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ZERO AND FINITE FIELD μSR IN SPIN GLASS AG:MN

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In this paper we present μSR data taken in both zero and finite fields for a Ag:Mn (1.6 at%) spin glass sample. The data allow us to determine, in the context of a particular model, the fluctuation rate of the Mn ions as a function of temperature. This rate decreases smoothly but very rapidly near the glass temperature, $T_g$. The corresponding behavior in Cu:Mn is more gradual [1].

The sample was prepared by arc melting and then annealing at 800 C for one hour. The low field AC susceptibility of our sample shows a sharp cusp at the expected $T_g$ = 7.6 K. Muon data were obtained at the stopped muon channel of LAMPF. A conventional time differential technique was used to obtain transverse depolarization rates at several fields and temperatures. Zero field data were obtained with a pair of counter telescopes along the beam direction. The effects of counter efficiency, solid angle and beam polarization were estimated by using the same counters to measure a μSR spectrum in a small transverse field. The zero field data were thereby analyzed to yield the muon polarization as a function of time. All measurements below $T_g$ were made by cooling the sample in an external field of less than one gauss.

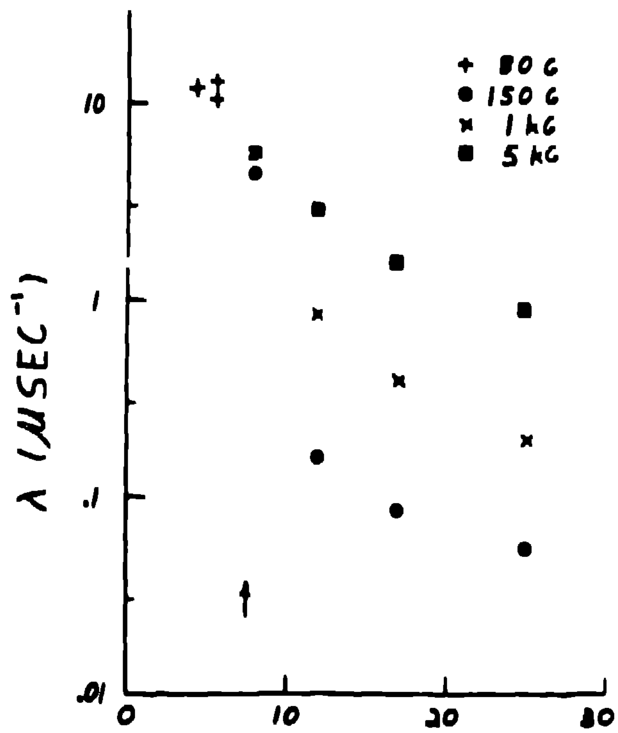


Fig. 1. Relaxation rate λ for an assumed exponential depolarization, versus temperature. The error bars are approximately the size of the plot symbol. A point at 8 K and 1 kG lies between the plotted values for 150 G and 5 kG. The arrow indicates $T_g$.

The transverse field data are summarized in Fig. 1, which plots exponential depolarization rate against temperature. The measured rates show a rapid increase as $T_g$ is approached from above. Below $T_g$, the rate appears to saturate at (12±2) $\mu sec^{-1}$, which is rather close to the expected [2] value of 11 $\mu sec^{-1}$ for a randomly frozen array, assuming a dipolar coupling between the muon and the impurity.

Well below $T_g$, the zero field polarization function shows a rapid drop to one third of its zero-time value, followed by a slower decrease to zero. A finite depolarization rate persists to 2 K, indicating that fluctuations in the local field are present down to 0.27 $T_g$. At temperatures well above $T_g$, a smooth but non-exponential decay is seen. More complex behavior occurs at intermediate temperatures.

In order to extract quantitative information from our zero-field depolarization curves, we use the weak collision model of Leon [3]. The model assumes that each stopped muon sees a magnetic field of fixed strength but time-varying direction. The field strength at the various muon sites is assumed to follow a Lorentzian distribution with half-width a. The fluctuations of the field direction are characterized by a single correlation time $\tau$, although recent neutron scattering results [4] indicate this may be an oversimplification.

The results of fitting this model to our zero field data are shown in Fig. 2, where we plot the Mn correlation time $\tau$ against temperature. The low temperature data require a = 18 $\mu sec^{-1}$ (210 gauss), which is somewhat larger than the value observed for small transverse fields. This value of a is held fixed in the higher temperature fits.

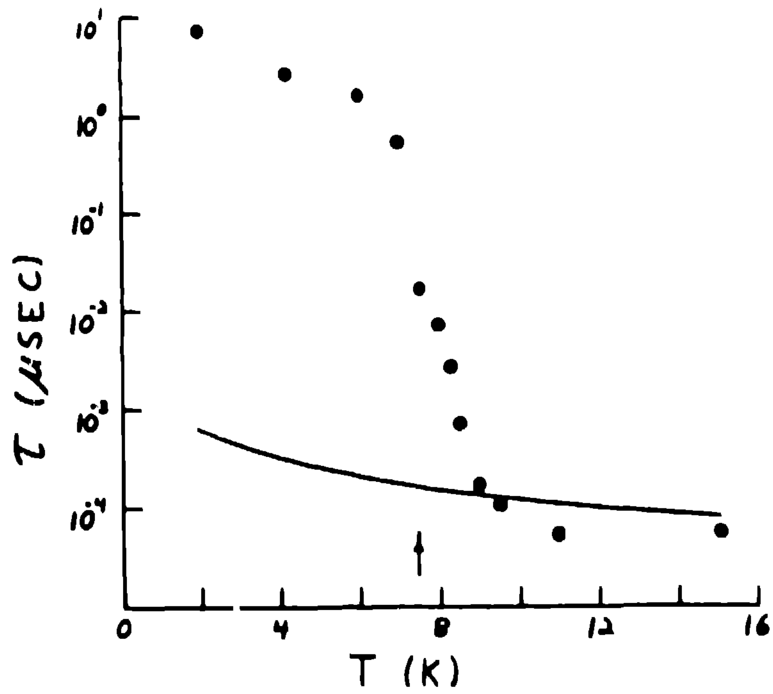


Fig. 2. Mn spin correlation time, in the weak collision model, versus temperature. The size of the dots represents the error in $\tau$. The solid line indicates the Korringa rate for an isolated Mn ion in Ag, and the arrow denotes $T_g$.

The variation of $\tau$ with temperature is obviously rapid, but still smooth on the scale of the susceptibility cusp width. It is interesting to note that the measured $\tau$ reaches an apparent saturation at a value near the observed [4] Korringa rate for free Mn at only 1.3 $T_g$.

The data do not follow an Arrhenius law over the full temperature range, as is clearly shown by the persistence of fluctuations to very low temperatures. If data between 6 and 10 K (0.7 - 1.3 $T_g$) are fit to an Arrhenius law a barrier energy of $E_b = 30\ k_BT_g$ is found, together with an attempt frequency $\nu_a$ of $2 \times 10^{20}\ \mathrm{sec}^{-1}$. These results are to be compared with values of $E_b = 10.5\ k_BT_g$ and $\nu_a = 2 \times 10^{12}$ previously found [1] for Cu:Mn(0.7%), which has $T_g$ = 7.5 K. In addition to the obvious lack of scaling between the two systems, the attempt frequency in Ag:Mn is unphysically large.

Future work will deal with a wider range of temperatures and concentrations, to test the scaling of the results presented here. It will also be necessary to construct more complete models which allow for a distribution of correlation times and for temperature variation of a.

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Footnotes and References

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