Experimental report

25/01/2024

Proposal: **5-41-1220** **Council:** 4/2023

Title: Investigation of the high-pressuretuning of magnetism in kagome metal HoMn6Sn6

Research area: Physics

This proposal is a new proposal

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Experimental team: PIKESH PAL

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Samples: HoMn6Sn6

Instrument	Requested days	Allocated days	From	To
D10	7	7	20/11/2023	27/11/2023

Abstract:

Strongly correlated magnetic Kagome material HoMn6Sn6 shows topological electronic properties below the pressure tunable spin reorientation transition at ~ 200K. We propose a systematic single crystal neutron diffraction study on HoMn6Sn6 in high pressure as well as in ambient condition to understand the correlation among different competing magnetic interaction with band topology in the system.

Investigation of the high-pressure tuning of spin reorientation transition in kagome topological metal $HoMn_6Sn_6$

Motivation and Scientific background

Pressure is one of the clean and unique external parameters to understand the complex intercoupling of different degrees of freedom that are responsible for complex magnetic and electronic phases of quantum matter [1-5]. The topological Kagome materials RMn_6Sn_6 are in extreme focus for their rich semi-explored magnetic phase diagram with competing magnetic interaction in different temperature regime [6-8]. Some of these magnetic phases are favorable to the topological electronic phases. The correlation of topological electronic properties and magnetic correlations are difficult to understand due to the coexistence of different competing phases simultaneously. Therefore, understanding on stabilization and tuning of magnetic phases favorable to topological properties are highly interesting. Recently, two candidates of the family RMn_6Sn_6 (R= Tb and Ho) are studied under hydrostatic pressure [9,10]. Though pressure evolution of low temperature magnetic phases and its correlation with different topological electronic parameters are evident in their studies but they are not explored microscopically with neutron diffraction. Our prime goal is to understand the pressure evolution of competing magnetic correlation to understand the microscopic P-T phase diagram in the low temperature ordered state with high pressure muon and neutron probe to understand the correlation among competing magnetic interaction and band topology.

Previous results:

We performed pressure-dependent in-house magnetization and neutron scattering experiments on our high-quality single crystals, which were grown by the flux method.

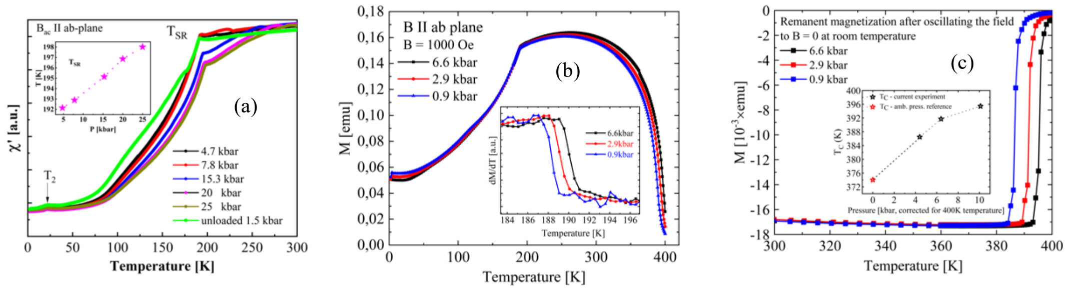

Fig 2: High pressure measurement (H//ab) of $HoMn_6Sn_6$ single crystal; (a) temperature dependent AC magnetic susceptibility (inset: T_{SR} v. Pressure in kbar), (b) temperature dependent DC magnetization in SQUID (inset: magnified view near about SR), (c) temperature dependent Remanent magnetization (T_C vs. Pressure in kbar),

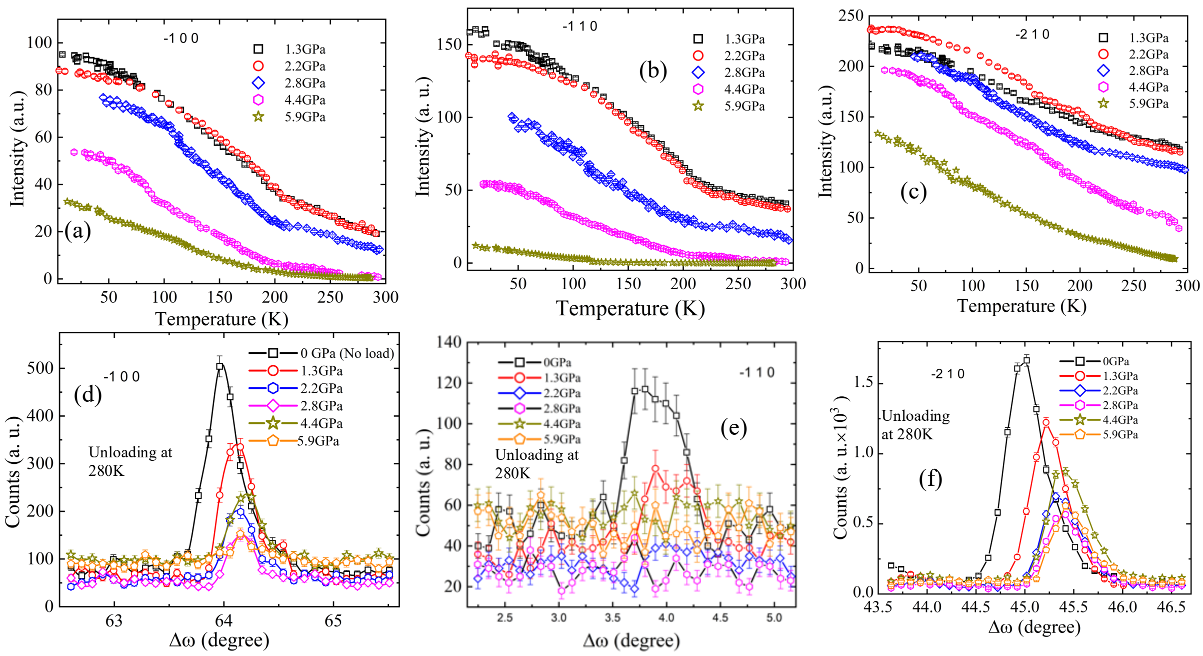

Fig2: Integrated intensity vs. temperature of a) (-1,0,0), b) (- 1,1,0) and c) (-2,1,0) reflections. Pressure unloading profile of rocking curve of d) (-1,0,0), e) (- 1,1,0), f) (-2,1,0) reflections

The results from both experimental techniques collectively demonstrate a non-monotonic increase in the transition phenomena up to 2.2 GPa. We followed three major accessible (hk0 configuration) reflections: (-1, 0,0), (-1,1,0), and (-2,1,0) to track the pressure evolution of the spin reorientation transition using a Paris-Edinburgh pressure cell at D10+. Among the three probed reflections, (-1,0,0) and (-1,1,0) are magnetically dominated, whereas (-2,1,0) is dominated by nuclear contribution. The temperature variation of the integrated intensity of the measured reflections shows the spin reorientation transition by a clear change in slope (fig. 1(a,b,c)) at 200 K for 1.3 GPa and 2.2 GPa applied pressure. Beyond 2.2 GPa, the change in slope becomes less prominent, and (-1,1,0) is suppressed at 5.9 GPa. The temperature variation of the integrated intensity of -1 1 0 shows gain in intensity (fig. 2) below 100 K. As the peak (-1,0,0) has significant magnetic contribution, there is a possibility of both structural and magnetic phase transitions. Though it is not a legitimate argument to conclude the transition as we only have omega scans of each reflection. The unloading characteristics of each reflection show that each peak retains its shape (fig. 1(d, e, f)) under pressure removal. So, there may occur some change in lattice when the pressure is applied and the effect is reversible under pressure (fig 3(a,b)). Thus, we believe a legitimate conclusion can be found if we investigate further the average crystal and magnetic structure under applied pressure via powder diffraction.

Future plans

During our last measurement, we compelled to measure using hk0 orientation due to availability of suitable crystal suitable for PE cell in h0l orientation and restricted coverage of out of plane reflection as we were using PE cell. Thus, we missed another two reflection (1,0,0) and (1,0,1) that are almost purely magnetic origin. We also could not measure the temperature variation of integrated intensity of magnetically dominated reflection for reference. Therefore, with the past experience of handling PE cell, we propose to measure the system with h0l configuration with the same pressure condition but with less temperature window form 80K-250K. This time we will use mainly analyzer and point detector to have Q-scan and microstrip 2d point detector only to align the sample using nuclear dominated reflection.

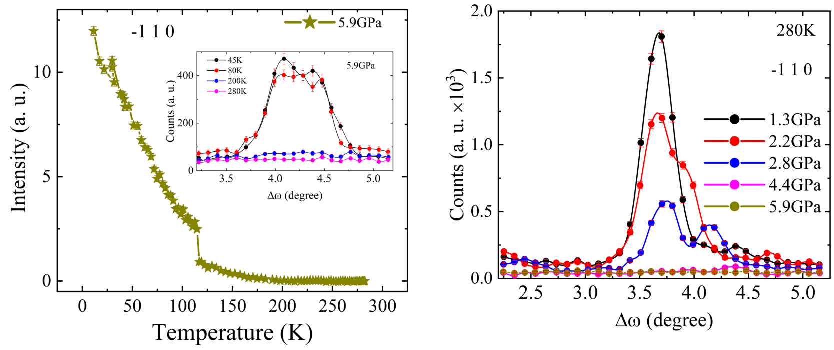

Fig 3: Integrated intensity vs. temperature of a) (- 1,1,0) reflection at 5.9GPa and inset shows rocking curve for 5.9GPa at different temperature. b) rocking curve at 280K for different fixed pressure

We would also like to perform neutron powder diffraction study using the powder prepared from the single crystals of the same batch that was used for our previous study. The study will enable us to conclude the occurrence of any kind of phase transition as intricated by the single crystal neutron diffraction study performed at D10+. The magnetization study suggests that the ferrimagnetic transition at 374K (ambient pressure) varies significantly (Fig 1(b)) and goes beyond temperature window of the magnetization measurement. Our plan to determine the average crystal and magnetic structure under applied pressure to have understanding about the pressure dependency of lattice parameter as well spin anisotropy. Therefore, we would like to perform pressure dependent powder diffraction experiment at high intense neutron powder diffractometer D20 as a continuation of the measurement performed at D10+. We would like to check complete loading and unloading behavior of crystal and magnetic structure using PE pressure cell at 300K in the same pressure range as D10 experiment.

References

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