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Comments

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Comment on "Time decay of the saturated remanent magnetization in a metallic spin glass"

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The data of Granberg *et al.* [Phys. Rev. B **35**, 2075 (1987)] are consistent with our previous observation that the saturated remanent of *Cu*Mn relaxes like t^{-m} where $m \sim 0.2T/T_g$ up to $T \sim 0.7T_g$

Chamberlin, Mozurkewich, and Orbach[1] were pioneers in promoting the use of the Kohlrausch law to fit magnetization relaxations in spin glasses well below T_g. This law comes from the glass literature where those who use it to fit data over the glass transition are well aware that it contains (i) a specification on the shape of the relaxation $M \sim M_0 \exp(-t/\tau_p)^{1-n}$ and (ii) a specification on the characteristic time $\tau_p = [(1-n)\exp(n\gamma)\omega_c^n \tau_0]^{1/(1-n)}$.[2] The remarkable efficiency of the formula appeared from the very beginning when it succeeded in providing an excellent fit to the data with a wrong specification on τ_p. Despite that, recent developments tend to restrain the range over which the law allegedly applies.[3] The tendency is to use an expression of the form

$$M = M_0 t^{-m} \exp\left(-\frac{t}{\tau_p}\right)^{1-n},$$

as was reported, e.g., by Granberg *et al.* [4] In this particular work the authors were cautious to apply a field large enough to saturate the remanent magnetization, the relaxation of which is subsequently studied. They report that $n \neq 1$ only for $0.98\,T_g < T < T_g$. Skipping those 2% of the total range, it is found therefore that a simple power law t^{-m} suffices to describe the data, in agreement with the simulations of Kinzel.[5] Previous to these experiments and to these simulations other experiments[6-8] and other simulations[9] made this same conclusion with the focus put at the same time upon other points of interest to the discussion. In our own work[6,7,10] we stressed that at low enough temperatures ($T < 0.7T_g$) the magnetization[6] and the energy relaxations[7] are essentially functions of the variable $X = T/T_g \ln(t/\tau_0)$ where the function $f(X)$ depends on the procedure (field cooling, zero-field cooling, etc.). In the cases where the remanent magnetization is saturated it was found that the function $f(X)$ could well be approximated by an exponential over many decades. We had therefore

$$M \sim M_0 \exp\left[-\alpha \frac{T}{T_g} \ln\left(\frac{t}{\tau_0}\right)\right] = M_0 \left(\frac{t}{\tau_0}\right)^{-\alpha(T/T_g)}$$

This remarkable temperature dependence of the exponent, reminiscent of the *XY* model, was observed on the magnetization relaxation of several *Cu*Mn alloys[6] and on the energy and the magnetization relaxation of several *Au*Fe alloys.[7] The results agreed qualitatively with the simulations of Binder and Stauffer.[9] However, they reported $\alpha = d/4$ with Ising spins when we measured $\alpha = 0.4$ in *Au*Fe (for both the energy and the magnetization) and $\alpha = 0.2$ in *Cu*Mn (for the magnetization). The data of Granberg *et al.* confirm quantitatively this last figure (i.e., $\alpha \simeq 0.2$ in *Cu*Mn) as may be seen from Fig. 4 of Ref. 1 up to $T < 0.8T_g$. We believe that this is an important remark as it permits one to introduce some physics in a discussion otherwise limited to fitting considerations with a phenomenological formula. As we stressed in Refs. 6, 7, and 10, the $T\ln(t/\tau_0)$ variable is the natural variable to use in a frozen landscape of potential mountains and valleys [frozen distribution $P(W)$ of energy barriers W] which are populated through an activated process. For this reason the $T\ln(t/\tau_0)$ scaling applies to a wide variety of hysteresis phenomena[8] largely independent of their microscopic nature: spin glasses, superparamagnetic grains, wall motion in ferromagnets, vortices in type-II superconductors, plasticity of rubbers and polymers,.... The $T\ln(t/\tau_0)$ scaling also applies to corresponding states of the unsaturated remanent magnetization although the relaxation is not given by a power law in this case.[6,7,10]

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