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Nuclear Magnetic Ordering in Naphthalene

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Analogous to electronic magnetism, a nuclear spin system can undergo a transition from a paramagnetic to a ferromagnetic or antiferromagnetic state subject to mutual dipole-dipole interactions. This exotic phenomenon, known as nuclear magnetic ordering (NMO), has only been observed in a few cases that form simple atomic single crystals. We recently developed a model to describe NMO in molecular crystals, which exhibit more ordering possibilities since each molecule contains more than a single spin. Our model predicts a ferromagnetic order in a naphthalene single crystal with thin disk-shaped domains perpendicular to the magnetic field with alternating polarization. The critical spin temperature to reach this order is below the uK range and is achieved by hyperpolarization of the naphthalene protons followed by an adiabatic demagnetization in the rotating frame (ADRF). The latter reduces the effective field on the spins to zero and transfers the high degree of Zeeman order into pure dipolar interaction. Using NMR studies, we were able to confirm the existence of NMO, but only neutron scattering could provide clear evidence of the nature of the order or the size and shape of the domains. To investigate these properties, we performed neutron reflectometry measurements. Due to the polarization dependent interaction cross-section of the neutrons and the polarized protons, we were able to observe Bragg reflexes on the domain boundaries and study the ordered state in detail.

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