Comment on "2-Channel Kondo Scaling in Conductance Signals from 2-Level Tunneling Systems"

In a recent Letter [1], Ralph *et al.* attribute the zero-bias anomaly of a Cu point contact [2] to the scattering of electrons by two-level systems (TLS) acting as two-channel Kondo impurities. In this Comment we (1) point out a serious difficulty with the two-channel Kondo interpretation, and (2) propose an alternative explanation of the data.

The anomaly observed in the point-contact experiments [1,2] is a dip in the differential conductance around zero bias. While the two-channel Kondo model is very successful in accounting for the scaling form of the dip [3], for the model to be appropriate to the experiment requires many two-level systems, all with splitting $\lesssim 1$ K, in the vicinity of the point contact [1]. For regular Kondo impurities, the analogous splitting between spin states is guaranteed to be zero by time-reversal invariance [4]. In contrast, a TLS will be split by ordinary elastic scattering of conduction electrons, which is equivalent to magnetic scattering for regular Kondo impurities. We estimate, via perturbation theory in the elastic scattering rate, the average splitting of any two-level system in these experiments to be of the order $\epsilon_F/[\ln(\epsilon_F/k_BT_k)\sqrt{k_F\ell}] \simeq 100$ K, where ϵ_F is the Fermi energy, k_F the Fermi wave vector, ℓ the mean free path, and for the Kondo temperature we use the claimed value [1] $T_K \simeq 5$ K. The analysis also predicts zero probability of zero splitting. Even without this suppression, a distribution of TLS splittings on the scale of 100 K would lead to $V^{3/2}$ and $T^{3/2}$ zero-bias anomalies in contradiction to the observed $\sqrt{V}$ and $\sqrt{T}$ behavior.

Instead of an explanation based on two-level systems, we propose that the dip in the differential conductance in the experiments of Ralph *et al.* is due to the well known dip in the density of states near the Fermi energy in disordered metals, caused by interactions between electrons [5]. We suggest that the effect observed in Refs. [1,2] is essentially the same square-root suppression of the differential conductance near zero bias observed in tunneling into a disordered metal [5]. (Either there is a tunneling current through the thinned region of the Si_3N_4 insulator surrounding the point contact or the electrons pass through the point contact without significant loss of energy and are then incident on a disordered region.) In fact, the predicted suppression describes the experimental scaling results [1] quantitatively (Fig. 1). Moreover, the experimental results are consistent with a predicted $\sqrt{B}$ tunneling magnetoconductance, and suggest a reasonable diffusion constant $D = 15$ cm^2/s (i.e., $\ell = 30$ Å). This disorder must extend over 500 Å (the size of the bowl), but may be strongly inhomogeneous. For example, the phonon features in the point-contact spectra suggest a significantly longer mean free path near the point contact. The observation that the experimental zero-bias anomalies disappear on cycling to high temperature is naturally explained as the annealing away of the disorder. Finally, the positive sign of the magnetoconductance indicates an attractive electron-electron interaction at short range. This may indicate that the spikes observed in the differential conductance at high bias can be attributed to superconducting regions [6].

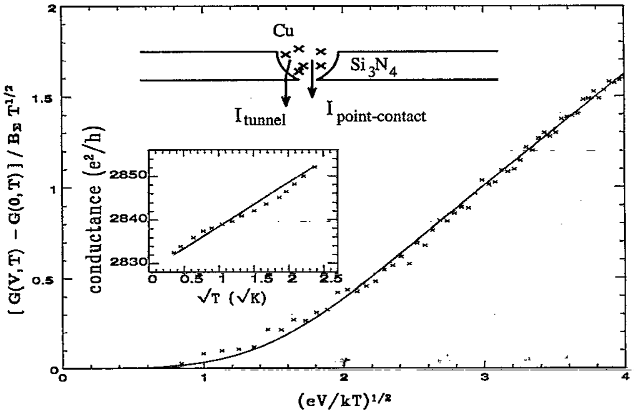

FIG. 1. Scaling plot of the conductance anomaly near zero bias. The data points are from experiment (Ref. [1], sample 1, $T = 0.4$ K); the solid curve is the analytical prediction for tunneling into a disordered metal, *with no free parameter* once the slope of the temperature dependence B_Σ is experimentally determined (lower inset). The upper inset shows the parallel point-contact and tunneling currents.

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