ABSTRACT

Magnetic disk drive technology has successfully reduced the size of multi-grain bits to \~30 nm, and there are intensive efforts to shrink the bit size further. The new generation hard disk drives shipped by Seagate Technologies’ around August 2009 boasts of recording densities of around 500 GB/inch\(^2\) using a combination of vertical recording, write head lithography, use of magnetoresistance sensors and better recording media. Though the research and development in this field is progressing at a fast pace the areal densities achievable using conventional scaling is limited to the so-called trilemma problem of satisfying the concurrent requirements of thermal stability, writability, and achieving a high signal to noise ratio.

Though technologies such as heat assisted recording and phase change memory are being explored as future data storage technologies, there has also been great interest in bit patterned media (BPM), where arrays of isolated magnetic nanodots act as individual bits which can be read and written by controlling their magnetization. One of the obvious advantages of BPM technique is that it would allow us to write one bit on a single grain as compared to the standard procedure of averaging a single bit over 25 – 30 grains (to prevent data loss due to thermal fluctuations and the demagnetizing field of the adjacent grains). This in turn would directly lead to a 30 fold increase in the storage capacity of the typical hard disks theoretically pushing storage densities to achievable upper limit of
around 30 TB/inch\(^2\). Further, this technique significantly reduces the jitter noise which gives it a significant advantage over other techniques.

Though the concept of patterned media has been around for over two decades the technology has not been able to achieve technological fruition as the lithographic fabrication of nanodots is commercially prohibitive due to issues of scalability and throughput. Hence, it is critical to develop highly cost effective solution for fabrication of BPM. Further, it is equally important for the thus fabricated media to satisfy the concurrent requirements of the aforementioned “trilemma problem” of magnetic recording.

In this work, a novel cost effective technique of fabricating large arrays of magnetic nanodots towards bit patterned media applications was developed. Ferromagnetic nickel nanodots were fabricated by electron beam evaporation using a nanoporous polysulfone membrane as a mask. The polysulfone membrane was synthesized using a simple phase inversion process and was found to be stable in vacuum and high temperatures. The nickel nanodots formed distinct islands of similar shape and slightly reduced size as compared to the pores of the nanoporous membrane. The structural and magnetic properties of the nanodots were explored to ascertain its use as a magnetic media. The magnetization data indicated that the nanodots exhibited a distinct magnetic anisotropy with an easy axis of magnetization perpendicular to the sample surface. Different techniques of template engineering were explored so as to identify the ideal technique for fabrication of magnetic nanodots such as prefabricated template fixation, dip coating and
spin coating followed by post development of the template which gave excellent structural results with the nanodots exhibiting good shape and size distributions. These nanodots also exhibited more favorable magnetic properties such as a slightly higher remanence and lower coercivity. Also, preliminary work was carried out on suitable surface modification techniques for post deposition processing in similar systems and for exploring alternative materials for the patterned media such as allotropes of carbon (carbon based magnetism). Further, in-depth study of the magnetic properties of the nanodots was carried out including the study of demagnetization and magnetization reversal dynamics. Further, the angular dependence of the magnetization was also investigated by measuring the magnetization of the nickel nanodots at different angles which gave us significant insights about the inter bit transition dynamics.

The polymer templated soft lithography technique used is a simple, inexpensive and scalable technique of synthesizing inorganic nanodots and can be extended to fabricate any metal, metal oxide, metal compound and metal alloy nanodots. Based on this, the applications of this fabrication technique can extend over several domains including fabrication of ultra fast data processing devices, sensors, nano electronics, nanoarray, lab-on-a-chip, etc.