Experimental report

02/12/2022

Proposal: **5-31-2754**

Council: 4/2020

Title: The effects of long-range magneticcorrelations on the magnetocaloriceffect in Fe2P

Research area: Physics

This proposal is a new proposal

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Local contacts: Nina-Juliane STEINKE

Samples: Fe2P

Instrument	Requested days	Allocated days	From	To
D33	3	3	14/05/2021	17/05/2021

Abstract:

Compounds based on Fe2P, such as (Fe,Mn)2(P,Si), are among the most promising candidates for magnetic refrigeration around room temperature. An area of research that has potential to reduce the amount of energy necessary for refrigeration. Fe2P is especially well suited, since substitutions to Fe1-xMnxP1-ySiy yields tuneability of both the ferromagnetic transition and magnetic moment of the compound. Fe2P based compounds can also give high refrigeration capacities without the use of rare earth elements. Therefore, the compound Fe2P is an excellent model system to understand the transitions that occur in Fe2P based compounds. Previous studies have shown fluctuations in the magnetic structure and appearances of magnetic domains close to the magnetic transition. This would be ideal to study with small angle neutron scattering (in the region of 0.01 - 1.0 Å-1) as it covers the length scales of the observed magnetic domains.

EXPERIMENT TITLE: "The effects of long-range magnetic correlations on the magnetocaloric effect in Fe_2P"
PROPOSAL NUMBER: (5-31-2754)
EXPERIMENTAL TEAM: Johan CEDERVALL, Mikael S. ANDERSSON and Pascale P. DEEN
INSTRUMENT: D33

Introduction

Global warming and an increasing industrialisation of the world increases the need for efficient cooling for both refrigeration and heat pumps. An energy efficient alternative to achieve this is magnetic refrigeration, which is based on an effect where a material changes its temperature when being magnetized [1,2]. Compounds based on Fe_2P, such as $(Fe,Mn)_2(P,Si)$, are among the most promising candidates for room temperature magnetic refrigeration via the magnetocaloric effect with great potential to reduce the amount of energy necessary for refrigeration. An optimised magnetocaloric material displays a first order ferromagnetic transition with enhanced entropy change. $Fe_{1-x}Mn_xP_{1-y}Si_y$ yields tuneability of both the ferromagnetic transition and magnetic moment of the compound [3] thus further optimising the magnetocaloric effect. To fully understand the interactions a model system of Fe_2P have been studied with diffraction and Inelastic Neutron Scattering (INS), and the results showed temperature dependent scattering features at low Q, which could only be resolved with Small Angle Neutron Scattering (SANS) [4].

Experimental details and analysis

Powder samples of Fe_2P were synthesised using the drop synthesis techniques followed by sintering and annealing at 1373 and 1073 K, respectively [5]. The samples were pre-characterized XRD and magnetic measurements. Neutron diffraction have also been employed at the instrument Polaris at ISIS neutron and muon source to study the local structure. The SANS experiments were performed using the instrument D33 at temperatures ranging between 10 and 300 K with and without and applied magnetic field of 5 T perpendicular to the beam direction.

Results

The integrated data have two distinct regions, the low Q Porod region, which is linear in a log-log plot, and the high Q region where magnetic features are growing as a function of temperature. The data can be integrated in two discrete directions, parallel and perpendicular to the applied magnetic field. When comparing the two directions, severe differences in the Porod region (low Q) can be observed in a zero field environment, shown as a azimuthal integration around Q = 0.01 $Å^{-1}$, in figure 1 below. This effect comes only from the samples as no similar trends are observed in the empty beam measurements. The effect is also clearly temperature dependent, and not as strong at 300 K as in 10 K. It might therefore be caused of a change in the particles du toe the crystallographic changes in *c*/*a*-ratio, that causes the voids between the particles to change dimensions. The voids are probably in a size regime that we see in the Porod region, therefore, this can be considered an indirect result of the magnetisation. Upon applying a magnetic field, the effect becomes less prominent with temperature, which makes sense when considering that the voids should not be altered by internal magnetisation of particles.

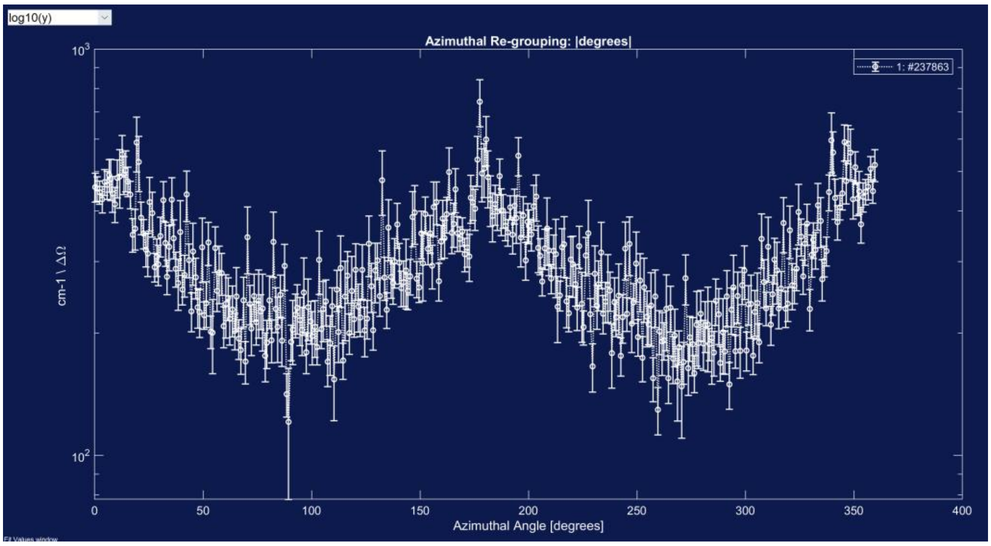

Figure 1. Azimuthal integration around Q = 0.01 Å^{-1} at 10 K.

In the high Q region, there are clear differences in the shape and magnitude of the "peaks" as a function of both temperature and applied magnetic fields, the observed features can be fitted with a number of different models. In the future, advanced microscopy will be used to give a model that will then be implemented in the fitting of the SANS data. In the end, the results, together with complementary magnetic Pair Distribution Function analysis, will advance the understanding of the Fe_2P- system.

Acknowledgements

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References

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