Experimental report

12/11/2018

Proposal: 5-41-982 **Council:** 4/2018

Title: Metastable Skyrmions in Zn-Doped Cu2OSeO3

Research area: Physics

This proposal is a new proposal

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Samples: (Cu(1-x)Znx)2OSeO3

Instrument	Requested days	Allocated days	From	To
D33	6	4	06/09/2018	10/09/2018

Abstract:

Skyrmions are vortex-like arrangements of magnetic moments that constitute a completely new magnetic topology, present only in certain chiral magnetic materials and occurring only in well-defined temperature and magnetic field conditions. Skyrmions are currently the focus of intense research due to their potential application in future data-storage devices. As the list of skyrmion materials expands, the focus is on understanding the relationship between the skyrmion lattice and the underlying crystal structure; on the development of techniques to control the properties of their host materials, and the ability to directly manipulate the spin texture.
We propose to perform SANS measurements on Zn doped Cu2OSeO3. The sample has already been characterised by the proposers via microwave absorption and resonant x-ray scattering. These measurements demonstrated the existence of a metastable skyrmion state that is stabilised by the increasing of Zn doping. At the same time, a strong directional dependence of the stability of this metastable state has been observed that was not fully investigated, and SANS is the ideal technique to probe such behaviour.

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Marta Crisanti

The purpose of this experiment on D33 was to fully characterize the behaviour of the skyrmion lattice in Cu_2OSeO_3 under the introduction of Zn non-magnetic defects. We used Small Angle Neutron Scattering to determine the differences in lifetimes of the metastable skyrmion lattice in pristine and 12% Zn substituted Cu_2OSeO_3.

Materials/samples:

The single crystals of pristine and 12% substituted Cu_2OSeO_3 have been aligned on OrientExpress. Each of them was mounted on a different sample holder for the Blue Charlie cryostat with a [110] direction parallel to the neutron beam, and another equivalent [110] direction parallel to the cryostat stick (perpendicular to the neutron beam). In this geometry it has been possible to access and probe during the experiment all three main crystallographic directions.

Experiment and results:

First, the pristine sample has been mounted and the metastable state has been identified with measurements of the diffraction patterns while cooling down in temperature at a 7K per minute rate, as shown in fig.1.

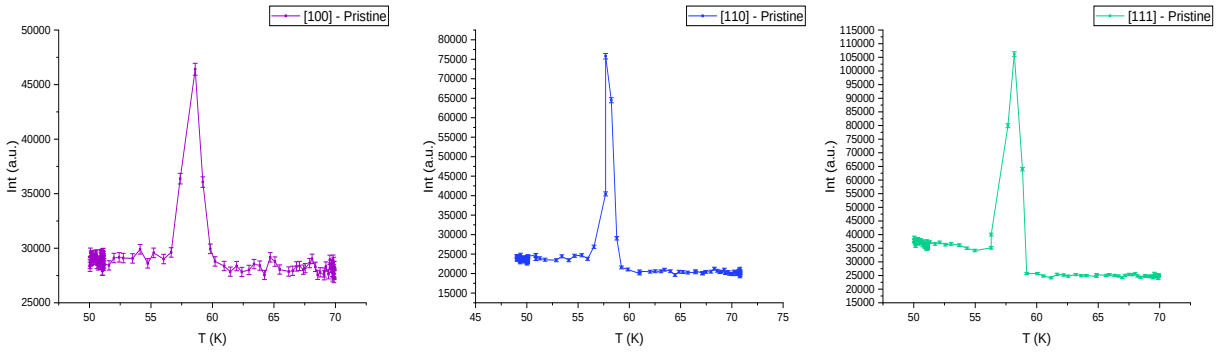

Figure 1: kinetic scans in the three main crystallographic directions for pristine Cu_2OSeO_3. The increased intensity on the lower temperature side indicates the presence of a metastable skyrmion state produced by the field cooling at 7K per minute through the skyrmion equilibrium phase.

With these scans it has been possible to identify the skyrmion equilibrium phase in the pristine sample and its extent in temperature. It can be observed that the volume fraction of the metastable skyrmion state is dependent on the crystallographic direction.

Lifetime measurements have been performed in the [110] and [111] direction only, since the population of the metastable skyrmion phase in [100] direction appeared to be too low to perform such measurements.

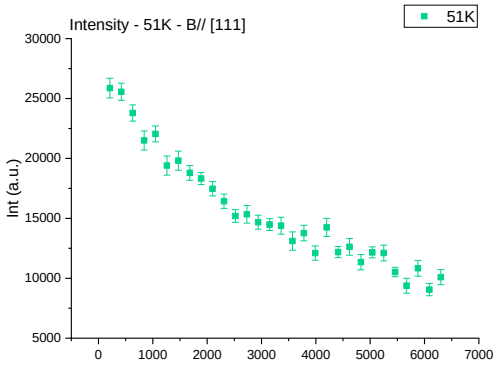

Figure 2: Lifetime measurement in the [111] crystallographic direction for pristine Cu_2OSeO_3.

For the lifetime measurements, series of rocking scans over time at selected temperatures have been performed.

Secondly, the 12% substituted sample has been mounted and the same procedure has been applied.

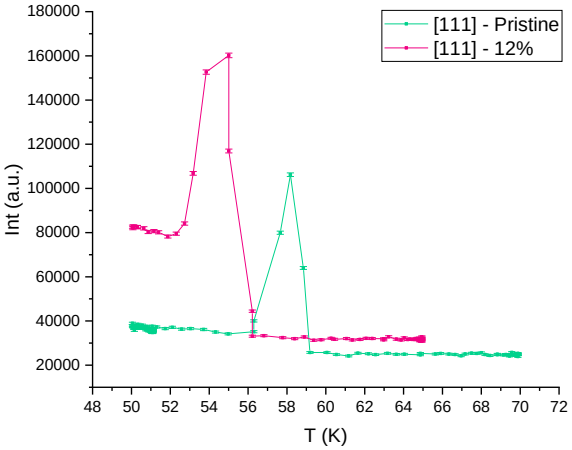

Figure 3 comparison between kinetic scans along the [111] direction for pristine and 12% substituted sample. The introduction of non-magnetic ions is observed to favour the stabilization of a more populated metastable skyrmion phase.

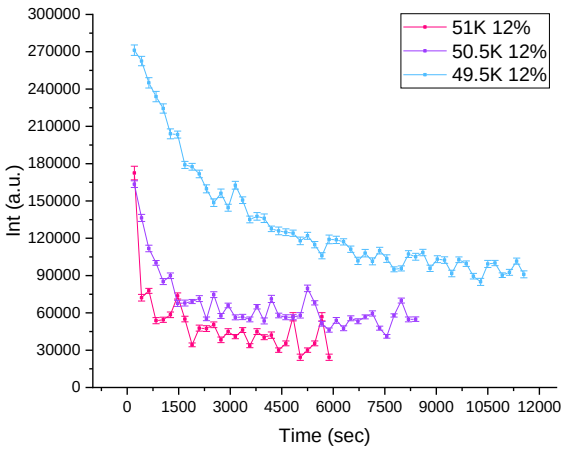

Figure 4: Lifetime measurement for the 12% substituted sample at different temperatures.

As shown in fig.3, the metastable skyrmion phase in the 12% substituted Cu_2OSeO_3 is characterized by an increased population, and by a shift of the equilibrium skyrmion pocket to lower temperatures. In fig.4 it is possible to observe the different lifetime behaviour associated with different temperatures.

Conclusion:

The experiment has been very successful: it has been possible to fully characterize the dependency of the metastable skyrmion lattice, both on the crystallographic direction, and on the introduction of doping.

Further analysis of the data will provide information on the perfection of the metastable skyrmion lattice and its behaviour over time.

With these data we have completed the characterization of the non-magnetic doping effect on the skyrmion phase.