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Spin-Electric Coupling Revealed by Electric Field Modulated EPR

Abstract

The possibility to operate on magnetic materials through the application of electric rather than magnetic fields - promising faster, more space confined and energy efficient circuits - continues to spur the investigation of magnetoelectric (ME) effects [1]. Symmetry considerations, in particular the lack of an inversion centre, characterize the ME effect. In addition, spin-orbit coupling is generally considered necessary to make a spin system sensitive to a charge distribution. However, a ME effect not relying on spin-orbit coupling is appealing for spin-based quantum technologies. We have very recently reported the detection of a ME effect that we have attributed to an electric field modulation of the magnetic exchange interaction without atomic displacement [2]. The effect is visible in electron paramagnetic resonance (EPR) absorption of molecular helices under electric field modulation (EFM- EPR) and confirmed by specific symmetry properties and spectral simulation.

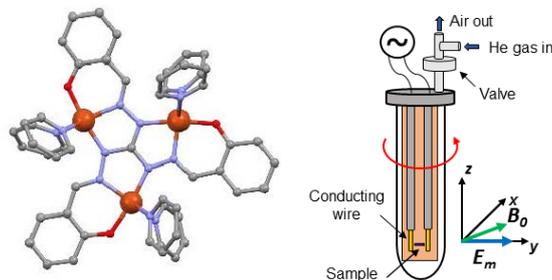


Fig. 1 Left: the molecular structure of the spin-frustrated Cu₃, with a ground state $S=1/2$. Right: schematic view of the modified version of the sample holder used for the EFM-EPR measurements. The orientations of the static magnetic field (B_0), and the electric field (E_m) are shown. E_m is obtained by applying an alternating voltage $V = V_0 \cos(\omega t)$, with $V_0 = 170$ V over a distance of 1.5 mm, and $\omega = 2\pi \times 30$ kHz.

After this report, an oscillating electric field ten times stronger was imparted to the sample by an improvement in the experimental setup. This made possible the observation of a ME effect in a single-crystal of a frustrated Cu₃ triangle (Fig. 1). The orientational dependence of the effect was recorded paving the way to its deep comprehension. Our experiment complements previous time resolved electron spin resonance studies performed on the same Cu₃ molecular cluster in frozen solution, which have shown sizeable effects of electric field pulses [3].

References

- [1] Spaldin, N. A. and Fiebig, M., *Science* **309**, 391-392, (2005).
- [2] Fittipaldi, M., Cini, A., Annino, G., Vindigni, A., Caneschi, A., and Sessoli, R., *Nat. Mater.* **18**, 329-334 (2019).
- [3] Liu, J., Mrozek, J., Myers, W.K., Timco, G. A., Winpenny, R.E.P., Kintzel, B., Plass, W., and Ardavan, A., *Phys. Rev. Lett.* **122**, 037202 (2019).