Probing spin-waves in individual ferromagnetic nanoelements

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Focused electron beam induced deposition (FEBID) is a technique of choice for direct-writing of nano-architectures with applications in nanomagnetism and magnon spintronics, Here, a series of our recent experiments on direct-write FEBID nanomagnets will be discussed. First, an original spatially resolved approach for spin-wave spectroscopy of individual circular magnetic elements with sample volumes down to about 10^{-3} μm^3 will be presented [1]. The key component of the setup is a coplanar waveguide whose microsized central part is placed over a movable substrate with well-separated CoFe-FEBID nanodisks (see Fig. 1). The circular symmetry of the disks allows for the deduction of the saturation magnetization and the exchange stiffness of the material using an analytical theory. Next, using this approach, the engineering of the magnetic properties of CoFe-based nanodisks fabricated by FEBID will be demonstrated [2]. The material composition in the nanodisks was tuned *in situ* via the e-beam waiting time in the FEBID process and their post-growth irradiation with Ga ions. The achieved saturation magnetization M_s variation in the broad range from 720 to 1430 emu/cm^3. Further, nanovolcanoes - nanodisks overlaid by nanorings – will be introduced as purpose-engineered 3D architectures for nanomagnonics [3]. The extension of 2D nanodisks into the third dimension allows for engineering their lowest eigenfrequency with 30% smaller footprints. The nanovolcanoes can be viewed as multi-mode microwave resonators. Finally, spin-wave phase shifters upon a single nanogroove milled by a focused ion beam in a Co–Fe microsized magnonic waveguide, characterized by all-electrical spin-wave spectroscopy, will be described [4]. By varying the groove depth and the in-plane bias magnetic field, we continuously tune the spin-wave phase and experimentally evidence a complete phase inversion. The proposed phase shifter can easily be on-chip integrated with spin-wave logic gates and other magnonic devices

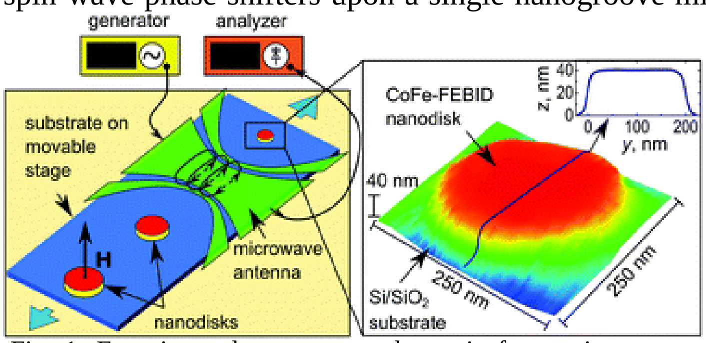

Fig. 1. Experimental geometry and atomic force microscopy image of the smallest nanodisk (R = 100 nm) with a cross-sectional line scan in the inset.

References

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