MODELING LOW-T_C TRANSITION-EDGE SENSORS MADE OF NS BILAYERS: THE SPECIFIC INTERFACE RESISTANCE

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MOTIVATION

To understand the physics of Transition-Edge Sensors made of normal metal – superconductor (NS) bilayers. To quantitatively characterize the interface transport parameters of NS bilayers by fitting experimental data of Ir/Au to a transition temperature calculation model.

APPROACH

The T_C of an NS bilayer can be calculated with the equations (1) – (4) below (Wang *et al*., IEEE Trans. on Appl. Supercon., **27**, 2100405 (2017)):

$$ln\left(\frac{T_C}{T_{CS}}\right) = -\int_0^{\hbar\omega_D} \frac{dE}{E}\, f_A\ tanh\left(\frac{E}{2k_B T_C}\right), \qquad (1)$$

$$f_A = \frac{f_1}{1+f_2^2}, \qquad (2)$$

$$f_1 = \frac{1+\frac{\hbar^2}{(E\tau)^2}}{1+\frac{\hbar^2}{(E\tau)^2}+\frac{d_S N_S}{d_N N_N}}, \qquad (3)$$

$$f_2 = \frac{\left(1+\frac{\hbar^2}{(E\tau)^2}\right) d_S N_S E a_L + \frac{\hbar\ d_S N_S}{E\tau d_N N_N}}{1+\frac{\hbar^2}{(E\tau)^2}+\frac{d_S N_S}{d_N N_N}}, \qquad (4)$$

where T_{CS} is the transition temperature of a bare superconducting film, $\hbar\omega_D$ is the Debye cutoff energy, τ is the electron spin relaxation time in the normal metal ($\tau = \infty$ for Au), $d_{N,S}$ are the thicknesses of the normal metal and superconductor respectively, $N_{N,S}$ are the densities of states of normal metal and superconductor respectively. The parameter characterizing the transport properties of an NS interface is a_L in equation (4). It is related to the specific interface resistance Rb of an NS interface, i.e., $a_L = 4\pi G_K Rb$ with $G_K = e^2/h$.

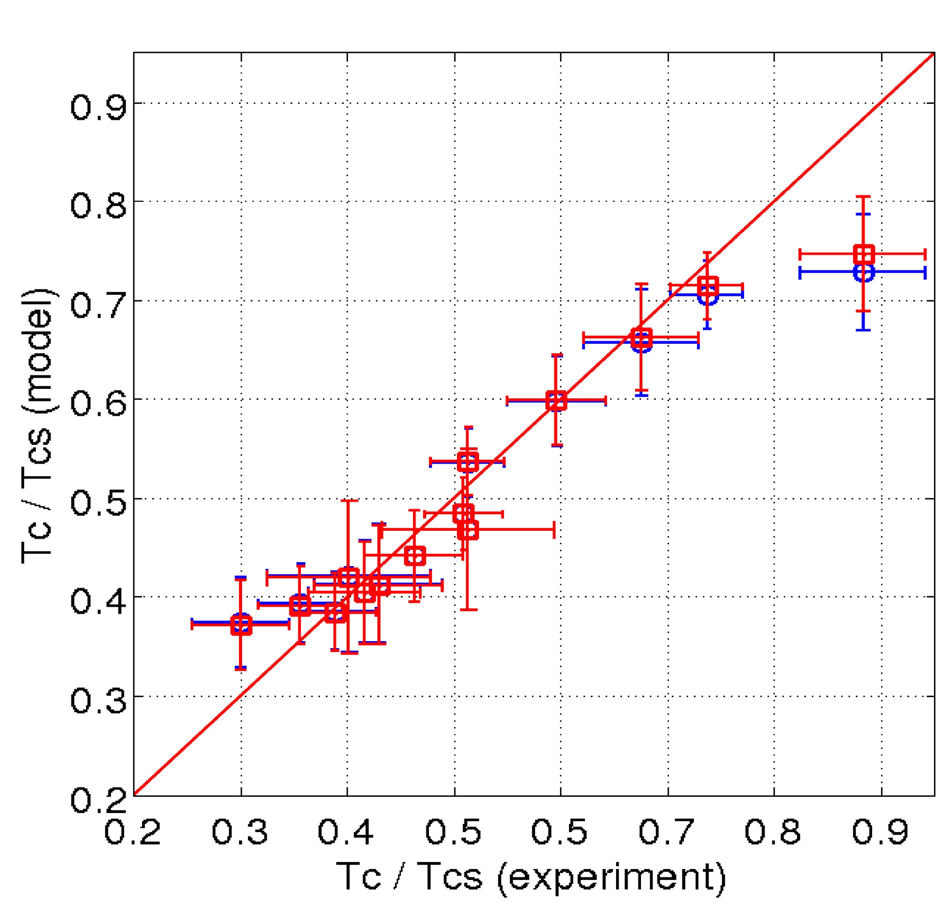
The temperature-independent specific interface resistance is $Rb = (\lambda_F/2)^2/2tG_K$, where λ_F is electron Fermi wavelength, and t is a parameter quantifying the electron transmission efficiency across an NS interface. Note that $1/Rb$ is the interface conductance in the unit of S/m^2.

The temperature-dependent specific interface resistance is $Rb(T) = F^*\, d_S\rho/2 + 1/g_{NS}$, where ρ is the resistivity of a superconductor at normal, F^* is for the quasiparticle injection efficiency, which is defined in the BTK model (Blonder *et al*., Phys. Rev. B, **25**, 4515, (1982)). The first term on the right is due to charge imbalance (M. Tinkham and J. Clarke, Phys. Rev. Lett., 28, 1366, (1972)). The tunneling conductance of an NS interface is

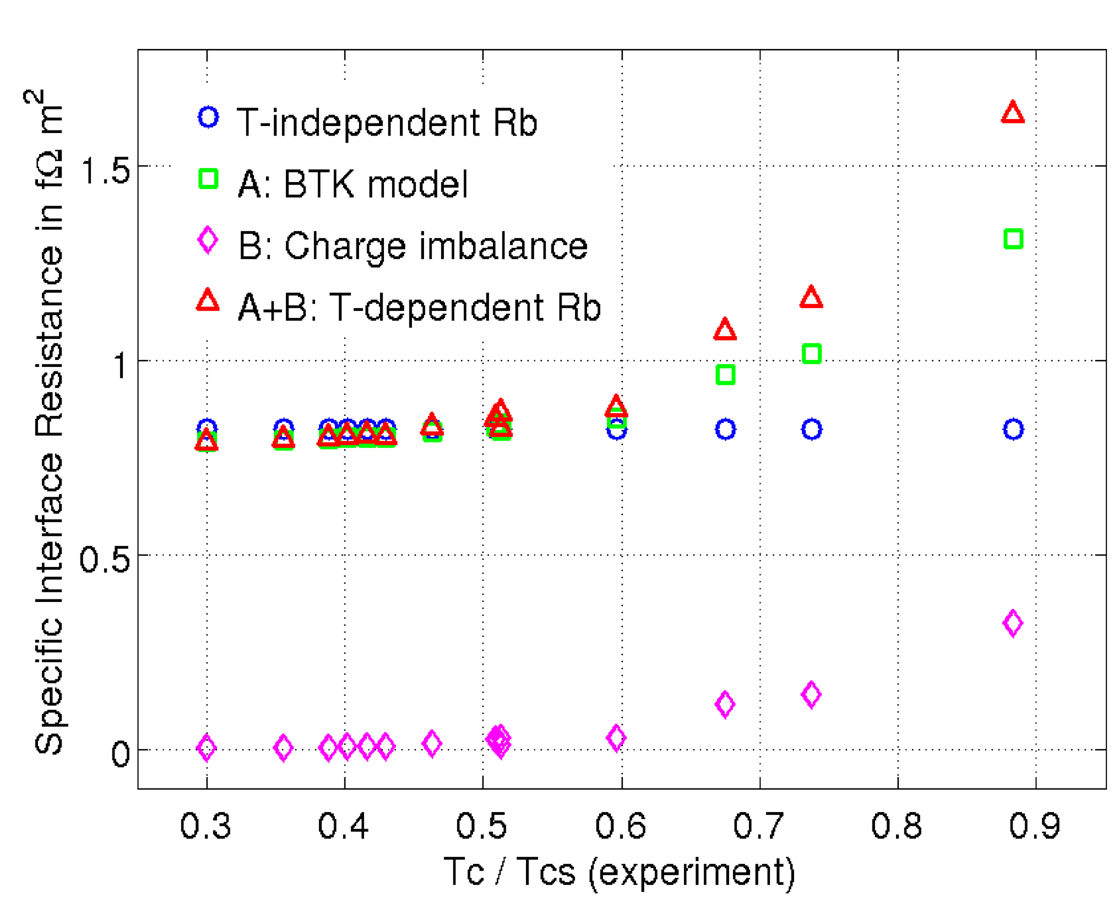
$$g_{NS} = g_0 \int_{-\infty}^{\infty} \left(-\frac{\partial f_0}{\partial E}\right)\left(2A(E) + C(E) + D(E)\right) dE, \qquad (5)$$

where the tunneling conductance constant $g_0 = 2N_S e^2 V_F$. V_F is Fermi velocity. f_0 is electron distribution function at equilibrium. A, C and D are summarized in the BTK model, and contain a hidden parameter, $Z = H/(\hbar\, V_F)$ which characterizes the NS interface barrier strength H.

RESULTS



Model vs. experiment of the reduced transition temperature T_C/T_{CS} of Ir/Au bilayers. T_{CS} is the transition temperature of the bare Ir films. Experimental data are from Nagel *et al*., J. Appl. Phys., **110**, 063919, (1994). Blue circles are the best fit results with reduced $\chi^2 = 0.95$ using temperature-independent Rb. The red squares are the best fit results with reduced $\chi^2 = 0.78$ using temperature-dependent Rb. The red line is for visual guide.



The specific interface resistances of Ir/Au bilayers estimated by fitting measured T_C to its calculation model. The blue circles are for the temperature-independent $Rb = 0.82\ \text{f}\Omega m^2$ obtained from a least χ^2 fit. The red triangles are for the temperature-dependent Rb obtained from a least χ^2 fit with two contributions: charge imbalance; and BTK tunneling model with $g_0 = 635.1\ TS/m^2$, and $Z = 0.02$, which means a metallic contact between the Ir film and the Au film.

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