Experimental report

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Proposal: 5-54-261 **Council:** 4/2018

Title: Study of the in-plane magnetic structure of thin magnetic multilayersat phase boundary of percolation transition

Research area: Methods and instrumentation

This proposal is a continuation of 5-54-182

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Samples: Fe/Ge multilayers

Instrument	Requested days	Allocated days	From	To
D17 He3 Spin Filter	6	5	06/09/2019	11/09/2019
D33	5	5	13/09/2019	18/09/2019

Abstract:

Neutron polarizing supermirrors are increasingly important devices for polarized neutron scattering experiments and need to extend the bandwidth of the polarization to meet a variety of research demands. The extension of the bandwidth is limited by the magnetic phase transition occurring at a certain thickness of the magnetic layer. The current proposal is aimed to verify whether this phase transition is understood by the percolation theory. Off-specular and grazing incidence small angle scattering with polarized neutrons can probe the dependence of the magnetic lateral correlation length on the Fe thickness around the critical point. The obtained data, together with the SQUID measurements, would give access to the information on how the magnetization is developed at early stage of the layer growth.

Study on in-plane magnetic structure of thin magnetic multilayers at phase boundary of percolation transition

Experimental report 5-54-261

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Neutron polarizing supermirror is one of the most important optical devices for polarizing neutron beam. To meet a variety of research demands, polarizing supermirrors need to extend the bandwidth of the neutron-spin polarization. The spontaneous magnetization of the Fe/Ge multilayer, however, disappears when the Fe layer thickness is reduced to 2-3 nm because the Curie temperature becomes to be less than room temperature. This limits the m-value of the polarizing supermirror because the multilayer fails to form a high and low contrast in the scattering length density profile for spin-up and -down neutrons. This proposal was aimed to observe the behavior of the magnetic moments on the boundary between the ferromagnetic and paramagnetic phases and the magnetic interlayer exchange coupling across the Ge spacer for this Fe/Ge multilayers.

Figure 1 shows the scattering geometry, scattering image, and magnetic scattering intensity profile projected onto the q_y-axis of the grazing-incidence small-angle scattering neutron scattering measurement performed on the D33

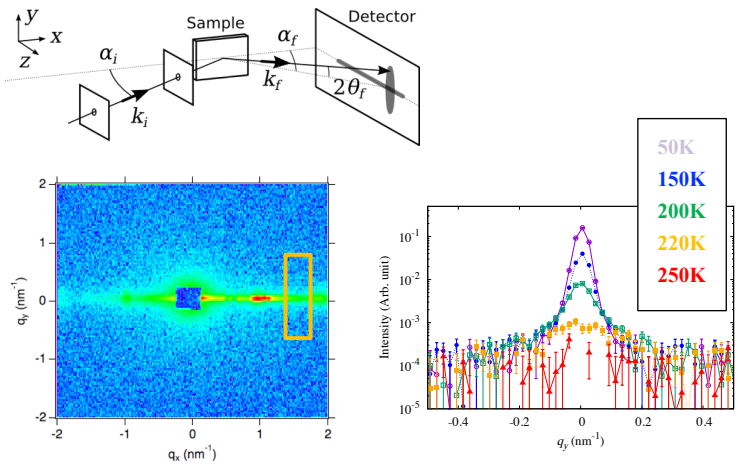

Figure 1: Scattering geometry, scattering image, and magnetic scattering intensity profile projected onto q_y-axis in the square area on the scattering image for Fe/Ge multilayer consisting of 1000 bilayers with a d-spacing of 9 nm.

small angle diffractometer. This result showed that the in-plane length of the magnetic domains was reduced with increasing temperature and that the correlation of moments was finally lost at 250 K, close to the phase boundary.

To find evidence of the correlation of moments between neighboring Fe layers, the polarized neutron off-specular measurement was performed for the Fe/Ge periodic multilayer with 30 bilayers (Fe: 5 nm, Ge: 1.8 nm) on the D17 polarized neutron reflectometer. The observation of a half-order superstructure scattering in the off-specular scattering image shown in Fig. 2 provides direct evidence of an antiferromagnetic order between the neighboring Fe layers. The origin of the magnetic interlayer exchange coupling in the ferromagnetic/semiconductor system has not been fully revealed despite investigations intensively conducted. Further study is needed to obtain insight into the mechanism that controls the interlayer exchange coupling across a semiconductor spacer.

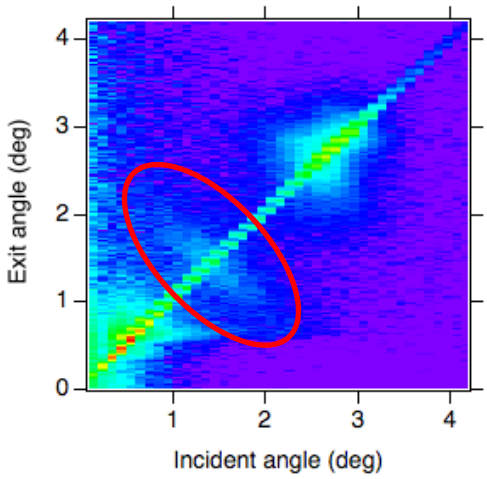

Figure 2: Measured polarized neutron off-specular image of Fe/Ge multilayer with 30 bilayers (Fe: 5 nm, Ge: 1.8 nm). Neutron spin state: (−+), External field: 17 Oe, Temperature: 18K. Half-order superstructure scattering is marked in red.

The precise analysis of the data with simulation for both measurements is currently performed, leading to a good understanding of the behavior of moments in the current system.