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TEMPERATURE DEPENDENT SPIN-FLIP SCATTERING IN A SPIN GLASS

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Abstract. - We have used electron tunneling to study the conduction electron spin flip scattering rate of AgMn. The spin glass metal film is induced superconducting by proximity with a lead film. We find that the spin flip scattering rate decreases markedly as temperature is lowered through the glass temperature.

Resume. - Nous avons utilisés l'effet tunnel afin d'étudier le taux de diffusion des spins des electrons de conduction dans l'alliage Ag-Mn. La couche métallique du verre de spin est induite dans l'état supra-conducteur par proximité avec une couche de plomb. Nous trouvons que le taux de diffusion des spins diminue d'une façon marquée lorsque la température est abaissée et passe par la température de gel du verre de spin.

When a metallic system undergoes a magnetic phase transition the spin flip scattering of the conduction electrons off the correlated spins shows a temperature dependence which may be used to characterize the magnetic ordering.[1] The most sensitive way of measuring the spin flip scattering rate is the use of superconducting electron tunneling. For extremely gapless superconductors the tunneling density of states at zero bias voltage provides a direct measure of the spin-flip scattering rate (τ_s^{-1}).

In order to study a well characterized spin glass system we have performed experiments on AgMn which has been induced into the superconducting state by proximity with Pb. The junctions were of the form N (3000 Å) - Oxide - AgMn (200-800 Å) - Pb (3000 Å), where N was Al, $Al_{.95}Mn_{.05}$, or Mg.

The zero bias conductance of two samples of AgMn with .35 atomic percent is shown in Figure 1 as the squares and triangles. The temperature dependence of the tunneling characteristics can arise from thermal smearing, a temperature dependent superconducting order parameter, and a temperature dependence of the spin flip scattering. The Pb order parameter is saturated at temperature below $\sim$ 3.5 K so that the order parameter throughout the sandwich will only be temperature dependent above this temperature.

The effects of thermal smearing can be calculated from the energy dependence of the zero temperature tunneling characteristics using:

$$\sigma_s(0,T) = \int_{-\infty}^{\infty} \sigma_s(E,0)\left(-\frac{df}{dE}\right)dE \qquad \text{I.}$$

where f(E) is the Fermi function. In order to compare our results with simple thermal smearing we measured the conductance of our junction from 0.040K to 8K. The 40 mK $\sigma_s(V)$ was then used to numerically

compute $\sigma_s(0,T)$ from eq. I. The calculated data appears as the solid dots in Figure 1. The calculated curve follows the experimental curve as temperature is raised and then deviates in the region around the glass temperature (T_G). Note that the deviation occurs at the same temperature for the two different thicknesses of the AgMn film.

For an extremely gapless superconductor the zero bias conductance is given by[2]:

$$\sigma_s(V = 0) \propto N_s(0) \simeq N(0) \quad \{1 - 1/2\ (\Delta\tau_s)^2\} \qquad \text{II.}$$

where N(0) is the normal state density of states at the Fermi energy. We attribute the difference between the experimental data and calculated temperature dependence to a change in the spin flip scattering rate. The fact that the computed curve falls below the measured one indicates that the spin flip scattering rate decreases below T_G in accordance with the idea that a degree of "spin-freezing" occurs at T_G. Note however that the freezing occurs in a narrow range about T_G (see inset, Figure 1) and manifests itself as a "step" and not a "cusp." The 10% change in conductance corresponds to at least a 5% change in τ_s across T_G. This is lower limit because part of the gaplessness may arise from the proximity configuration itself.

Measurements for a sample with 0.1 atomic % Mn are shown in Figure 2. Notice that the temperature at which the experimental and computed curves deviate has shifted to a lower temperature in proportion to T_G.

We may connect the temperature dependence of $1/\tau_s$ with the spin glass order parameter if we assume that conduction electrons cannot flip (second order in the localized conduction electron exchange) off the spin glass order parameter. Then,

$$\frac{1}{\tau_s} \propto 1/2[S(S+1) - \langle(\overline{S_0})^2\rangle] \qquad \text{III.}$$

where the brackets refer to a configuration average and the last term

represents the Edwards-Anderson[3] order parameter for the spin glass. The insert in Figure 1 then indicates the appearance of a finite order parameter as temperature is lowered through T_G in rough agreement with the changes observed in susceptibility.[4]

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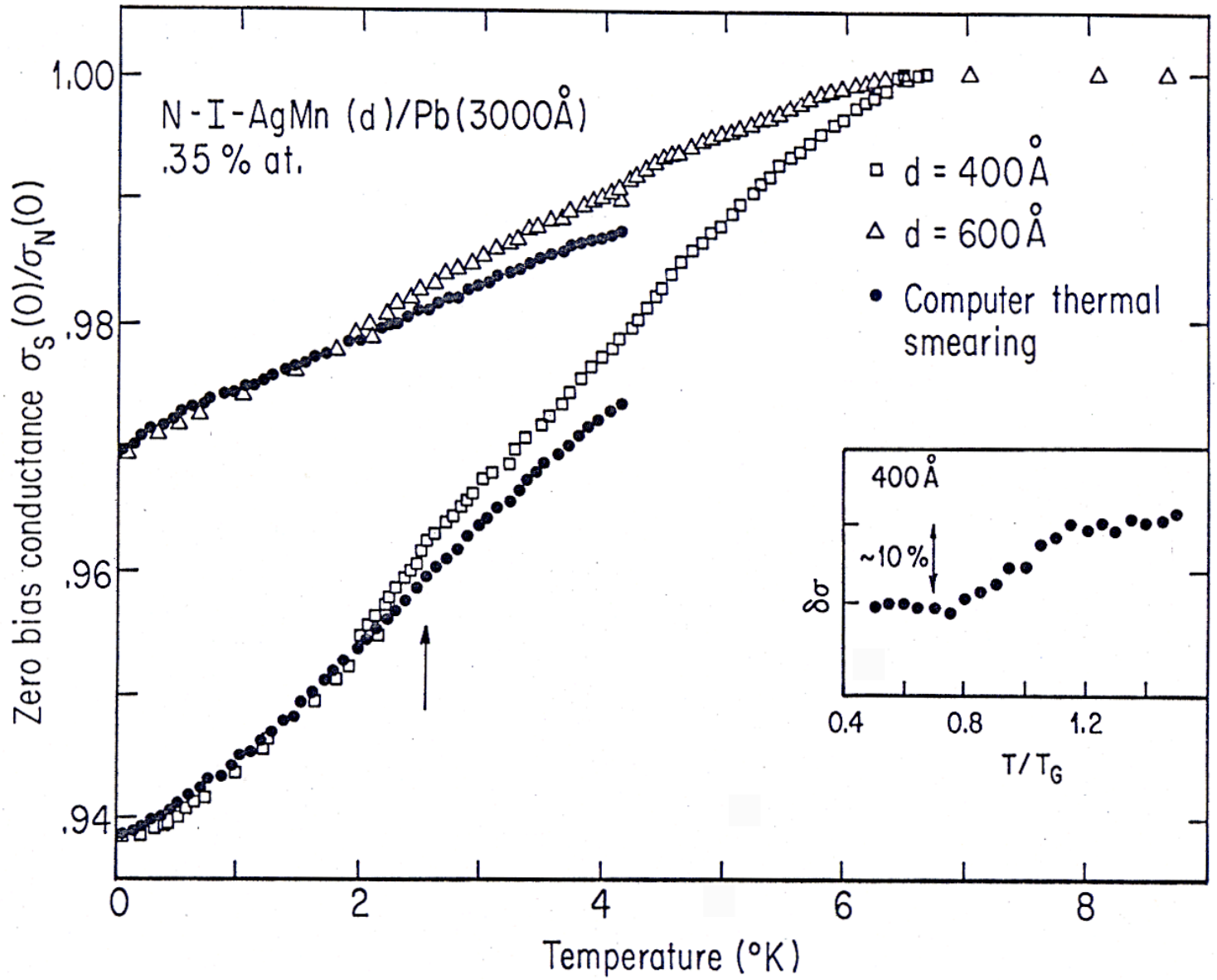
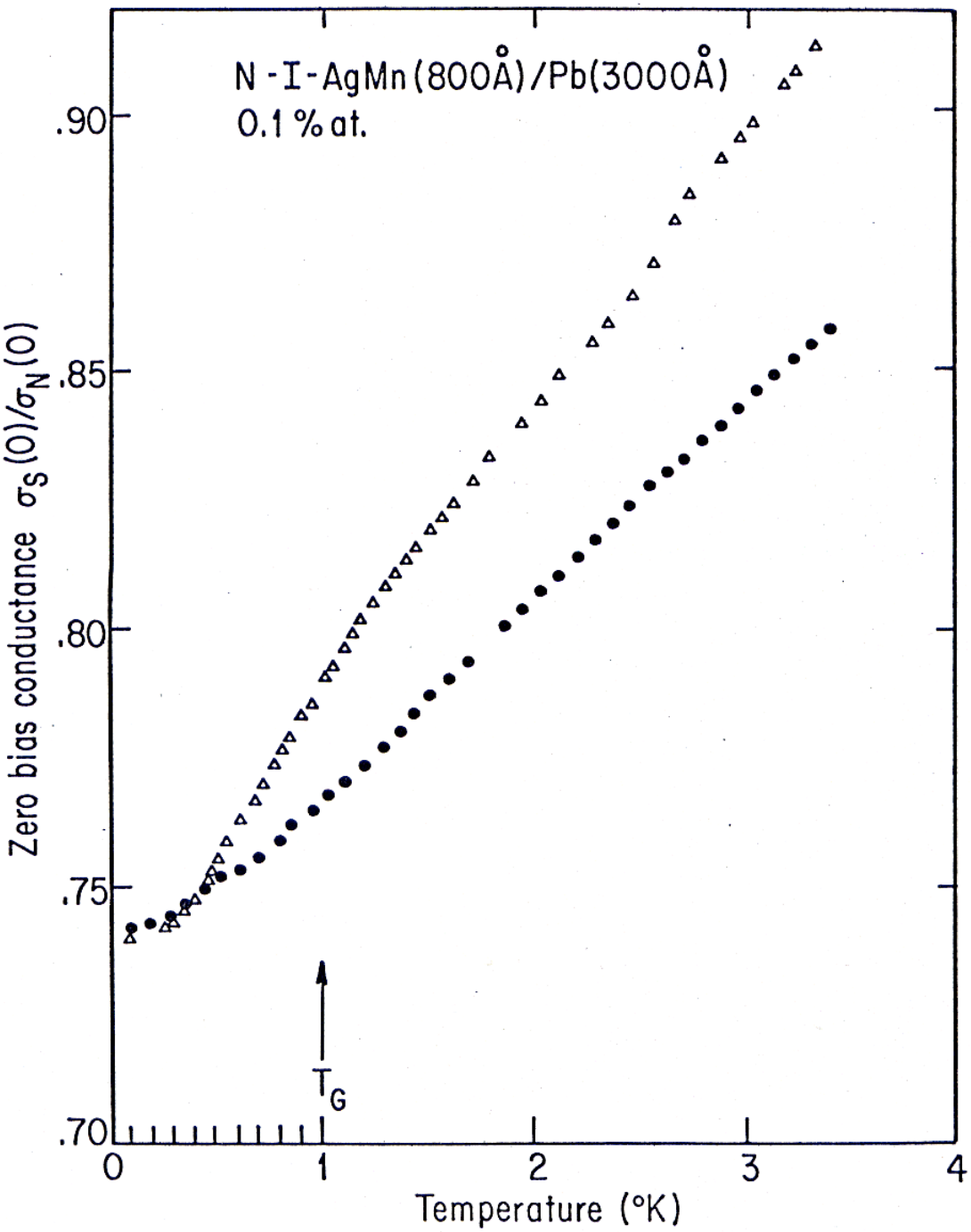

N-I-AgMn (d)/Pb(3000Å)
.35 % at.
d = 400Å
d = 600Å
Computer thermal smearing
Zero bias conductance $\sigma_S(0)/\sigma_N(0)$
1.00
.98
.96
.94
0
2
4
6
8
Temperature (°K)
400Å
~10 %
$\delta\sigma$
0.4
0.8
1.2
T/T_G


N-I-AgMn(800Å)/Pb(3000Å)
0.1 % at.
.90
.85
.80
.75
.70
Zero bias conductance $\sigma_S(0)/\sigma_N(0)$
T_G
0
1
2
3
4
Temperature (°K)