Size-specific dynamic properties of magnetic nano-spheres with a three-dimensional magnetic vortex

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1. Introduction

Magnetic resonant excitation of nano- and micron-sized magnetic particles has become a focus of attention in nanomagnetism and spintronics owing to its potential implementations in information processing devices [1], wireless power transfer in electric devices [2], and medical applications such as hyperthermia [3] and drug delivery [4]. Soft magnetic particles of spherical shape show different static spin configurations according to their size. For example, permalloy spheres, the radius of which is slightly larger than single-domain size and smaller than multi-domain size, form a stable three-dimensional magnetic vortex [5]. Notwithstanding the many studies on magnetic nano- and submicron-sized magnetic particles, reports on their dynamic features have been rare.

2. Results and Conclusion

Here, on the basis of finite-element micromagnetic numerical simulations of permalloy spheres of different radii (range: 10 – 75 nm), we report a novel dynamic behavior of size-dependent magnetic resonant excitations. We found that a single three-dimensional vortex precesses around a static magnetic field H_{DC} at a specific frequency. This precessional frequency, we discovered, varies with the size of the sphere when the vortex structure is retained, because the net magnetization of a given sphere projected in the direction of the vortex core $\langle m_r \rangle$ varies with its size, as expressed by a simple analytical form of $f = |g|\langle m_r \rangle H_{DC}$ (where $|g|$ is the gyromagnetic ratio, 2.80 MHz/Oe). The value of $\langle m_r \rangle$ is determined by the interplay of the constituent magnetic material's parameters and dimensions, since the vortex structure is the result of completion between the short-range exchange and long-range dipolar interactions. The simulation results obtained are in perfect agreement with the analytical form derived using Thiele's equation [6] of motion for a single three-dimensional vortex core in a sphere. The characteristic behavior observed implies the capability of application to selective activation of three-dimensional vortex precession. This simple but novel dynamic feature would open a new horizon in the field of high-frequency magnetic-nanoparticle applications.

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3. Reference

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