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Supplement materials-magnetic properties

Supporting data for frustrated ferromagnetic (FM) state of $GeNFe_3$ are performed in Fig. S1 and Fig. S2. In the left axis of Fig. S1(a), a bifurcation appears at an irreversibility temperature T_{irr} (defined by the temperature with $M_{ZFC} = M_{FC}$), and zero-field cooling curve exhibits a peak around the temperature T_f (defined by the maximum value of M_{ZFC}). Meanwhile, in Fig. S1(b), with increasing H, both T_f and T_{irr} shift to lower temperature. As shown in the inset of Fig. S1(b), the field dependence of T_f can be well described by the $H^{2/3}$ law. In Fig. S1(c)-(d), both $\chi'(T)$ and $\chi''(T)$ exhibit strongly frequency-dependent peaks. The relaxation time is described by a power law $\tau = \tau_0 [T_f(f)/T_0 - 1]^{-zv}$, $T_f > T_0$, where T_0 is the freezing temperature, τ_0 is the characteristic flipping time, τ is the relaxation time [$\tau = 1/(2\pi f)$], and zv is the dynamical critical exponent. All the parameters ($T_0 = 40.5$ K, $zv = 4.86$, $\tau_0 = 4.33\times10^{-12}$ s) are obtained by fitting the power law as displayed in the inset of Fig. S1(c). In addition, Isothermal remanent magnetizations (M_{IRM}) were measured on cooling the sample from 200 to 5 K at ZFC process. The data are fitted according to the formula $M_{IRM}(t) = M_0 - \alpha\ln(t)$ as shown in Fig. S2(a)-(e). These above results consistently confirm a magnetic frozen behavior in $GeNFe_3$, similar to a spin glass state or frustrated FM state. By comparison, the ground state of $GeNFe_3$ should be a frustrated FM state, similar to many other magnetic frustrated systems.[S1-S7]

FIG. S1: (a) Temperature dependent $M(T)$ and the derivative of ZFC curve dM/dT for $GeNFe_3$. The inset show the $M(H)$ curves at 5 K, 150 K, and 300 K; (b) $M(T)$ curves under ZFC/FC processes at different H. The inset displays T_f as a function of $H^{2/3}$. (c) and (d) Temperature dependence of ac susceptibility at several fixed frequencies: (c) real components. The inset presents the best fit by a power law; (d) the imaginary parts.

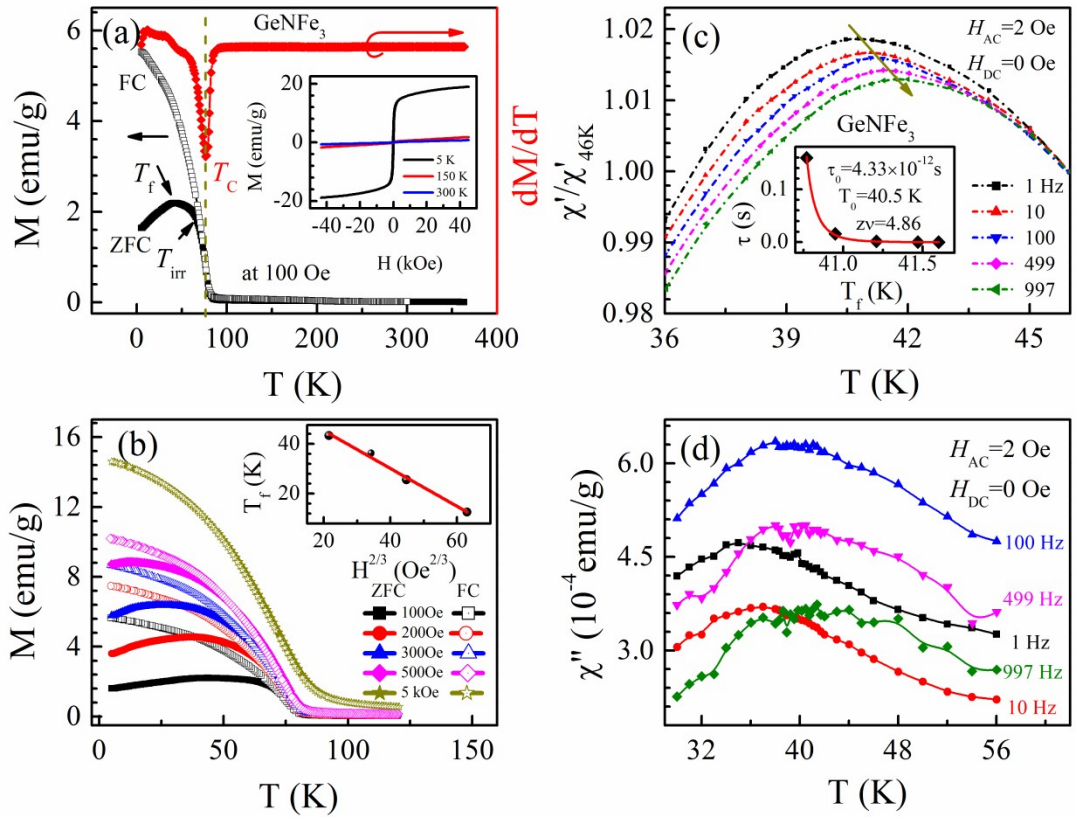
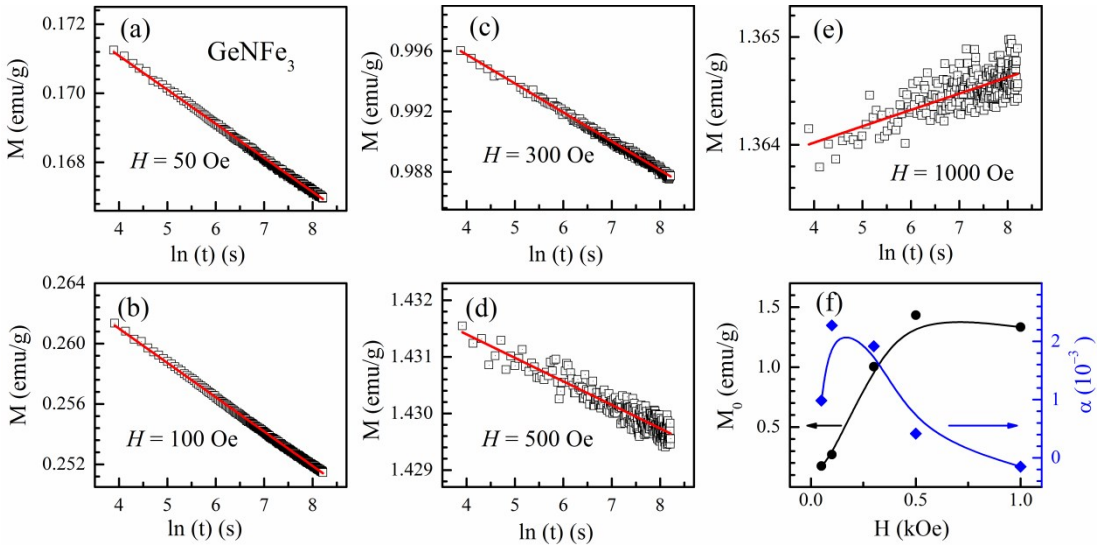


FIG. S2. (a)-(e) M_{IRM} vs t at different H and the solid lines are fitted by $M_{IRM}(t) = M_0 - \alpha\ln(t)$: (a) for 50 Oe; (b) for 100 Oe; (c) for 300 Oe; (d) for 500 Oe; (e) for 1000 Oe. (f) The fitted parameters M_0 and α as a function of H.



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