Time resolved Lorentz-TEM measurements of topological skyrmion decay in $Fe_{0.5}Co_{0.5}Si$

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The skyrmion, a whirl in the magnetic spin texture of a chiral ferromagnet, is believed to lead to major advances in data storage technologies due to its small size and inherent topological protection [1-4]. Theoretically, its topologically non-trivial spin structure is equivalent to an energy barrier that needs to be overcome in order to annihilate the skyrmion [5,6]. This property grants the skyrmion the robustness against external influences that made it prominent in the field of solid-state physics. Therefore, it is vital to study this energy barrier quantitatively and identify the decay mechanisms of a skyrmionic structure into the other phases of the chiral magnet.

In this work, the decay of a metastable skyrmion lattice into the field-polarized and helical phase of the chiral B20 material $Fe_{0.5}Co_{0.5}Si$ is studied. For this, a ≈ 240 nm thick lamella is cut from the single crystal in (110) direction and field cooled at 23mT to ≈ 20K which is below the critical temperature and skyrmion phase space region. The obtained metastable (frozen) skyrmion lattice is subsequently destroyed by either an increase or decrease of the externally applied magnetic field (decay into conical or helical phase). Time-resolved non-stroboscopic cryo Lorentz-TEM (LTEM) is used to record real-time videos of the skyrmion decay far from its thermodynamic equilibrium.

The analysis and evaluation of the time-resolved data show two different decay mechanisms consistent with theory. Upon decrease of the externally applied magnetic field, the skyrmions merge to stripes that make up the helical phase. Upon field increase the skyrmions appear to be simply switched off. Theory suggests that this happens via a magnetic Bloch point that travels through the sample in field direction and we show that this process can be interrupted when the Bloch point gets trapped at crystal defects (see Fig. 1) [5,6]. We further observe the skyrmion lifetime to depend exponentially on temperature and follow an Arrhenius law with a single energy barrier.

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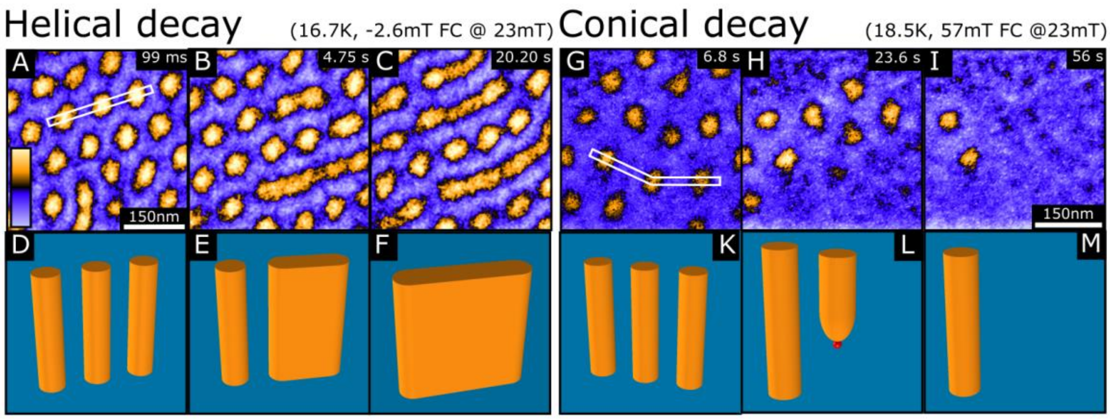

Fig 1: *Decay mechanisms of the metastable skyrmion lattice. Upon magnetic field decrease, the skyrmions merge to stripes which result in the spin configuration of the helical phase (A-C). When the field is increased, the skyrmions are simply switched off via a magnetic Bloch point that runs vertically through the sample (G-I). Figure (H) shows the trapping of such a magnetic Bloch point at a lattice defect due to reduced contrast. Figures (D-F) and (K-M) show in-plane magnetization iso-surfaces of the theoretically expected spin structures for the images above (white boxes) [1].*