Self-organisation of colloidal particles: Future magnetic recording media

R.W Chantrell[1] and A Satoh[2]

[1] *Department of Physics, The University of York, Heslington, York, UK, YO10 5DD*
[2] *Department of Mechanical Engineering, Akita Prefectural University, Akita, Japan*

Introduction

The continued increase in the areal density of magnetic recording media requires the use of smaller particles as well as a smaller number of particles per recorded bit. This is essentially determined by the requirement of good Signal to Noise Ratio. The ultimate limit that can be achieved would be using one particle per bit. In order to achieve this, a certain number of difficulties must be met including the physical ability to safely store the information on a single particle for a sufficiently long period of time. This is related to the energy barriers to magnetisation reversal, which are provided by the intrinsic anisotropy. Essentially, long-term thermal stability of written information requires values of KV/kT≈60, where K is the anisotropy constant and V the particle volume. Clearly a small particle volume requires a large K for stability, which suggests the use of L_10 alloys such as FePt, which have values of K up to $7x10^7$erg/cc, more than an order of magnitude larger than obtainable in current media. The properties of FePt Self-Organised Magnetic Arrays (SOMA) have been extensively investigated following the pioneering work of Sun et al [1]. Sun et al developed chemical techniques for the preparation of FePt alloy particles and showed that it was possible to prepare materials with particle sizes around 4-5nm. After annealing to produce the ordered (fct) L10 FePt high anisotropy phase, it was demonstrated that high coercivity nanoparticles could be prepared having the potential for extremely high recording densities >1Tb/sqin. However, the practical application of such media requires the solution of a number of problems, including that of producing the high anisotropy L_10 phase without sintering and particle growth, which has been the subject of considerable effort.

In this paper we consider the second major factor in the use of FePt nanoparticle arrays, specifically the problem of self-organisation and easy axis orientation, and its effect on the magnetic properties. We start by outlining the recording physics leading to the requirement for SOMA media for densities of 1Tbit/squ in and beyond. We will then review the chemical techniques used in the preparation of FePt colloidal dispersions, and also the techniques used in the production of self-organised films.

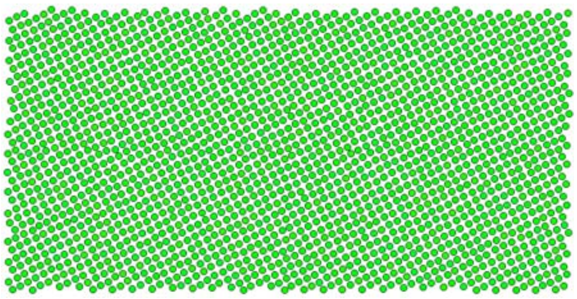

Figure 1: Square lattice formed at high density

We then present a Monte-Carlo model of the self-organisation process which predicts the essential requirement of narrow particle size dispersion. The model also demonstrates the importance of the interparticle repulsive potential, stressing the role of the surfactant chemistry in the self-organisation process. It is also shown (see fig. 1) that although the ordering is predominantly hexagonal, square arrays such as observed in [1] (beneficial for patterned media) can be obtained over a narrow range of packing densities. This is found to depend strongly on the strength and form of the repulsive interactions provided by the surfactant.

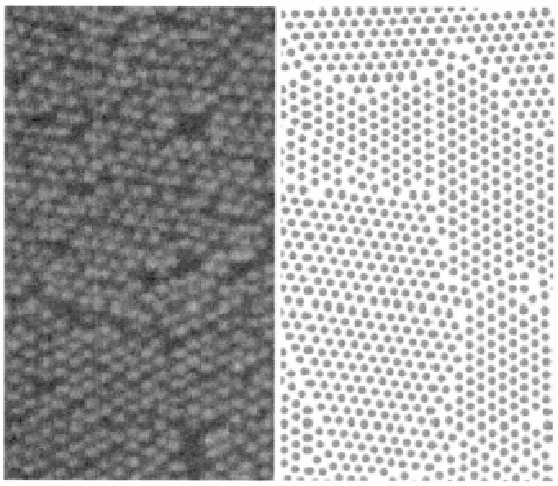

Figure 2: Experimenal (left) and simulated (right) images of self-organiesd films. The calculations include an empirical attractive potential.

Interesingly, comparison with experiment (see fig. 2) suggests that there may exist an isotropic attractive interaction which causes a film to break up into small self-organised regions below the critical density required for self organisation under an entirely repulsive potential. It has been demonstrated [2], using quantum chemistry calculations that an attractive potential may exist due to Van der Waals interactions between surfactant molecules on separate particles. This effect occurs as the surfactant molecules begin to overlap, but is dominated by the repulsive interactions for smaller separation..Clearly the sufactant chmistry is an important factor in the self-organisation process.

We also describe analytical and MC models of the orientation process. The models assume that the orientation is achieved via the application of a magnetic field. It is shown analytically that the alignment requires large values of KV/kT in order to ensure sufficiently strong coupling of the easy axis to the magnetic moment, and simple analytical results are presented which allow good estimations of the degree of easy axis alignment. The MC model predicts the easy axis alignment and also the chaining phenomenon which is observed experimentally. The theoretical model has been compared with experiment in [3]. The experimental data show evidence of partial alignment. A comparison between theory and experiment shows smaller than predicted alignment, which is probably due to aggregates in the dispersion.

We conclude with an overview of the current status of the preparation of FePt SOMA and some remarks on possible future developments. In particular it is concluded that easy axis orientation will require elongated particles, and possibly some interaction with chemical species deposited on the substrate. A major conculsion, given the importance of the surfactant chemistry, is that the potential applications of FePt SOMA media are strongly dependent on the Physico Chemistry of the colloidal stages of the preparation, and would represent an interesting challenge to the ferrofluids community, and one with considerable industrial benefit.

References

[1] S. Sun, C.B. Murray, D. Weller, L. Folks, and A. Moser, Science 287, 1989 (2000).

[2] C. Verdes, J. Ahner, P.M. Jones, N. Shukla, R.W. Chantrell and D. Weller, Appl. Phys. Lett. 86, 263106 (2005)

[3] J.W. Harrell, S. Kang, Z. Jia, D.E. Nikles, R.Chantrell and A. Satoh Appl. Phys. Lett., (in press)