Nonuniform Softening of Spin Waves as a Tool for *In Operando* Tuning of Band Gaps in Two-Dimensional Magnonic Crystals

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Magnonic crystals (MCs) are the magnetic counterpart of photonic and phononic crystals, with spin waves acting as information carriers [1]. Here we study bicomponent MCs based on permalloy (cobalt) thin film with cobalt (permalloy) inclusions arranged in sites of a two-dimensional (2D) hexagonal lattice. Our theoretical approach uses the Plane Wave Method (PWM) adapted to the treatment of 2D MCs with in-plane magnetization [2]. For both material compositions, i.e. Co in Py and Py in Co, we found some peculiar effects in the spin-wave spectrum appearing at the low external magnetic field. First of all, spin waves are excited in Co much more likely than in Py, regardless the matrix or rods are made from Co. In other words, the reversal of modes occurs, i.e. modes which are excited mostly in the material with higher saturation magnetization have lowest frequencies then modes excited in the material with low saturation magnetization. This leads to the mode-dependent softening of spin waves and finally opens a new possibility for the control of band gaps just by changing the external magnetic field magnitude.

The softening of spin waves is also accompanied by the wave-vector dependent change of the concentration factor, which measures in which material the spin wave is exited mostly. Thus the concentration of the spin wave in Co or Py is highly nonuniform even within the particular mode. This effect brings an additional contribution to the bandwidth and, consequently, to the possibility for the opening of magnonic gaps.

We address these features to the growing influence of the demagnetizing field combined with the spin-wave profile [3]. Since the demagnetizing field enhancement, e.g. caused by the squeezing of the MC, is of crucial importance for the non-uniform mode softening, we can design 2D MCs, for which the SW spectrum exhibits omnidirectional band gaps with different sensitivity of the gap width to the tiny change of the external field. Together with the possibility to squeeze the structure *in operando*, it shows 2D MCs as considerable candidates for designing of the tunable magnonic devices.

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