Synthetic Antiferromagnet Spintronics

Abstract: We investigate the dynamics of bimerons and skyrmions in synthetic antiferromagnets. Synthetic antiferromagnets are advantageous for decreasing the bimeron and skyrmion Hall angles and enabling texture detection through local magnetization, bypassing the need to rely on the Neel order parameter. Using micromagnetic simulations and Thiele's equation approach we calculated the bimeron/skyrmion Hall angles.

Motivated by the differences between of skyrmions and their in-plane magnetized analogues – bimerons – in synthetic antiferromagnets (SAFs), we investigated their current-driven dynamics employing micromagnetic simulations and analytical Thiele's equation approach. We considered SAF structures consisting of several antiferromagnetically coupled layers. For bimerons, we considered additional ferromagnetic layers with fixed in-plane magnetization adjoined to the SAF, see Fig. 1.

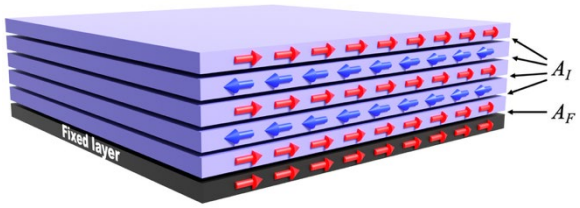

Fig. 1 Schematic representation of a 5-layer SAF for bimerons stabilization with one fixed layer.

In this case, the effect of exchange bias from the fixed layer is similar to a magnetic field, i.e., increasing the strength of exchange bias reduces the bimeron's size in the adjacent layer. This translates through the rest of SAF via interlayer antiferromagnetic exchange. Since the strength of the exchange bias can be modified by changing interlayer exchange coupling between a fixed layer and the SAF, this configuration offers additional control over the size of the spin texture and its motion. However, since this effect diminishes with distance from the fixed layer, bimerons are smaller at the bottom and become larger at the top layers of the SAF. To prevent this asymmetry and increase the number of layers where the bimeron size is controlled by this effect, we also considered a configuration with the second fixed layer added on top of the SAF.

We have shown that in the uncompensated SAFs, bimeron and skyrmion Hall effects diminish in the bulk limit, which can be understood by the decrease in the averaged topological charge with increasing the number of layers. However, bimeron/skyrmion Hall angles have a quite nonmonotonic dependence on number of layers N with an extremum for a certain N. The bimeron (skyrmion) Hall effect vanishes for compensated SAFs with two fixed layers, whereas the SAFs with only one fixed layer exhibit nonzero Hall angles, which becomes more evident when interlayer exchange interaction is weak. Remarkably, we identified the conditions when bimerons and skyrmions in uncompensated SAFs can move faster than in antiferromagnets. Depending on spin-transfer torque strength, spin texture velocities in uncompensated SAFs increase or decrease with the number of layers. Finally, we have studied finite temperature effects on bimeron and skyrmion dynamics and stability in SAFs by employing stochastic Landau-Lifshitz-Gilbert equation with white-noise correlated random magnetic fields. Our findings offer a comprehensive understanding of the topological magnetic texture dynamics in SAFs, which is essential for designing topological spin-texture based logic and memory nanodevices.

Furthermore, the interplay of these spin textures with spin-orbit coupled substrates [1] would be interesting to study as well in SAFs, since the previous studies mainly focused on the Hall responses of skyrmions coupled to heavy-metal substrates. Finally, this study can be extended to the investigation of domain-wall bimerons [2] and their dynamics in synthetic antiferromagnets. These findings will deepen the understanding of SAF dynamics and offer guidance for their implementation in skyrmion- and bimeron-based spintronic devices.

References

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