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199

Coupling between Surface Acoustic Waves and Spin Waves in Uniform or Patterned Magnetic Films

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The simplest structure in which the magnetoelastic coupling between spin waves (SWs) and surface acoustic waves (SAWs) can be observed is the magnetostrictive layer deposited on the non-magnetic substrate. The surface localization of SAW ensures the co-existence of both kinds of waves in the magnetostrictive layer. The strength of the magnetoelastic interaction depends on the direction of the static magnetic field. Moreover, this interaction is different for different types of SAWs, specifically, Rayleigh-SAWs (R-SAW) and Love-SAWs (L-SAW). Thus, the coupling is strongly anisotropic and cannot be observed for arbitrary selected SAWs and SWs, even if their frequencies and wave vectors match. This effect is well-known and broadly discussed in the literature [1]. Our study shows an additional factor limiting the interaction between SAWs and SWs. The SAW/SW coupling proves to require an appropriate profile of the elastic wave near the surface of the magnetostrictive structure, at distances much smaller than the wavelength. For R-SAWs the tangential component of displacement can have nodes within the magnetic layer, resulting in a reduction of the net strength of magnetoelastic interaction even if the related strain is locally significant, whereas for L-SAW the displacement does not have any nodes (changes monotonously in the normal direction). We have shown [2] that this additional factor plays a role for some types of surface acoustic waves (R-SAWs), while other types (L-SAWs) are insensitive to it.

We extended our work and considered the impact of the patterning on magnetoelastic interactions. We calculated the magnetoelastic dispersion relation for an array stripes (of the width 200 nm or 100 nm) differing in saturation but identical in terms of elastic properties. Such structure can be potentially fabricated from the CoFeb/Au by ion implantation in the selected strip areas. We found that (i) the higher SAW dispersion branches, folded into 1st BZ, are exhibited only due to the magnetoelastic interactions, (ii) the partial confinement of SWs within the stripes and non-uniform changes of SWs' phase affect their coupling with freely propagateing SAWs.

We studied CoFeB/Au multilayer as a magnetostrictive medium deposited on Si substrate. In CoFeB layers (2.1 nm) the magnetization is oriented in-plane and the presence of Au layers (0.9 nm) reduces the SWs' frequencies due to out-of-plane anisotropy.

We measured the dispersion relations of thermally excited SAWs and magnetostatic SWs in non-patterned multilayer using a six-pass tandem Brillouin spectrometer. The finite element method (COMSOL Multiphysics) was used to solve numerically the coupled equations of motion for magnetization and mechanic displacement both for uniform and patterned multilayer.

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[2] N. K. P. Babu, et al. Nano Lett. 21, 946 (2021).