Thermal Hysteresis in Magnetic Phase Changes in Solid Oxygen

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Introduction

Measurements of the dielectric susceptibility of solid oxygen in the temperature range 4<T<54K, have revealed large hysteresis effects for the dielectric response in the α and β phases of solid oxygen on thermal cycling below 44K. The behavior in the frustrated a phase is similar to the effects for the frustrated ordering of molecular alignments in solid N_T-A mixtures.

Experimental

The anisotropic component of the dielectric susceptibility of molecular solids is directly related to the short range correlations between the ordering of the molecular axes and the order parameters for the molecules, $\sigma=\langle(3\cos^2\theta-1)/2\rangle$, $\eta=\langle 2\sin^2\theta\cos^2\varphi\rangle$, where θ,φ specify the polar angles of the molecular axes with respect to the mean alignments. The polarizability is given by $\alpha_{aniso}=-1/3\ \Delta\alpha\langle\langle\sigma_i(T)P_2(\cos\Theta_{E\,i})+3/2\eta_i(T)\sin^2T\Theta_{E\,i}\cos2\Phi_{E\,i}\rangle\rangle$ [1] where $(\Theta_{E\,i},\Phi_{E\,i})$ are the polar angles specifying the orientation of the applied electric field with respect to the local symmetry axes. $\Delta\alpha=\alpha_{//}-\alpha_{\perp}$ where $\alpha_{//}$ and $\alpha_{\perp}$ are the polarizabilities parallel and perpendicular to the molecular axes, respectively. The anisotropy for oxygen is high with $\Delta\alpha/\alpha_o$ =0.72., making the susceptibility very sensitive to the ordering of axes and the magnetic ordering in the solid state at low temperatures. The temperature dependence of the susceptibility was measured using a three terminal ac capacitance bridge having a sensitivity of 2×10^{-9} for the real part of the susceptibility and 2×10^{-7} for the dielectric loss[2].

Results and Discussion

The observed temperature dependence is shown in Figure 1. One observes the sharp phase changes from the α-phase (T<23.8K), a two sub-lattice antiferromagnet, and the trigonal β-phase, a highly frustrated quasi-helical magnetically ordered structure (23.8<T<43.8 K). While the phase transitions are well-known what was observed for the first time was a very strong hysteresis on thermally cycling in the β-phase.

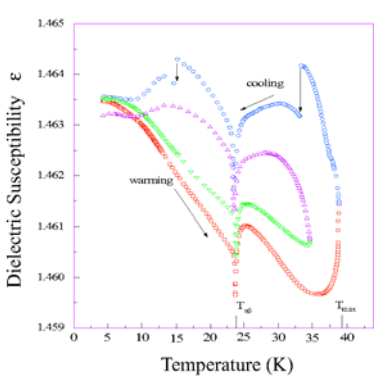

Figure 1. Thermal hysteresis observed for the dielectric susceptibility of solid oxygen of the phase transition at 23.86 K between the antiferromagnetic phase (α) and the frustrated helical magnetic phase (β).

Conclusions

The observed areas of the thermal hystereses scale accurately with the extent of the thermal extension in the β-phase. This result is consistent the predicted memory effects expected for frustrated glass-like systems.[3]

References

[1] Pilla, S., *et al*., Phys. Rev. B, **67**, 174204 (2003).
[2] Pilla, S. *et al*., Rev. Sci. Instrum. **70**, 4055 (1999).
[3] Cugliandolo, L.F. et al., Phys. Rev. Lett. **71**, 1 (1993).