Twisted surface states in the magnetic structure of MnSi thin films

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Surface states, finite size effects and anisotropy play important roles in stabilizing complex magnetic textures in chiral magnetic thin films that could ultimately be exploited for spintronics applications. In our previous polarized neutron reflectometry measurements, we demonstrated the existence of a new surface state in chiral magnetic thin films [1]. This state is predicted to persist well above the typical saturation field found in bulk chiral magnets. To compare with the analytical expressions for this state [2], we conducted SQUID magnetometry and polarized neutron reflectometry (PNR) on a 26.7 nm thick MnSi sample grown on Si(111) (see Ref.[3] for details about the growth).

SQUID magnetometry of MnSi/Si(111) is complicated by the large diamagnetic contribution from the Si substrate. One typically determines the substrate contributions from the high-field portion of the *M*-*H* loops, far above the saturation field. However, in the case of MnSi, the high-field susceptibility is non-zero, which makes it impossible to separate the film's contribution from that of the substrate with this method. We used PNR to measure the high-field susceptibility of our MnSi thin films for proper subtraction of the substrate contribution to the SQUID data.

We conducted measurements on the D3 reflectometer mounted with the M5 superconducting magnet cryostat.[4] An Fe/Si supermirror and a Mezei-type precession spin flipper produced a neutron beam with a spin polarization in excess of 95%. From the measured spin-up R_+, and spin-down, R_-, reflectivities, we calculated the spin-asymmetery $\alpha = (R_+ - R_-)/(R_+ + R_-)$. The first peak in α at low scattering vectors $0.08 < q < 0.17$ nm provides an excellent measure of the average magnetization across the film. In order to extract the magnetization, we fitted the measurement of α in the inset of Fig. 1 to simulations calculated with SimulReflec.

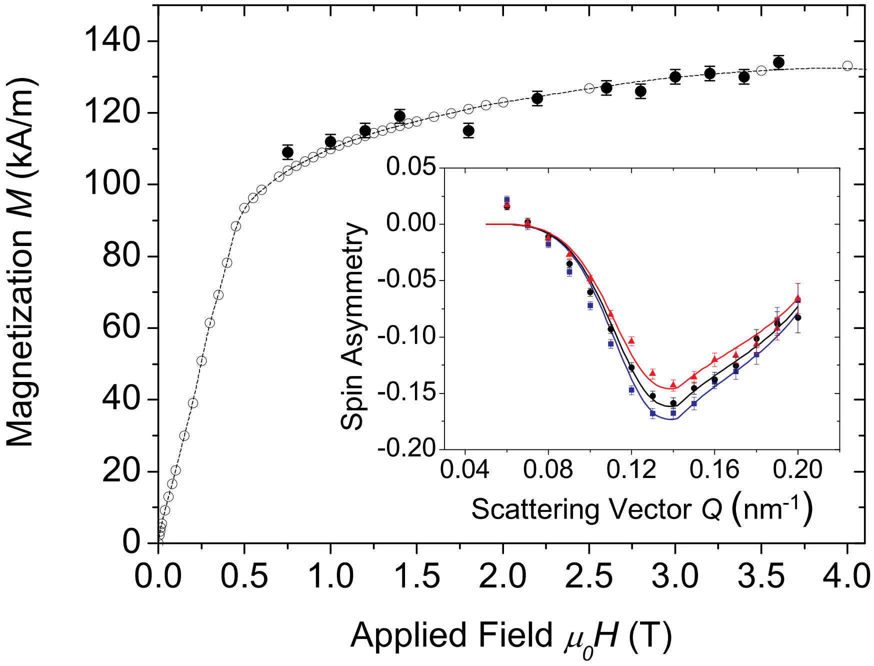

Figure 1 The inset shows the three representative measurements of the PNR spin-asymmetry α from a 26.7 nm thick MnSi film measured at a temperature of 40 K in magnetic fields of 1.0 T (red triangles), 2.2 T (black circles) and 3.2 T (blue squares). The lines are fits to the data. The magnetization obtained from the fits is plotted in the main figure (filled points) which enables a subtraction of the substrate magnetization from the SQUID magnetometry data (connected open points). (Figure taken from Ref.[2])

The structural parameters in the simulations are obtained from the x-ray reflectometry and PNR measurements presented in Ref. [5] The magnetization profile is calculated from the theoretical model for the surface states presented in Ref. [2] by accounting for the surface twists at both interfaces. The sole parameter used to fit the PNR data in the inset of Fig. (1) is the average magnetization plotted for various fields in the main figure. The value for the substrate susceptibility subtracted from the SQUID measurements is then adjusted to bring the magnetometry measurements into agreement with the PNR data, as shown by the open circles in Fig. (1).

At low temperatures, the magnetic field dependence *H* of the deviation in the magnetization from the saturated value follows the theoretically expected $\Delta M \sim H^{3/2}$ for chiral twisted surface states [2]. However, as the temperature increases, this power law gradually approaches the $\Delta M \sim H^{1/2}$ dependence expected from spin-fluctuation theory.

References

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