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Magnetic fans, propellers and twist structures: Micromagnetic simulations to describe polarised neutron reflectometry data

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Can simple mechanical rotation in an applied field be used as a tool to twist the spin-structure of a magnet at nanometre scales?

Here we present a simple 1D micromagnetic simulator (microM-ref1D) which is integrated with the Ref1D software for polarised neutron reflectometry to provide self-consistent fitting to magnetic thin film data in different field rotations. This is parametrised in terms of the fundamental exchange interactions, interface exchange terms, and anisotropy of the film layers.

Using this new software approach, we show that the exchange interaction at a ferromagnetic/antiferromagnet interface, when combined with a mechanical rotation of the film in an applied field, can be used to manipulate magnetisation at the nanoscale, to wind a variety of distinctive 1D magnetic structures: exchange springs, fans, propellers and solitons. Each of these structures can be identified by its unique finger print in the Q-dependent neutron spin flip signal of the reflection pattern. The winding angles are determined, primarily, by the exchange stiffness term which is related to the exchange interaction.

A proof-of-concept experiment using the Platypus polarised reflectometer at the ACNS was conducted to explore the magnetic winding in the well-characterised Ni80Fe20/⊠-Fe2O3 thin film system[1,2]. After field-cooling and rotation, the presence of a non-collinear component in the spin structure was detected using neutron spin flip analysis. We rule out slow relaxation effects using time-resolved rebinning of the time-of-flight data. We find we can describe the data well using the 1D micromagnetic model for the twist,[3] with the caveat that one additional parameter is needed to describe domain formation. These promising results imply that the mechanical rotation method has the potential to generate numerous stable and exotic non-collinear magnetic structures. Furthermore, the 1D micromagnetic simulation approach is a general strategy that can be widely applied in polarised neutron reflectometry fitting to constrain complex models. The benefit using this physical model, is that it also simultaneously describes or predicts other testable magnetic properties such as the coercive field, magnetization, Curie temperature and ferromagnetic resonance frequency to provide a holistic description of the magnet.

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Topics

Magnetism and Condensed Matter

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