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Scaling behaviour of the skyrmion phases of Cu2OSeO3 single crystals from small angle neutron scattering

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A skyrmion is a topological stable particle-like object comparable to a spin vortex at the nanometre scale. It consists of an about 50 nm large spin rotation and its spin winding number is quantised. Skyrmions emerge in chiral crystals as the result of competing symmetric exchange and asymmetric Dzyaloshinskii-Moriya (DM) interactions and typically form two dimensional hexagonal lattices perpendicular to an applied magnetic field. Its dynamics has links to flux line vortices as in high-temperature superconductors [1-2].

Cu_2OSeO_3 is a unique case of a multiferroic material where the skyrmion dynamics could be controlled through the application of an external electric field. The direct control of the skyrmion dynamics through a non-dissipative method would offer technological benefits applicable in energy-efficient data storage and data processing devices or for testing fundamental theories also related to the Higgs Boson whose theoretical description has similarities to skyrmions [3].

The technological applications crucially depend on the stability conditions of the skyrmion phase up to room temperature. While some materials host skyrmion lattices above room temperature [3], Cu_2OSeO_3 is the only insulating skyrmion material discovered so far, which orders magnetically below 58 K. It is interesting to note that the appearance of two different skyrmion phases have been reported along the temperature and magnetic field phase diagram of Cu2OSeO3 when the sample is aligned with its main crystallographic axes parallel to the incoming neutron beam and performing Zero Field Cooling (ZFC) or Field Cooling (FC) across the high-temperature skyrmion phase. However, the stabilisation processes of these two phases and their thermodynamic connection are still under debate [4-6]. We have used small angle neutron scattering and Lorentz transmission electron microscopy [7] to study the scaling behaviour of helical phase and the magnetic skyrmion lattices, i.e. the systematic change of their distances in single crystals of Cu_2OSeO_3 in order to gain insight on the balance between the different competing magnetic exchange interactions.

Therefore, we have examined the field, temperature and sample alignment dependence of the scaling behaviour of skyrmions as an order parameter for the emergence of the two aforementioned skyrmion phases. The obtained data provide valuable information on the formation mechanism of the skyrmions and their stability range. This is an important step towards the understanding of the manipulation of skyrmions, which is required for technological applications.

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No

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