Abstract of the Thesis

Title: Investigations and stabilization of the vortex states in Cobalt and Permalloy nanorings in contact with nanowires.

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Magnetic nanorings are the object of increasing scientific interest because they possess the vortex (stray field free) state which ensures lower magnetostatic interactions between adjacent ring elements in high packing density memory devices. In addition, they have other potential applications such as single magnetic nanoparticle sensors, microwave-frequency oscillators and data processing. The stabilization of magnetization state, types of domains and domain wall structures depends on the competing energies such as magnetostatic, exchange and anisotropy. The nucleation/ pinning of domain walls depends on the local inhomogeneity in shape such as roughness, notches etc, which play an important role in stabilizing domain configurations that can be controlled by magnetic field/spin polarized current etc. The information gained by the study of magnetization reversal in the nanoring devices could help in understanding the possible stable magnetization states, which can be incorporated into the development of magnetic logic and recording devices in a NR-based architecture.

The magnetization reversal and the stable states in the symmetric cobalt nanorings (NRs) attached with nanowires (NWs) (at diametrically opposite points), is studied through magnetoresistance (MR) measurements by application of in-plane magnetic field (**H**). Here, a strong in-plane shape anisotropy is introduced in cobalt thin films by patterning them into NR and NWs. The presence or absence of a DW in the device is detected utilizing the AMR property of the material, where the presence of DW leads to a decrease in the resistance of the probed section of the device. It is demonstrated that the magnetization reversal of the device with smaller width, proceeds through four distinct magnetization states, one of these is the stabilized vortex state that persists over a field range of 0.730 kOe. The effect of width (from 70 nm to 1 µm) and diameter (from 2 µm to 6 µm) on the switching behavior is demonstrated. The magnetization states observed in the MR measurements are well supported by micromagnetic simulations. A statistical analysis of switching fields in these devices was demonstrated by histogram plot (of switching counts) to understand the repeatability and reproducibility of switching characteristics.

In addition, the magnetization reversal of permalloy NR is also studied by MR experiment when two NWs are attached to it in two different configurations. It has been demonstrated that a vortex state can be stabilized if the NWs are attached in a way that they are at an obtuse angle with respect to each other (type-II device) which is not the case if the NWs are attached at diametrically opposite points (type-I device). This occurs because the NWs reverse at different fields as they are asymmetric with respect to applied magnetic field at every angle. The angular dependence study of the magnetization states indicates that the vortex state could be always stabilized in the type-II device irrespective of the direction of in-plane applied magnetic field while it is not the case in type-I device. The experimental observations are in good agreement with micromagnetic simulations performed on similar device structures.

Further, in the last part of the thesis, the magnetization reversal of geometrically engineered cobalt NR (of width 80 nm) devices are studied by application of **H**. Two types of cobalt nanoring devices were fabricated. In type-1 devices the NR is attached with two nanowires (NWs) at diametrically opposite positions. In type-2 devices the NR is attached with one NW, whose other end is attached to a 5 µm x 5 µm square pad. In type-2 device, the pad reverses first, thus causing the generation of a DW at the junction of the nucleation pad and the NW. The device type-2 possesses five distinct magnetization states, one of these is the vortex state. Easy nucleation of domain walls (DWs) results in a decrease of switching field corresponding to the reversal of the nanowire. This leads to an increase in the range of fields, where the vortex state exists. In addition, angular dependence of the switching behavior indicates that the vortex state can be stabilized at all in-plane orientations of **H**. This occurs because of the fact that symmetry was broken due to the presence of single domain wall pinning center which was the junction of the NR and NW. The results of our micromagnetic simulations are in a good agreement with the experimental results. These results are important to understand the role of NWs which allows the formation of vortex state at every angle of the in-plane **H**. In type-1 device, the simulation shows that when the field is applied at any angle away from the axis of the NW, the vortex state cannot be stabilized. The width dependent study of switching fields indicates, that the switching fields decrease with increasing the width of NR devices due to a reduction of the demagnetization field.