Centre for Neutron Scattering

Seminar of Dr Dr Samuel Yick, University of Auckland

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Controlling Skyrmions in Cu_2OSeO_3 through Doping; an insight to the relationship between crystal structure and magnetic ordering

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Magnetic Skyrmion lattices (SkL) are topologically protected spin ordering due to their quantised winding number. This, along with other helimagnetic orderings offer a plethora of fascinating phenomena for fundamental research and applications.[1] Cu_2OSeO_3 is an insulating multiferroic material that has shown to host SkL at specific conditions.[2] It possesses a magnetic structure with both ferromagnetic (FM) and antiferromagnetic (AFM) super exchange interactions being present and has a 3-up 1-down ferrimagnetic arrangement of Cu^{2+} ions.[3] The lack of inversion symmetry in the corner shared O-Cu_4 tetrahedra lattice results in an appreciable DMI between Cu^{2+} sites; this competes with FM/AFM interactions leading to spin canting formation of helical/conical spin textures at different fields and temperature conditions.[2] Due to the absence of a crystallographic transformation throughout the temperature range alongside the formation of the magnetic phases, it has been commonly assumed that the structure plays a passive role in magnetic ordering.[3] Yet, published studies have challenged this assumption. The work by Wu *et al.* shows that internal expansion leads to a decrease in T_c for the helical to paramagnetic transition.[4] Furthermore, observation by Nishibori *et al.* shows that by applying a pressure, T_c increases as the unit cell volume contracts.[5]

In this work, we incorporated both magnetic and non-magnetic ions into the Cu_2OSeO_3 host. The inclusion of Te into the Se-sites and Co into the Cu-sites changed the crystal and magnetic structure, respectively. The skyrmion dynamics and spin interactions within these materials were then studied using synchrotron X-ray powder diffraction, neutron powder diffraction, and magnetometry. Using X-ray powder diffraction at the Australian synchrotron, we identify a structural anomaly where the Cu network distorts around the paramagnetic-helical ordering temperature. This alludes to the possibility that structure is also a contributing factor to the magnetic ordering of the material despite the lack of structural phase transition. Through neutron diffraction, we found that the magnetic response of the spin ordering is highly susceptible to chemical doping. This implies that the rigidity of the spin coupling might be affected by both magnetic and non-magnetic dopants. We also studied whether doping changed the universality class through magnetometry. These results give us insight as to the relationship between materials structure and magnetic ordering. This highlights the importance of the crystal structure and an avenue to design novel spintronic materials.

[1] S. Mühlbauer, *et al.*, Science 323, 915 (2009).
[2] S. Seki, *et al.*, Science 336, 198 (2012).
[3] J.-W. G. Bos, *et al.*, Phys. Rev. B 78 (9), 094416 (2008).
[4] H. C. Wu, *et al.*, J. Phys. D: Appl. Phys. 48, 475001 (2015).
[5] E. Nishibori, *et al.*, Phy. Rev. B 102, 201106 (2020).

Speaker Blurb

Dr Samuel Yick is an Australian scientist who specialises in advanced material. His fields of interest include spintronic materials, nanomaterials, and surface engineering. He completed a BSc in Nanotechnology from the UNSW and obtained his PhD from the University of Sydney in the area of carbon nanomaterials. He held a joint postdoctoral fellowship at CSIRO and the University of Sydney from 2015-2018, working on the fabrication of inorganic plasmonic nanoparticles for heterogeneous catalysis and energy storage applications. He then held a 2-year postdoctoral fellowship co-funded by the University of New South Wales and ANSTO where he focused on studying multiferroic materials using neutron scattering and magnetometry. Since 2021, he has been employed as a Senior Research Fellow at the University of Auckland, to lead a Marsden project on studying the dynamics of skyrmion lattices in Cu_2OSeO_3.