High-Frequency Magnetization Dynamics in Three-Dimensional Interconnected Nanowire Geometries

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Recent progress in the nanofabrication of three-dimensional magnetic nanostructures [1] has opened unprecedented opportunities to generate arbitrarily shaped artificial magnetic samples whose properties are governed by their geometric features. Suitably tailored three-dimensional magnetic samples of this type can effectively constitute novel types of materials with unique magnetic properties. Among such artificial materials, extended arrays of interconnected soft-magnetic nanowires have recently emerged as a subcategory of particular interest. Such systems display features of three-dimensional artificial spin-ice system, thus exhibiting a broad variety of nearly degenerate magnetization states including defect-like magnetic structures forming at the vertices at which the wires intersect.

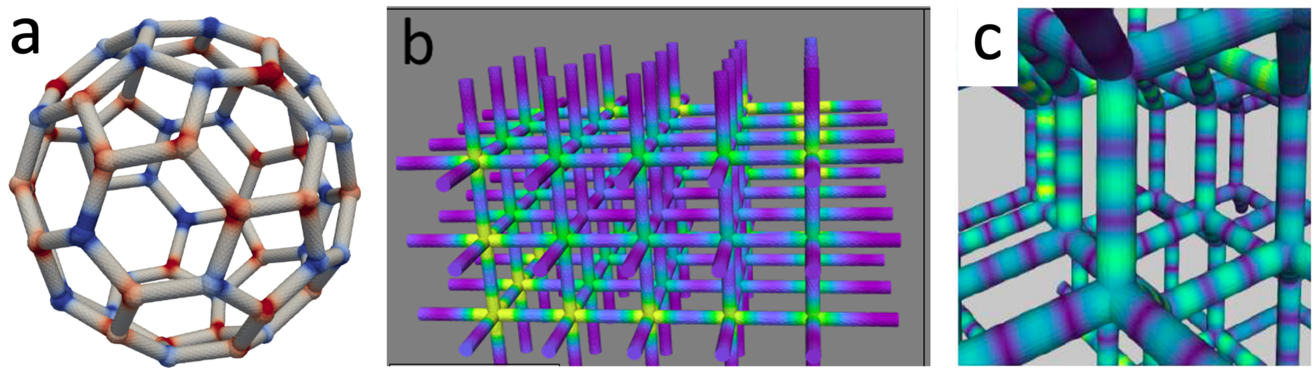

Figure 1: Simulated high-frequency magnetic oscillations in different types of interconnected nanowire arrays. (a) Buckyball geometry, (b) regular cubic array of nanowires, (c) artificial diamond-type magnetic lattice of nanowires. The typical length of the nanowires is around 100 nm and the total size of the objects is in the micron range. Standing spin-wave patterns are observed in the nanowires, in addition to oscillations localized at the vertex sites.

By using advanced finite-element micromagnetic simulation methods [2], we investigate high-frequency magnetization oscillations in various types of magnetic nanoarchitectures consisting of interconnected soft-magnetic nanowires, ranging from buckyball-type geometries [3] to cubic arrays and diamond-type artificial magnetic crystals [4]. In all cases, we find distinct resonance peaks in the absorption spectra, which can be attributed to specific geometric and micromagnetic features within the lattice. The magnetic high-frequency dynamics depends particularly sensitively on the micromagnetic structure developing at the nanowires' intersection points. Moreover, at higher frequencies, characteristic standing-spin wave modes develop within the individual nanowires. The sensitivity of the high-frequency oscillation modes to nanoscale micromagnetic and geometric features, in combination with the high precision of modern sample fabrication methods, underlines the potential of these magnetic systems for three-dimensional magnonic applications with tunable and reconfigurable properties.

References

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