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実験課題番号 Project No. 2009A0089 実験課題名 Title of experiment Neutron scattering study of high-Tc superconductors 実験責任者名 Name of principal investigator Masatoshi Arai 所属 Affiliation J-PARC Center	装置責任者 Name of responsible person Kenji Nakajima 装置名 Name of Instrument/(BL No.) AMATERAS (BL14) 利用期間 Dates of experiments 2011/02/04-06 2011/03/08-11

1. 研究成果概要(試料の名称、組成、物理的・化学的性状を明記するとともに、実験方法、利用の結果得られた主なデータ、考察、結論、図表等を記述してください。

Outline of experimental results (experimental method and results should be reported including sample information such as composition, physical and/or chemical characteristics.

Spin dynamics of metallic $(Mn,Fe)_3Si$ near the ferromagnetic-antiferromagnetic phase boundary

Sample

Composition: $Mn_{1.4}Fe_{1.6}Si$. (Fig. 1)
Magnetic property: Ferromagnetic below T_C = 150 K, and spin-canted below T_{cant} = 80 K.
Form: Single crystal with ϕ10×40 mm. (Fig. 2)

Experimental procedure

Sample alignment: (*h*, *k*, *k*) horizontal plane with a^* = 1.10 $Å^{-1}$ and b^* = 0.78 $Å^{-1}$. (Fig. 2)
Incident energy (multi-E_i): E_i = 93.9, 23.6, 10.5, and 5.9 meV.
Crystal angle: 60°covered with 10-deg step.
Temperature: T = 100 K (ferromagnetic phase).

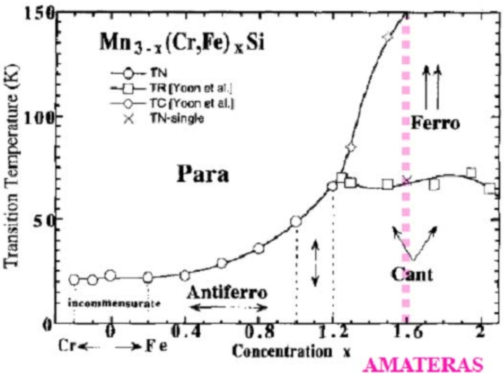

Fig. 1. Magnetic phase diagram of $(Mn,Fe)_3Si$.[1]

$Mn_{1.4}Fe_{1.6}Si$, (*h*, *k*, *k*) scattering plane

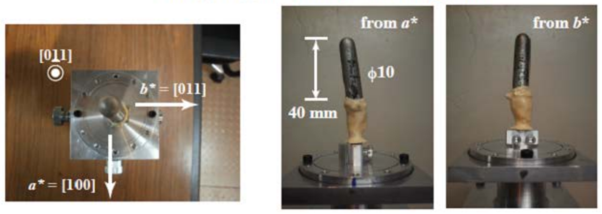

Fig. 2. Single crystal of $Mn_{1.4}Fe_{1.6}Si$ used in INS experiment on AMATERAS.

Results

As expected, ferromagnetic fluctuations (most likely spin waves) were observed in a wide energy range. Moreover, we found antiferromagnetic fluctuations in an energy range of 2-6 meV in the ferromagnetic phase. In other words, ferromagnetic and antiferromagnetic fluctuations coexist even if this compound is a ferromagnet in the ground state. As per the magnetic phase diagram in Fig. 1, the observed antiferromagnetic component is probably originated from the small *x* region, where Mn-Mn antiparallel spin correlations are dominant. Upon increasing *x*, the ferromagnetic component is introduced through Mn-Fe parallel spin correlations. Because of the presence of the spin-canted phase in this composition (Fig. 1), a energetically competed state is expected around the antiferromagnetic-ferromagnetic phase boundary ($x \sim 1.2$).

In order to clarify the characteristic magnetic phase transition, further investigation from the spin-dynamics viewpoint is required in a wide (Q, ω) and temperature region.

Ref. [1] H. Miki *et al*., Physica B **237-238**, 465 (1997).

1. 研究成果概要(つづき) Outline of experimental results (continued).

Spin gaps and in-plane anisotropy of spin excitations in the underdoped $Ba(Fe_{1-x}Co_x)_2As_2$ superconductor

Recent discoveries of iron-based superconductors such as $LaFeAsO_{1-x}F_x$ and $Ba_{1-x}K_xFe_2As_2$ have generated tremendous interests in the studies of high-T_C superconductivity. For iron-based superconductors, the presence of static collinear antiferromagnetic (AF) ordering in their parent compounds and the remarkably similar doping dependent phase diagram to that of the high-T_c copper oxides suggest that AF spin fluctuations may play an important role in the superconductivity of these materials. Thus, it is essential to understand the interplay between magnetism and superconductivity via microscopic probes. Especially the underdoped region of the phase diagram is very interesting since superconductivity and magnetic order can coexist and compete on a microscopic scale. We carried out a detailed study of spin excitations in the underdoped $Ba(Fe_{1-x}Co_x)_2As_2$ superconductor (x=0.05, T_C~16K, T_N~56K, T_S~68K) via inelastic neutron scattering at the cold neutron chopper spectrometer AMATERAS at J-PARC. The obtained main results are summarized in the following sections,

(1) The openning of a small spin gap E_g=2 meV in the superconducting state is confirmed (see Fig. 3).
(2) Spin excitations up to energy transfer E_n=67 meV in three difference phase regimes have been obtained via the multi-E_i mode at a cold neutron chopper spectrometer (see Fig. 4).
(3) The analysis of spin excitations have been undertaken based on both the linear spin wave model and the spin diffusion model. Both models yield very similar fitting results.

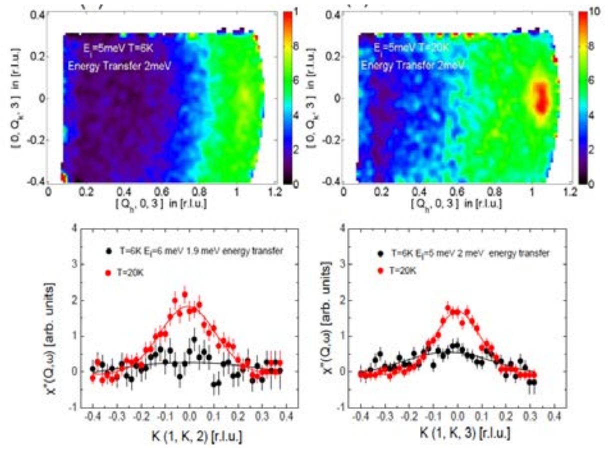

Fig. 3. The spin gap in the superconducting state of the underdoped $Ba(Fe_{1-x}Co_x)_2As_2$.

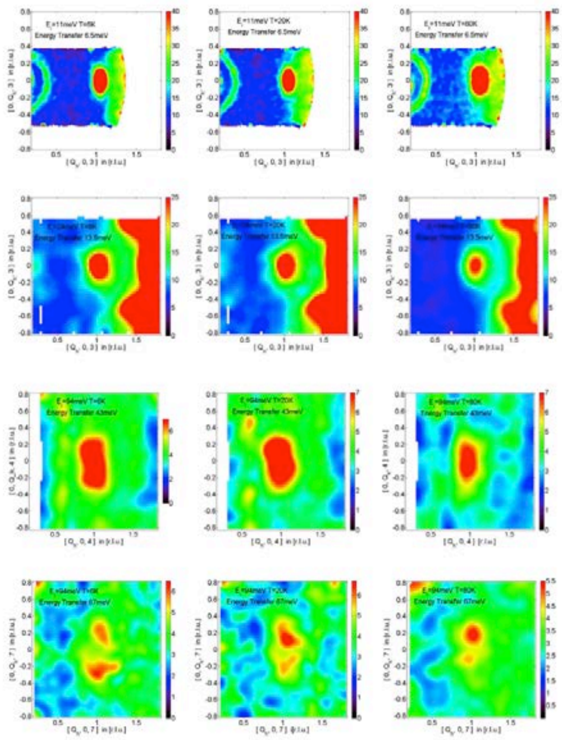
Fig. 4. Spin excitations in three difference phase regimes measured with the multi-E_i mode at AMATERAS.

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