Fast-field-cycling, ultralow-field nuclear magnetic relaxation dispersion

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Optically pumped magnetometers (OPMs) based on alkali-atom vapors are ultra-sensitive devices for dc and low-frequency ac magnetic measurements. Here, in combination with fast-field-cycling hardware, we demonstrate applicability of OPMs in quantifying nuclear magnetic relaxation phenomena. Relaxation rate dispersion across the nT to mT field range enables quantitative investigation of extremely slow molecular motion correlations in the liquid state, with time constants >1 ms, and insight into the corresponding relaxation mechanisms. The 10–20 fT/$\sqrt{\text{Hz}}$ sensitivity of an OPM between 10 Hz and 5.5 kHz ^{1}H Larmor frequency suffices to detect NMR signals from ∼2 mL bulk liquid, or 0.5 mL liquid imbibed in simple mesoporous materials, following nuclear spin prepolarization adjacent to the OPM. The expected limits of the OPM technique are discussed regarding measurement of relaxation rates above 100 s^{-1}.

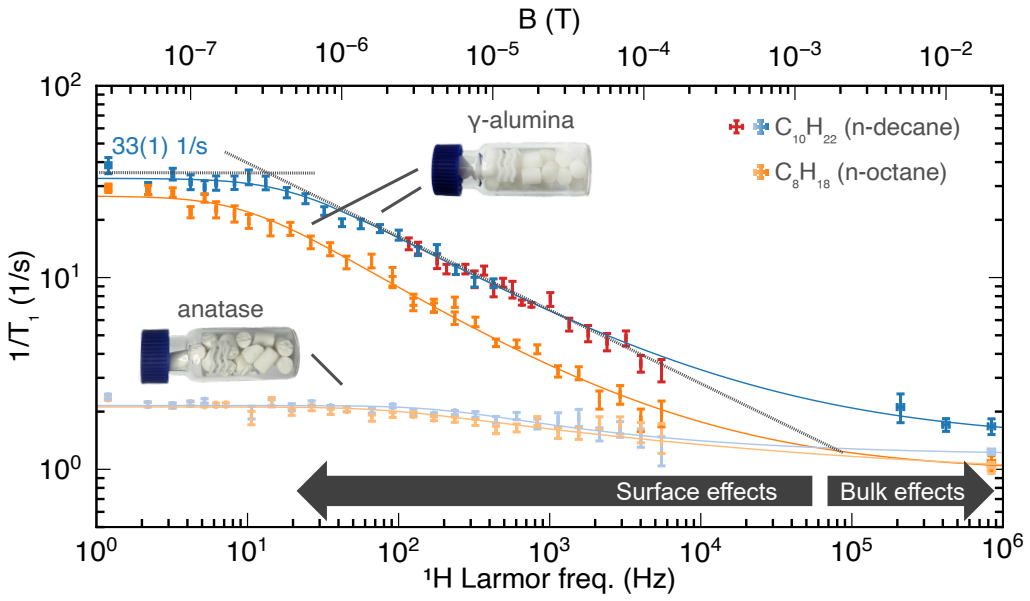

Figure 1. Longitudinal relaxation rates between Larmor frequencies 1 Hz and 5.5 kHz for n-octane and n-decane in porous γ-alumina and anatase titania.

[1] S. Bodenstedt, M. Mitchell, M. C. D. Tayler, Fast-field-cycling, ultralow- field nuclear magnetic relaxation dispersion, arXiv:2012.05546, (2020).

[2] M. C. D. Tayler et al., Instrumentation fornuclear magnetic resonance in zero and ultralow magnetic fields, Rev. Sci. Instrum. **88**, 091101 (2017)

[3] M. C. D. Tayler, J. Ward-Williams, and L. F. Gladden, NMR relaxation in porous materials at zero and ultralow magnetic fields, J. Magn. Reson. **297**, 1–8 (2018)