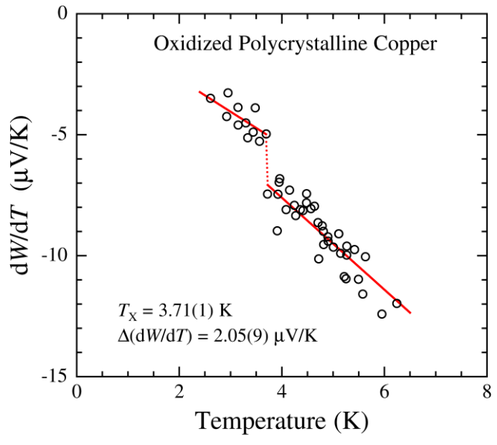
$T > T_C$ *– normal-state shielding*

RESULTS T = 4.2 K …

$n \simeq 1.6 \times 10^{12}$ cm^{-2}

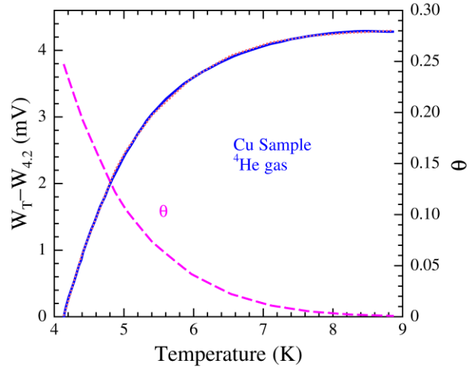
$T_C \simeq 7.9$ K *Intrinsic critical temperature*

$T_{BKT} \simeq 4.4$ K *Phase-stiffness (BKT) transition*



Superconductivity on Cu

Differential work function shows a step-like jog, similar to Nb at its T_C. (after Free *et al.*).

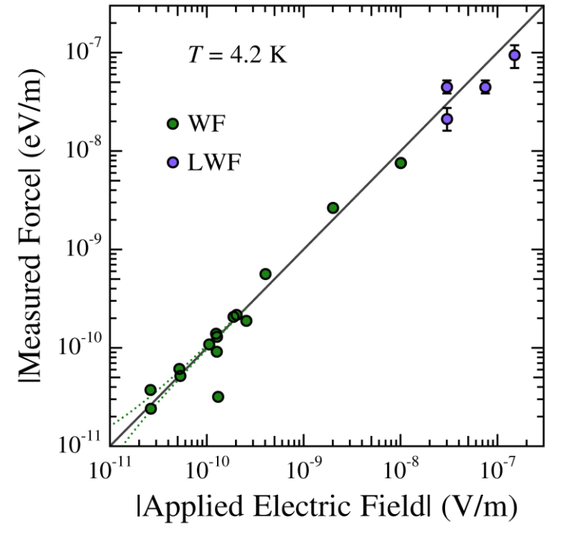


^{4}He-induced Charge on Cu

Work function is enhanced, owing to charge induced by sub-monolayer ^{4}He adsorption θ.

blue: data pink: theory

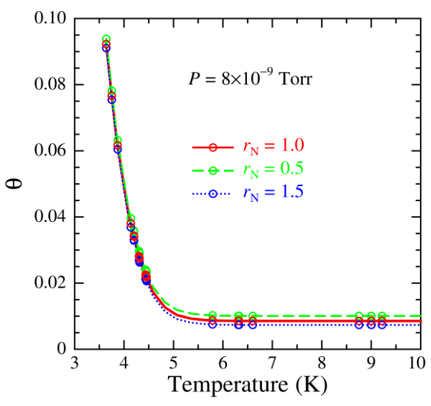
(after de Waele *et al.*)



Shielding of Ambient Electric Fields by Cu

Electron free fall experiments of Witteborn, Fairbank, and Lockhart (**WF & LWF**).

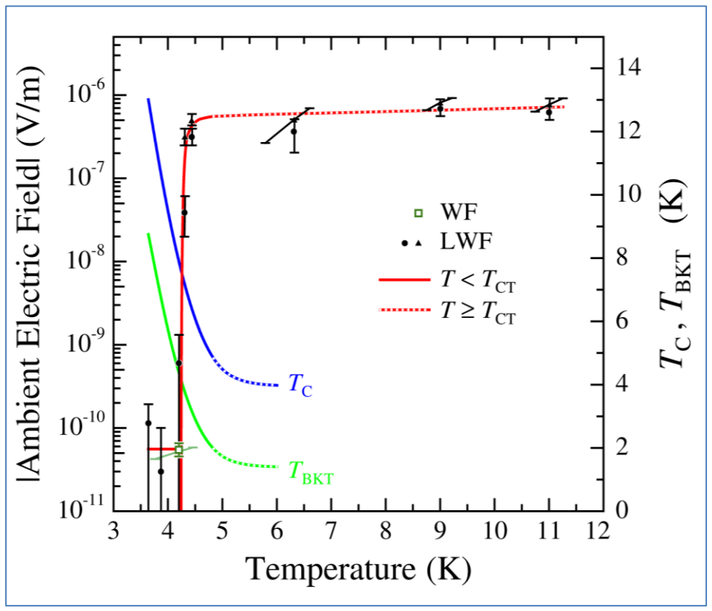
Ambient electric fields from Cu patch and lattice compression are shielded at 4.2 K by the Cu surface, as the intercept is nearly zero.



^{4}He coverage derived by modeling shielding of ambient electric fields in WF & LWF experiments.

r_N – normal resistance in $h/4e^2$

θ – fraction of ^{4}He monolayer

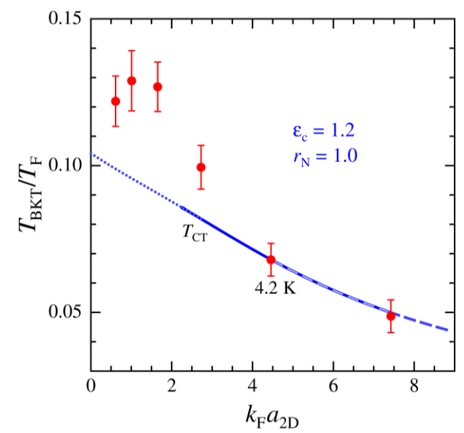


Ambient electric field on falling electrons in WF and LWF experiments – symbols / bars.

Superconducting shielding model – red curve

T_C and T_{BKT} – derived from ***n vs.*** θ

$T = T_C$ *defines* T_{CT}



Proximity to Bosonic Crossover

blue curve – 2D superconductor model

symbols – 2D Fermi gas model (after He *et al.*)

T_F, k_F – Fermi temperature, wave vector

a_{2D} = 141 ± 18 Å interaction length

ε_c – BKT theory renormalization factor

References and further information: Physica C: Supercond. Applic. **632**, 1354600 (2025), doi: 10.1016/j.physc.2024.1354600. https://arxiv.org/abs/2505.02328