Abstract

In recent years, a great deal of interest has been attracted by the physics of designer materials called 'Artificial Spin Ice' (ASI) systems. One of the most promising aspects of ASI system is their high tunability of the array geometry and nanomagnet parameters which has become possible due to the availability of the modern lithography techniques. ASI can be considered as model systems to study the physics of frustration in a controlled way thereby allowing exploring new avenues which is not always possible in natural materials. Despite great progress in the understanding the frustration and interactions between the nanomagnets in different lattice geometries in these systems, in-depth information of magnetization reversal in reduced lattice in literature is very limited. In this thesis, a detailed investigations of magnetization reversal of the building blocks of square artificial spin ice systems are presented. Controlled defects have been introduced in the building blocks to study in details their role in modifying the interactions and the overall energetics of the system.

Firstly, extensive micromagnetic simulations were performed to study the switching behavior of *individual* ASI vertices of elliptical nanoislands which behave as Ising-like macrospin. Starting with regular closed edge vertices without any artificial defects, defects viz. vacancy and misalignment defects are introduced systematically in a controlled way. It is observed that introduction of such controlled artificial defects alters the magnetic switching behavior of a vertex drastically. An interplay of defect and dipolar interaction has been found to lead to predictable stabilization of isolated emergent magnetic monopole at vertex.

Inspired from our simulations, we fabricated stadium shaped nanoislands of permalloy arranged in a regular structure with and without artificial defects, using electron beam lithography. Field-dependent magnetic force microscopy (MFM) and vibrating sample magnetometry (VSM) measurements were employed to probe

the local and global switching behavior in these systems. Remarkably, an isolated emergent magnetic monopoles could be stabilized with the application of field in these systems. The experimental results were also verified theoretically by performing Monte Carlo simulations.

The defect in the form of controlled misalignment breaks the rotational symmetry of the system. The broken symmetry leads to an energetically inequivalent system under rotation in an applied magnetic field and allows easy access to different energy landscapes. Using the angle between the field and the system's geometric axis as the control parameter, different vertex states - from magnetically chargeless verex of type-I to charged type-III vertex can be stabilized systematically. Importantly, we find a route to stabilize the system in its lowest energy state where the external field and the effective anisotropy orient along the same direction.

Finally, high-sensitive 2DEG based micro-Hall magnetometry measurements are employed to study the magnetization reversal of dipolar coupled nanomagnets of strong shape anisotropy arranged in two square ring-like geometry, a building blocks of square ASI system. We observe that although magnetic force microscopy images exhibit single domain like magnetic states for the nanostructures, their reversal processes may undergo complex switching behavior. The details of such reversal behavior are observed as specific features in micro-Hall magnetometry data which compares well with the micromagnetic simulation data.