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Nanomaterial for High-Density Magnetic Data Storage[1]

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1. INTRODUCTION

The interdisciplinary field of mesoscopic and nanoscale systems is important for fundamental physics, as well as for some new technologies. Nanometer-sized structures are an intermediate form of matter, which fills the gap between atoms/molecules and bulk materials. These types of structures frequently exhibit exotic physical and chemical properties differing from those observed in bulk three-dimensional materials.

Advanced heterostructures with nanosized components have been the subject of much investigation in recent years [1–3]. The real advance in this direction is the development of new functional materials and the use of novel principles of device functioning. The tendency in the development of high technologies is toward direct physical and interdisciplinary investigations in the field of mesoscopic and nanoscale systems. One way to progress in the field of high-density data storage systems is to utilize magnetic nanoparticles (magnetic particles with sizes on the nanometer scale). In this context, systems of magnetic nanoparticles embedded in various matrices are particularly promising.

Generally, the electrical and magnetic behavior of nanostructured systems is governed by both the intrinsic properties of the nanostructures and their interactions with the matrix. Thus, the magnetic behavior of the system can be controlled by the size, shape, chemical composition, and structure of the nanoparticles and/or by the nature of the matrix in which they are embedded. However, the preparation of stable magnetic nanoscale materials that contain uniformly distributed nanoparticles (in a specified range of sizes of nanoparticles with a narrow size distribution) using conventional techniques is rather difficult. The fabrication and future utilization of such types of nanosized systems require using novel technological processes.

The areal data density on magnetic media, especially hard disk memory, has increased at an astonishing rate over the last three decades (30% per year for 1970–1990, 60% per year since 1990, and up to 100% per year in recent years). Extrapolating the 60–100% growth rate leads to bit sizes which clearly cannot be achieved using current technology [4]. In recent years, increasing the data storage density has meant decreasing the number of magnetic grains needed to store a bit of data from a thousand down to a few hundred and also decreasing the grain size. Today, the highest density hard disk drives store up to 120 billion bits (120 Gb) per square inch of the disk surface. As the bit density increases, all components of the system—the media, read head, write head, tracking system, detection and error correction electronics, etc.—become more difficult to design and construct. The fabrication of appropriate magnetic media is one of the most serious problems and is the major objective of our investigations.

All magnetic data recording systems are currently based on the media, which are comprised of a thin sheet containing small, single-domain, magnetically decoupled particles, which switch independently [4]. The granularity of the medium produces noise, which becomes unacceptable at small bit sizes. The media noise is now the primary factor that limits ultra-high-density magnetic recording systems. Reducing the grain size, which reduces noise, is a challenge, because there is a critical size of the thermal instability of magnetization [4]. To solve this problem, the particles should have a strong magnetic anisotropy. The single-domain status of the particles is important, because it prevents the undesirable magnetization reversal through domain wall motion.

All current commercial disk drive systems (excluding optical memories) operate using continuous granular media magnetized in-plane, called longitudinal recording. The magnetic recording industry has an enormous investment in longitudinal recording technology and is understandably very reluctant to move to an alternate technology. A number of disk drive companies commissioned a study, managed by the National Storage Industry Consortium (NSIC), to determine the limit on conventional longitudinal magnetic recording. The study group concluded that the extension of continuous longitudinal recording to 100 $Gbit/in^2$ was not impossible. The study concluded that a grain diameter of 8 nm, with an appropriately adjusted anisotropy field (6000 Oe), would meet both the thermal stability and the signal/noise requirements [4]. Media with an average grain size of 8 nm should not be extraordinarily hard to generate, but the model imposes another, very difficult to achieve requirement on the grain size, namely, that the grains should be monodisperse. In sum-

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