SYNTHESIS AND APPLICATION OF MAGNETIC NANOMATERIALS FOR MEMORY STORAGE DEVICES

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Abstract

Nanomaterials have been the topic of intense industrial research for the past several years. They have unique physical, chemical, optical and magnetic properties as compared to those of their bulky counterparts. Intense research has been done on reducing the size of memory devices in the electronics industry. This requirement has made it extremely urgent to explore the materials with larger scope of functionalities on their surfaces. In this respect the conventional silicon based materials have been engineered for better and better control and modification of their surfaces but unfortunately this conventional route does not provide us with both higher functionalities as well as high speeds. In this regard, magnetic nanomaterials have been researched for interesting and far sighted effects. These have been the hot destinations for their sensitive responses in the biomedical and diagnostic applications. Magnetism at nanoscale is also significantly different from the one observed at bulk scale. Magnetic nanoparticles are normally made up of materials which have sensitive magnetic properties arising from the unpaired electrons in their d-orbitals and their coupling effect with their nuclear spins. This review explores the synthesis methods of the magnetic nanomaterials and their possible implementation in making memory based electronic storage devices. This also highlights the significant benefits and aspects that compel the use for investigating memory based potential for magnetic nanomaterials.

Keywords:
Nanomaterials, functionalities, electronics, engineered, magnetism, memory, biomedical, diagnostic.
**Introduction**

Magnetic materials have long served as dependable mediums for digital data storage and have efficiently served as basis for audio and video recording. With the size of computers and most of the conventional memory storage devices on the verge of rapid shrinkage the need for miniaturization of the memory storage units in the electronic devices has indeed stepped up. This has resulted in the rapid and large scale engineering of the conventionally used magnetic memory storage devices. Another important idea about the possible modification regarding the use of magnetic materials for memory storage and considering the ever increasing miniaturization is the fact that leads to the thinking that such large scale electronic functionalities can be achieved by using them in the form of thin films. Thin films possess highly sophisticated chemical and physical textures and provide a lot of scope for the adhesion of different electronic and memory storage components over them. Moreover, the features and ingredients possessed by the magnetic materials to be used as storage devices are not the conventional properties of hard and soft natured magnetic matter [1]. Magnetic nanomaterials are in
general composed of elements possessing sensitive magnetic properties such as iron, cobalt, nickel and their corresponding oxides such as magnetite, maghemite, chromium dioxide and so on [2]. The magnetic properties of a material are judged by its magnetic susceptibility, which in simple words can be defined as relative measure of the strength of magnetization induced (M) with reference to the strength of applied magnetic field (H). Each material has some characteristic magnetic moments which are the determining features of its magnetic potential. These magnetic moments are aligned either along or in the opposite direction to the applied magnetic field, thereby determining the magnetic potential of a material which in turn is the basis for the application of a material. This extent of magnetization is different for different materials and is the main factor for deciding that what kind of magnetic material a particular substance is? Magnetic materials which are strongly magnetized in the presence of an external magnetic field are said to be strongly magnetic. They are either superparamagnetic or ferromagnetic in nature. However there are some materials which are weakly magnetized under the influence of an external magnetic field. These materials can’t be used for sophisticated magnetic applications as the field they produce is comparatively weaker in its strength. The most important aspect of these so different kinds of magnetic responses is the fact that all these effects are transient in nature and disappear as soon as the externally applied magnetic field is removed [3]. This makes the applications of the magnetic materials to be best suited for the technical requirements as this enables the retaining of their behavior in the original configurations. Moreover, this has also made magnetic materials and in particular to be highly preferred choice for biomedical applications. Another very important point to note here is that the magnetic behavior of materials in the presence of externally applied magnetic field depends upon several factors which need to exist in an optimized manner for the requisite magnetic effects. These parameters are strength of applied magnetic field, atomic structure of the material concerned and the temperature at which the material of interest is to be operated upon. If the temperature of the operational processes involving such transient magnetic materials is higher, it imparts higher kinetic energy to the magnetic spins which then become free to move, orient and align. As a result which is decisively determined by the orientation of magnetic domains of a material under external magnetic influence is altered [4].

**Magnetism at Nanoscale**

Nanoscale magnetic particles have been a vivid topic for researchers not only from technological point of view but also from application point of view. Whenever we talk about nanoscale or the nanosized dimensional level, we mean that the surface area of a material is being exposed gradually and this is in most of the cases intentional because this enables us to achieve higher and higher functionalities.
**Fig.1. Magnetic behavior of Nanomaterials.**

Figure 1 gives us an idea about the magnetic behavior of the materials, telling that that even though magnetic nanomaterials can be magnetized as desired like paramagnetic materials when no external field is there but still these materials have more magnetic susceptibilities. All these phenomena arise from finite size and surface effects which dominate and dictate the magnetic behavior of individual particles making up the nanomaterial [5]. In a comprehensive study, Frenkel and Dorfman were the first persons to show that particles of a ferromagnetic material, below a critical particle size, approximately of the order of 15 nanometers would consist of a single magnetic domain and this will give us the material made up of particles that carry only a single magnetic domain i.e. a particle that exhibits a uniform state of magnetization corresponding to any value of the applied field strength. Moreover, it was also comprehensively studied that the behavior of these magnetic nanomaterials above a particular characteristic temperature known as blocking temperature becomes paramagnetic in nature [6]. Magnetic nanomaterials are excitingly of significant interest on the basis of their size dependent properties. These materials carry nanoparticles which exhibit superparamagnetism. A chief characteristic of the superparamagnetism is that it operates at the nanoscale and it arises due to spin based momentum of the unpaired electrons present in a material. To add to this, superparamagnetism is characterized by the presence of single magnetic domains in the material concerned, i.e. the magnetization induced in a material is same throughout across a material in the presence of an external magnetic field [7]. This feature is a very essential characteristic for the use of magnetic materials in the storage applications. Interestingly enough, the magnetic nanomaterials exhibit the property of anisotropy, which says that magnetic properties of a material vary as per the direction of the applied magnetic field. This says that there are two stable orientations for a magnetic nanomaterial to place itself. These two orientations of a nanomaterial are antiparallel to each other and are separated by an energy barrier. So, there is a finite probability of a material to undergo a change in its spatial orientation when it operates at a finite temperature. The average time lapse between the exhibitions of two flips is termed as Neel-relaxation Time ($\tau_N$) [8]. The turning point involved in most of the applications of nanoscale magnetic materials is the time during or for which the magnetic effect of a particular material is observed. Interestingly, if it is lower than the Neel-relaxation time, the magnetization flip will not occur and the material will show the same state as it was at the very instant of beginning. This state of magnetic nanomaterial is termed as the blocked state while if the measuring time is more than that of the Neel-Relaxation time, the material will flip its domain several times and the instantaneous magnetic picture will be significantly altered. This state is termed as the superparamagnetic state. So, in all the measuring time of the nanomaterial’s magnetic behavior is acutely responsible for its observed particular nature. The transition from superparamagnetic state to the blocked state typically occurs when the measuring time is equal to the Neel-Relaxation time. In other words, we can say that the possible nature of nanoparticles which is observed depends on the measuring time. Most of the industrial scale applications therefore aim at keeping the measuring time constant and the temperature is varied so as to observe the transition between the superparamagnetic and the blocked state as a function of applied temperature. Due to their significant and excellent prompt behavior magnetic nanomaterials have been capitalized for achieving
distinguished outputs in numerous industrial scale applications such as being used as magnetic seals in motors, use as contrasting agents in biomedical and magnetic resonance purposes, magnetic recording of data and therapeutic agents for drug delivery in cancer [9-11]. The overall gist of the different kind of magnetic responses at the nanoscale is the fact that as a material is gradually brought to the nanoscale dimension from the bulk stage; it stands at the risk of losing its ferromagnetic nature. In terms of applications for magnetic storage, we require a material that is the nanosize as well as possessing ferromagnetism. The challenging task to accomplish the goal of information storage is that we have to reduce the size of a bulk material to the nanoscale keeping its ferromagnetic nature intact. In general this is not the case as materials tend to lose their ferromagnetic behavior at nanoscale. The materials at nanoscale show zero coercivities and nil remnant magnetism [12] due to the effect of thermal annealing at the nanoscale and the resultant superparamagnetic limit, while applications like that of the data storage require materials with considerable values of coercivity and residual magnetism. Each kind of application is based on a particular characteristic of the material involved. For instance, in memory storage applications, the storage material is desired to be made up of particles that are stable and possess a switchable magnetic state which is compatible to represent the information stored in the form of bits and these should not be readily affected by the fluctuations in temperature. Similarly for biomedical applications, the use of such materials is preferred which possess superparamagnetism at room temperature which is chiefly characterized by virtually nil residual magnetism for the rapidly fluctuating values of the applied magnetic field [13-15].

Therefore, we can say that magnetic nanomaterials behave in a highly different manner as compared to their conventional counterparts. They have superparamagnetic limit critically effecting their magnetic behavior and performance. Essentially for memory storage applications, we require materials which do not demagnetize rapidly and have uniformly magnetization abilities. These requirements will be discussed further in detail.

**Synthesis Methods for Magnetic Nanomaterials: A Brief Overview**

In very simple and broadest terms, there are three distinct methods being employed for the synthesis of magnetic nanoparticles. These methods are namely, physical, chemical and biological. These are very popular and well documented and studied throughout the literature studies. These methods have been named on the basis of their characteristic mechanisms of operation. The most interesting thing about these synthesis methods is the fact that these are employed specifically for a particular kind of application. For instance, it is a well-known method that nanoparticles are used as bioactive agents for drug delivery and gene transfection in living cells. Since this application requires that particles should be biocompatible in nature, so here we use biological methods for nanoparticle synthesis which are discussed a little ahead in the text. For most of the in vivo applications, we employ either biological or chemical methods for the synthesis of magnetically sensitive nanoparticles. However, physical methods of nanoparticle synthesis are used when we intend to use them for in vitro applications such as industrial operations such as metallurgical processes and catalytical activities.

In usual conventional sense, the chemical methods are based on bottom up approach. These are very versatile and possess excellent control over the shape, size and geometry and overall surface features of the synthesized nanoparticles. Some examples of chemical methods widely used for magnetic nanoparticle synthesis are liquid co-precipitation methods, reverse micelles method, hydrothermal method, sol-gel method and microemulsion methods. A detailed summary of the
several chemical methods used for magnetic nanoparticle preparation has been comprehensively reported in a review article by Lu et al. In their contribution, they have discussed the core details of the controlling parameters and the corresponding yields with the changes in the precursors employed [16]. Fig.2 ahead depicts the different methods used in the synthesis of magnetic nanoparticles. This figure also briefly recalls the main inputs and features of different methods being used.

Fig.2. An overview of Magnetic Nanoparticle Synthesis methods

Physical methods of magnetic nanoparticle synthesis involve the pyrolysis of a magnetically sensitive material to deposit magnetic nanoparticles on a desired target. These methods are cumbersome in the sense that they need high energies, skilled manpower and sophisticated parameters to be optimized for their operations. Examples of such methods include chemical vapor deposition method, heat mediated decomposition of a substrate via laser and spray pyrolysis methods [17], arc discharge, plasma vaporization [18] and solar energy induced vaporization [19]. These methods are mostly suited for in vitro applications.

Biological methods of magnetic nanoparticle synthesis are unique in the sense that they prevail within the bodies of some living creatures. It is believed that a particular gene segment known by the name magnetosomes is involved in the synthesis of iron nanoparticles in well-defined lipoprotein chambers. This unique characteristic enables the host organisms to have their own inbuilt magnetic field and respond to earth’s magnetic field with its proper orientation. The presence of such features in some specialized living creatures also enables the synthesis of magnetic peptides which can be used for a number of biomedical applications. This method is highly localized in terms of its existence and is particularly used for in...
vivo applications. The detailed discussion of synthesis methods is beyond the scope of this review article and here we would focus the synthesis only with reference to magnetic storage applications. This is covered further in the text.

**Magnetic Nanomaterials for Memory Storage**

Magnetic materials are very popular media in use for the storage of data in the form of non-volatile memory. There several examples of magnetically working memory storage devices such as floppy disks, magnetic recording tapes and magnetic stripes that are positioned on the credit cards. The basis of this information storage is the differently magnetizable patterns created or generated within the magnetic materials. The surface of a magnetic material that is desired to be used for memory storage purpose traditionally consists of extremely small micrometer sized magnetic regions that are referred to as magnetic domains. Each of these regions has almost a uniform magnetization extent.

Magnetic entities in these materials are polycrystalline in nature and that’s why the role of magnetic crystal grains is important here. Magnetic storage media can be classified as either sequential access memory or random access memory although in some cases there is no clear-cut distinction of the method that is operating. Another term important to be mentioned here is the access time. This can be defined as the average time required for gaining an access to the stored information. The overall mechanism of this information storage is the periodically regulated via well distinct functioning of three main distinct units, namely the read head, the write head and the media as highlighted clearly in Fig.3. Both the write head as well as the read head are sensitive electromagnetically tuned data storage entities, which are mounted over the rolling circular platforms that are regularly moving. The overall mechanism of this information storage is the periodically regulated via well distinct functioning of three main distinct units, namely the read head, the write head and the media as highlighted clearly in Fig.3. Both the write head as well as the read head are sensitive electromagnetically tuned data storage entities. Both are mounted on the rolling circular platforms that are regularly moving. The information is in the form of sound energy at the very initial source. From that, this information is magnetically and electronically coupled to the electronically magnetized write head. Then from here, the information moves on under the influence of electric and magnetic fields. It is then carried over to the read head from where it is made available to the user. In case of computer usage, we call this memory as magnetic storage while in case of audio and video recording; we call this phenomenon as magnetic recording.
The actual data storage or gathering framework is provided by the component media. The storage of data or information via the magnetic materials is regulated by data holding capacity of media. Media is made up of the magnetic material carrying the data in the form of magnetic domains of that material. It stores the data in the form of magnetized bits. The limits for holding data are between the positive and negative values of magnetization extents of the magnetic material of the media that are located on the hysteresis loop. The critical property of magnetic materials which is responsible for these applications is the magnetic anisotropy. It is due to this property that the nature of media is determined; whether it can store enough information to a long term extent in a stable manner or not. Magnetic anisotropy can be defined as the exhibition of differential magnetizable extents by a magnetizable material in different directions. There can be several causes of magnetic anisotropy \[20\]. For instance, it may be due to irregular or non-homogeneous shape that the effect of magnetic field of a material is exerted differently in different directions, in such a case the anisotropic effect is termed as shape anisotropy. It is named as magneto-crystalline anisotropy, if it is due to the atomic structure of the magnetic material used. It is named as magneto-elastic anisotropy if the source is the tension between surface constituents of a magnetic material. Quite recently, one new type of magnetic anisotropic effect has come to the fore that is named as exchange anisotropy. In this case, there is difference in the usual expected magnetic trends because of the interaction of differently natured magnetic materials \[21\]. This is the property which enables us to control the magnetic nature of a magnetically anisotropic material even in the absence of an external magnetic field. This is due to the fact that an anisotropic material aligns itself only in two preferential and minimum energetic orientations in the absence of an external magnetic field. These two magnetic orientations along which the magnetic domains of a magnetic material point out in null external magnetic field are termed as easy axes. The anisotropy energy is the critical thermodynamic parameter which decides the extent of stability of the stored information over the magnetic material as this is the energy which acts as a deciding factor for the magnetic anisotropy of the magnetically sensitive media used in magnetic storage devices. In most simple terms, the more is the energy required to randomize the electronic spins of the magnetic material which further shape up or decide its critical orientation towards one of the stable orientations either through thermal heating or by increasing or changing the values of applied magnetic field strength, the better is the stability of the media and the lesser are the chance of the stored...
information on the magnetic disc to be erased and get lost. Of note here is the fact that two primary threats for the loss of stored information are the so many randomly oriented magnetic fields and the local heating of the working device. In addition, magnetic anisotropy of a material is also determined by coercivity of the magnetic material concerned and is believed to be positively correlated with it. This is chiefly due to the fact that the coercivity of a material is one of its vital properties that can regulate the extent of residual magnetism in the material and affect its magnetic anisotropy being strictly limited to the specified two easy axes. Thus, to optimize the performance of magnetic storage devices, tailoring of devices with higher values of magnetic anisotropy is equally important as that of the optimization of its coercivity values. For achieving high density of data storage, mostly the materials with high magnetic coercivity are desirable. Such materials that exhibit high values of coercivity are particularly named as magnetically hard materials. These critical requirements force us to shift our domain of thinking to the magnetic nanomaterials for memory storage devices. This is so because magnetism at nanoscale is highly different in expression when compared to that of the bulk scale. Studies from literature report a number of methods such as electrodeposition [22], sol-gel technique [23] and plasma laser deposition technique [24] for the synthesis of nanomaterials in highly diverse forms ranging from thin films, to nanorods [25], nanocrystals [26-27], ordered nanocrystal arrays [28] and even nanocrystal superlattices [29]. In these attempts, the oxides of transition metals, in particular ferrites have been studied and analyzed most extensively and it has been equally properly observed that these materials combine their electrical and magnetic properties in very stable combinations and remain stabilized with oxidation and other external influences. The nanomaterials have to be engineered or tuned so that they do not show nil coercivities and residual magnetisms. The key difference between the magnetic behavior of a bulk material and that of the collection of small single domain ferromagnetic nanomaterials lies in the manner in which magnetism is recycled along their hysteresis curve [30]. To sum up, we can say that nanomaterials are highly hot destinations to be tagged for data storage applications as these have sensitive behavior with the response to external changes and can be varied by number of innovatory routes.

The Mechanistic Details of Data Storage: Mechanism and Complications

It was in 1956, that the quest for electromagnetic data storage came to the fore of world through the design of IBM’s computer named as RAMAC. This system possessed a total memory storage capacity of 2 kilobits per square of an inch [31]. Gradually, through the invent of hard disk drive the fortune for data storage devices witnessed a unique encouragement. More and more potent researches began to be carried out for the design of materials aimed at achieving high room for data storage applications. The situation reached to such an extent that for nearly 25 years on the trot, the search for high density data storage kept on being stimulated and saw an exponential increase. At one stage, the growth of these devices even jumped the prediction of Moore’s law hypothesis with consistently twenty five percent increase in the efficiency on an annual basis [32]. It therefore explains clearly that why nanomaterials have become hot objects of destination for the purpose of memory storage applications.

Before switching over to the use of nanomaterials and their increasing involvement for such applications, we must gather sound information about the basic procedure of storing information in magnetic materials. The information is stored in the magnetic media in the form of characteristic magnetic domains. The smallest unit of information or data storage is a bit. So, data is stored in the form of magnetic bits. Each magnetic bit is positioned in a specified manner over the magnetic platform and communicates the stored information via the functioning of read and write elements. In principle, there is an
arrangement similar to those of semiconductor transistors whereby the media is responsible to keep read and write element isolated and separated from each other and also maintains their distinct functioning. There are two ways in which the magnetic domains carrying the information can be stored onto the magnetic medium. One is the longitudinal arrangement in which the domains are aligned parallel to the existing magnetic field of the storage platforms. The other method involves the perpendicular assembly of the magnetic domains over the magnetic platform. Till date, most of the devices working on the principle of magnetic storage of data are based on the longitudinal data storage recording methods [33]. The storage element in such systems which is media consists of magnetic grains whose magnetic moments lie in the plane of disk. The process starts with the action of write element that stores the data in the horizontal magnetization manner. From here, the information is read by the read element through its giant magnetoresistive mechanism that prevents the surrounding magnetic fields to interfere in the overall process. In the last step, the stored information by the read element is converted from the analog form into digital form and is deposited as a stream of data bits. This conversion takes place via the regulated functioning of signal processing unit. Interesting observation at this point is the fact that how the media of such systems is made up of. To support so many diversely oriented magnetic domains in a regulated manner without one interfering the other, we need a platform that is magnetically strong, stable and can operate to the different magnetic tunes in a very sensitively and coordinated manner. So, such longitudinal storage devices are made up of thin films which are put in place by the magnetron sputtering process. These thin films are granular in nature so that their working is not affected in an adverse manner by the thermal fluctuations coupled with the overall systems. In addition to the longitudinal recording layer carrying magnetic domains, there are some other layers also which constitute the media in magnetic storage data. These layers are in a polycrystalline state and help to support the proper coordinated growth of grains, regulate their size and shape and nullify the interfering and non-specific magnetic fields. A key importance of these layers lies in their ability to keep the non-relevant interactions between the read and write elements at bay. As a consequence of thin film growth process, the grains of the recording medium usually have randomly directed orientations with respect to the plane of film. It is due to this randomness that a group of grains are used for each unit of storage. The signal to noise ratio varies directly on the number of grains in a bit. The grain size in these granular films also has a critical impact on the signal to the noise ratio of the systems. So, it is desirable that the number of grains in a bit is reduced. This is achieved by reducing the distribution of grain size in a bit, which is achieved by optimizing the growth of recording layer or by the use of additional seed layers [34-36].

In order to accomplish high density storage in these devices, a main problem encountered is the fact that whenever we try to magnetically impose a particular configuration on the media, each grain is individually magnetized in its own direction. Under such circumstances, it is highly susceptible that the surrounding grains can be disturbed and their own magnetic fields get adversely affected. In order to prevent this disturbance, each grain is surrounded by a thin boundary of oxide material so as to keep it isolated from the other grains in the vicinity [31]. The entire process of information communication within the read head, write head and the media in a magnetic storage device is under tight control of sensitive current passage and depends on the timid sequencing of coordinated events that are regulated in a characteristic and well controlled electromechanical manner. All the constituent particles of the media which take part in information storage, particularly the grains of the individual constituents; are composed of single magnetic domains, are magnetically decoupled from each other and are switched on independent of each other. Grain size reduction though favors the overall
process feasibility by reducing the noise ratio but it is a highly challenging task to go beyond a particular limit in the grain size reduction. This is so as there is a critical grain size that withstands the thermal instability of magnetization.

**Current Status of Nanomaterials used for Magnetic Storage**

In terms of the nanomaterials currently, the most prominent and popular materials are face centered tetragonal iron and platinum based alloys. The use of rare earth transition metals and their alloys has also been encouraged owing to their high anisotropic effects and good magnetically coupling nature. Research efforts dedicated to this field report that if nanomaterials or nanoparticles are used for this memory storage, the information that can be stored is comprehensively increased in the quantity. This is so as the information on the surface is stored in the form of bits and if surface area is more as it is the case of nanomaterials, the scope for storing more information gets much better. If magnetic nanoparticles with grain size to the tune of 3 nanometers can be designed, it can simply bring wonderful breakthrough changes in terms of data storage as the information density can easily surpass the value of one tetra-byte per square inch (37). Magnetically developed memory storage devices are of two main types, namely analog and digital. The major difference between the two types is the nature of corresponding magnetism which stores the information. Analog method of information storage is based on the dependence of residual or remnant magnetism of the storage medium on the magnitude of the externally applied field. Though this method was very popular in terms of its usage in audio and video recording but it is no more used at present. However, the digital mode of information storage works on the assumption that there are two stable extreme extents of the magnetization determined by the coercivity curve of the magnetism cycle of a material. The information has to be stored in between these permissible extents in the form of bits. This method of data storage is popular in floppy disks and high density data storage devices. There is still another mechanism of data storage known as magneto-optical recording. This method employs laser beams as optical conversion of stored data in a temperature sensitive manner.

The text ahead summarizes the major nanomaterials that have been employed in data storage applications. Two classes namely, iron platinum and cobalt platinum based compounds are the most popular materials being used as magnetic storage devices. Besides, the research work is also going on to synthesize thin films and their variants through doping that are based on transition metal conjugates with alkaline earth metals. The main chemical approaches for their synthesis methods have also been discussed with specific use of each process and the possible ease of usability. Further, we will shift the focus of discussion on the particular specific arrangements of nanomaterials based on approaches like self-assembly, patterning and lithography with respect to specific applications of data storage. The alloys of rare alkaline earth metals have also attracted recent interests for these applications. To emphasize, the crucial task still occupying a special spot among the scientific minds is to engineer the magnetic effects to suit this particular application.

**FePt nanoparticles for Magnetic Storage Applications**

FePt is normally formed as a face centered cubically (fcc) configured alloy with equal percentages of iron and platinum in the crystal structure. This alloy is initially formed at low temperatures via chemical synthesis; this crystal structure has an equal probability of finding out iron and platinum at any location. However, this material in the cubic phase has a low magnetic anisotropy and behaves as a soft magnetic material. These are the primary reasons for its conversion into tetragonal form which results in its magnetic anisotropy getting significantly improved. This conversion takes place through a high temperature annealing process. As a result, the structural transition to the tetragonal form is manifested by the structurally arranged alternative layers of iron and platinum. The structural phase change results in the overall lowering
of the crystal symmetry, causing a preferential magnetic alignment in a characteristic direction. This particular change appears or expresses itself in the form of high magnetic anisotropy. In a significant effort, Weller et al. (1992) have evaluated that FePt in the form of nanoparticle texture could be of great use and possesses unique thermal stability for magnetic performance, even to a grain size tune as small as of 3 nanometers [38]. Further the spin based coupling and hybridization of half-filled electronic states of iron and platinum impart a higher chemical stability to the overall structure as compared to many other strong and potent ferromagnetic materials made up of iron and cobalt as well as many high coercivity possessing materials, making them useful for a plethora of applications [39]. However, current efforts are being dedicated or focused at optimizing the size shrinkage in the structure of FePt based nanoparticles so as to withstand the magnetic effects. Theoretical studies have no doubt, pointed out at the fact that using these materials in the nanoscale proportions can significantly increase the magnetic data storage density. It is largely susceptible that the high magnetic anisotropy and chemical stability of the FePt based systems would make them very strong candidates for designing the media for magnetic storage in the form of thin films that use the perpendicularly driven storage mechanisms of the magnetic domains using sputtering methods. Till date the lowest grain size of FePt based materials that has been employed for data storage purpose is 6.6 nanometers [40]. In this particular effort, an underlayer of particles with small grain sizes is used so that the recording layer can have the size of its constitutive components popularly regulated at the nanoscale. In other attempts, several efforts have been made by doping the crystal structure of FePt with additives such as carbon, silver and copper, so as to reduce the grain size. Grain sizes to the limit of around 4 nanometers have been obtained using 50% carbon doping [41]. However, doping should be done carefully so that the properties of magnetic anisotropy and characteristic grain sizes are not compromised.

### Synthesis of FePt Nanoparticles for Magnetic Storage

There are a number of differently enabled methods for the synthesis of FePt nanoparticles. For instance, studies reported by explain the popular top-down mechanism based physical methods such as vacuum deposition techniques and gas-phase evaporation methods for the synthesis of FePt nanoparticles in polydisperse phase [42-44]. However, the as-synthesized particles are face centered cubic in nature and require thermal treatment as modification so as to be obtained in face centered tetragonal form. There were further problems reported in the synthesis as this modification resulted in the aggregation of the synthesized nanoparticles. This was resolved by carrying out the process embedded in a magnetic matrix composed of silica or alumina. To a great extent problem is resolved but still this mode of synthesis is not fit for the design of nanoparticles which could be used for forming arrays as required for magnetic storage applications. Instead the chemical synthesis methods based upon the solution mediated co-precipitation techniques are far more promising and appropriate with reference to the desired application. With reference to this, [45] have reported a chemical precursor based method via its co-precipitation in a liquid medium. They have carried out the simultaneous thermal decomposition of iron-pentacarbonyl (Fe(CO)₅) and the reduction of organometallic platinum based chelator compound in the presence of 1,2-alkanediol. Iron-pentacarbonyl is thermally unstable and readily decomposes upon heating to act as an excellent precursor for iron. Similarly, alkanethiol mediated reduction of platinum based organometallic chelator gives the platinum. Following this, iron and platinum combine together to form clusters and serve as perfect deposition sites for the deposition of further FePt nanoparticles. The most challenging task lies ahead. Table.1 shows the different routes for the synthesis of FePt nanoparticles. It also mentions the yield of different methods employed and the corresponding nature of the particles
employed to give a fair idea as to why chemical methods are the most preferred ones. It deals with controlling the size and geometry of as synthesized nanoparticles. This is so the most sensitive and crucial task is to get the magnetic anisotropy intact in the synthesized magnetic nanomaterials. Only then can our material be effectively used for data storage applications. A variety of chemical interventions, ranging from the use of carboxylic acids and treatment with amines have been employed to passivated as synthesized nanoparticles and prevent any non-specific chemical activities. Of note, the synthesis of FePt nanoparticles in proper configuration also depends on maintaining the proper ratios of the two initial combining reactants. In one such related study, Momose et al have shown that the size of the synthesized nanoparticles can be tuned by controlling the molar ratio of the stabilizers to the organometallic precursors of platinum as well as by regulating the thermal treatment conditions [53]. They have also predicted that a characteristic ratio of 8:1 of the stabilizers to the platinum precursors is essential to make FePt nanoparticles larger than 6 nanometers. Likewise, a number of studies have evaluated the characteristic experimental parameters for the synthesis of nanoparticles of a particular shape. A number of other methods have also been reported in the literature for the chemical synthesis of FePt nanoparticles. One of these methods uses the reverse micelles approach involving Cetyltrimethlyammonium bromide (CTAB) as a surfactant

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<tr>
<th>Sr. No.</th>
<th>Brief Description of the Method</th>
<th>Nature of product obtained</th>
<th>References</th>
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<td>2.</td>
<td>Chemical Method: Co-precipitation of precursors (thermal decomposition of participating precursors)</td>
<td>Smaller size of particles, better potential to self-assemble and get dispersed in organic solvents.</td>
<td>[45]</td>
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<td>3.</td>
<td>Seed-based growth mechanism</td>
<td>Particularly good for larger sized particles</td>
<td>[45]</td>
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<td>4.</td>
<td>Thermal Decomposition followed by oxidative and reductive annealing</td>
<td>FePt particles of size 17 nanometers are obtained</td>
<td>[49]</td>
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5. Thermal decomposition and simultaneous reductive annealing | Change in precursors yields excellent particles with perfect stoichiometry and required tetragonal geometry of structure | [50]


7. Reverse Micelle systems, just like nanoreactor systems. | Uses C-TAB as surfactant, 1-butanol as cosurfactant and octane as oil phase in emulsions. | [52]

Table 1. Synthesis Methods for FePt nanoparticles.

molecule, butanol as co-surfactant and octane as oil phase [52]. Thus the micelle based emulsion systems are selectively engineered to give the requisite particles of interest. Another method employs the organometallic reduction of precursors for the net desired product, in an alcoholic medium [49]. The only difference lies in the involvement of different kind of molecules as precursors and surfactants. Unfortunately, the yield of this process is too low to make them fit for magnetic storage applications. Quiet recently, the use of fatty acids as reducing agents in the chemical synthesis of FePt nanoparticles has also been reported, in a method that uses iron stearate as a fatty acid [54]. Some studies have also reported the formation of FePt nanorods by implementing slight modifications in the manner of surfactant addition to the overall chemical modification of the precursors. The formation of nanorods has been reported in the cases where octyl ether and dichlorobenzene have been used as solvents to dissolve chemical precursors [55-56]. The particularly additional benefit that has been observed in the case of nanorods synthesis is their exceptional shape anisotropy property which makes them strong candidates to be used for magnetic data storage devices. In this way, FePt based magnetic nanoparticles can be effectively used in magnetic storage applications and can be optimized for still better performances as reported by several recent overlapping studies.

**Application specific Optimization Strategies for Controlled FePt synthesis**

The optimization of iron platinum alloy systems with respects to their magnetic properties and usage for data storage applications is a far more comprehensive and cumbersome task as compared to their synthesis. It has been rigorously examined by the crystallographic studies that the phase transition to the face centered tetragonal form is responsible for their higher magnetic anisotropic properties. In addition to this, the shape anisotropy of FePt nanoparticles is beneficial for three other important purposes. Firstly, it is easier to restrict the magnetization energy of the particles when they are elongated in size. This shape anisotropy imparts an elongated shape to the nanoparticles used which in turn makes the shifting of their magnetization from one easy axes to the other a lot much more feasible. That is why the spherical shape of the synthesized nanoparticles is not preferred in which the shifting of magnetism from one easy axes to the other on a
patterned surface in the form of self-assembly is difficult and requires energetic monitoring from outside. Third and most important fact for optimized synthesis deals with the packing density of the synthesized materials. Therefore, a particular shape which allows for maximum packing density fraction is generally preferred and in general the spherical shape that allows a packing fraction of only 70% is normally not a desired for the purpose of high density storage devices. Several study groups have reported the modification of spherical to cubical shapes in FePt nanoparticle synthesis by controlling several parameters during their chemical synthesis from organometallic precursors. The addition of surfactants and the order in which a particular kind of surfactant is added are the crucial parameters [55-56, 57]. The mechanism here is a likelihood energetically permissible interaction of the successive precursor materials added. It says that platinum particles have a special affinity for carboxylic acid group. Further, it is also claimed that the addition of amines first hinders the activity of platinum particles and restricts their aggregation which means it is a favorable route for spherical natured particles. In their comprehensive studies, Shukla et al (2009) have proposed one modification for the synthesis of FePt nanoparticles in the form of nanorods that are in particular, more suited for data storage applications [56]. They have suggested using a high temperature and pressure conditions and the use of dichlorobenzene as solvent and addition of surfactant in high quantities. This particular configuration gives the particles with high magnetic anisotropy and aspect ratios and in particular optimized for magnetic recording purposes. Similarly, hexagonal shaped nanoparticles have also been reported using high temperature and pressure interest but the details of this process are not properly understood.

To a surprise, most of the above discussed methods give nanomaterials in face centered cubic form which needs to be converted into tetragonal form so as to make these materials functional for magnetic storage purpose. For this an extra step of annealing is carried out in the synthesis of FePt nanoparticles and interestingly as the name itself suggests, the process of annealing requires increasing the temperature of process. The other general factors that critically affect the annealing process are the time for which this annealing is carried out and the critical relative concentrations of iron and platinum.

Significant studies using transmission electron microscopy and X-ray Diffraction have shown that the the structural transition of as synthesized face centered cubic crystals of FePt into the tetragonal form begins at a temperature of 500°C [58-59]. Further in detailed analysis of the crystal structure by XRD, it has been shown that the required tetragonal phase FePt nanoparticles having optimized values of magnetic anisotropy are obtained when the relative extents of iron to platinum is 1:1 [60]. This was therefore clearly understood by this exhibition that the magnetic behavior of FePt nanoparticles depends not only on the relative extents of iron and platinum with respect to each other but also on the respective interactions of iron and platinum within the prepared nanomaterial [62-64]. In a related study, Sun et al (2001) have claimed that the best composition of FePt providing optimum anisotropy and coercivity as required for data storage applications is obtained in the configuration of Fe55Pt45 for magnetic data storage applications. Interestingly enough, this has been verified by Weller et al (2000) while carrying out the synthesis of FePt thin films using physical deposition methods and found to be true [38, 59]. The exhibition of anisotropic and coercivity properties is further different when we move to even small scale nanoparticles. This is largely due to characterized surface dominance of the nanoparticles. In another significant study, Sun et al (2001) as well as Zeng et al (2002) have concluded that the room temperature coercivities of the assembled FePt nanoparticles increase proportionately with the increase in annealing time and temperature of annealing, reaching a maximum value corresponding to an annealing temperature of 650°C [59,64]. Unfortunately every success is coupled with failures. Thermal annealing is also no exception as sometimes due to
annealing at high temperatures, there are serious effects on the overall monodispersive nature of the particles, in other cases, the problem of particle aggregation has also been observed. One such remedy to overcome this problem of aggregation of nanoparticles and enable optimized FePt nanoparticles has been suggested by Maeda et al. 2002 in which they have proposed the doping of FePt with copper. They have analyzed this doping effect to a high limit of precision and have found that on doping FePt crystal with copper, copper occupies the slots or positions of iron. Further, this innovation has significantly helped in lowering of the transition temperature from the usual 500°C to 400°C. Several cases of monodispersed nanoparticles carrying gold, copper, silver as dopants have been explored and it has become possible to lower the phase transition temperature to even 300°C [65-68]. The lowering of annealing temperature no doubt lowers the extent of aggregation. A very interesting solution to these problems has been suggested via coating these particles by oxides or by embedding the synthesized nanoparticles into highly dense and complex organic and inorganic matrices [53, 67-72]. Another point of note is the fact that we can also overcome this problem even by controlling the synthesis of nanoparticles during their formational kinetic steps. Using such routes, the first report of synthesizing the stable FePt nanoparticles by recovering them at a particular phase of their synthesis and then again resuspending them in some selective materials like those of silica or other oxide based solvents, and exploiting the chemical favouritism of nanoreactors was put forward by Yamamoto et al. 2005, Tamada et al. 2007 [73-75]. They have used SiO2 as carrier systems of the nanoparticle formation. A vital study was carried out by Tomou et al. 2007 has evaluated the comparison of magnesium dioxide and silicon dioxide as coating materials for keeping and regulating the synthesis of FePt nanoparticles and explained that the use of magnesium oxide is much better for efficient separation of the particles formed. Thus, merely synthesizing the FePt nanoparticles is not enough and their optimization for the specific application is perhaps more important task. The complex factors mentioned above are very complicate to optimizer completely but still the chemical method of FePt nanoparticle synthesis using organic precursors and surfactants for controlling geometry is the preferred choice.

**CoPt Nanoparticles for Magnetic Storage Applications**

The use of CoPt alloy system for magnetic storage applications has also been explored in several studies and it has been also reported that these nanoparticle assemblies have very good magnetic anisotropy properties during a particular stage of their chemical synthesis procedure [31, 76-77]. The use of CoPt has been employed for magnetic data storage in the form of thin films; this is particularly because of high coercivity values of thin films which is not normally seen in the case of nanoparticles. Similar to FePt nanoparticles, there are several popular methods available for the synthesis of CoPt nanoparticles but to a keen observation, most of these methods do not provide the optimum synthetic yield of these as far as their use for magnetic storage applications is concerned. Even though thin films of CoPt have been used for data storage applications but the optimization of enough physical and chemical methods for the synthesis of CoPt nanoparticles is far lesser. This is due to a technical fault in the values of reduction potentials of cobalt and platinum. For cobalt this value is 20.28 volts while for platinum, it is 1.2 volts [77]. This clearly highlights that platinum is far much easier to be reduced decomposition of organometallic precursors and hence most of the chemical and physical methods aimed at reduction of corresponding precursors are not feasible to be carried out. Table 2 (ahead) highlights the various synthesis methods conventionally employed for the synthesis of CoPt based nanoparticles. As it is mentioned in the table, the methods using aqueous reduction media and dihydrogen to carry out organometallic reduction are the most preferred ones. The first ever
method reported for the synthesis of CoPt nanoparticles. The earliest ever reported method for the synthesis of CoPt nanoparticles proceeds through the reaction of organometallic precursors in the presence of hydrogen [77]. This method used two precursors, each for cobalt and platinum solvated in particular specific organic solvent and three other stabilizing agents in organically suspended form. This method is time consuming and cumbersome in terms of experimental feasibility. Although it yields the particles of mean diameter 1 nanometer but there are few evidences citing this method available in the literature. The product shows superparamagnetic characteristics at room temperature and this is a good method for obtaining large sized particles. Owing to the non-feasible prevalence of their reduction potential values, another method for formation of CoPt nanoparticles in the form of reduction of metallic precursor salts in aqueous solutions using very strong reducing agents has been suggested. Thereafter, the technique of microemulsion has been popularly used for carrying out simultaneous reduction of the two precursors involved [78, 80, 85]. Even reverse micellar systems have also been implemented to synthesize nanoparticles using a variety of combinations of solvents and surfactants. Here the ratio of water to the surfactant governs the size of the resultant particles obtained. In these reverse micelle systems special care is taken to prevent the non-specific oxidation of metals by water through the use of powerful surfactants like those of sodium borohydride (NaBH₄). These systems use metallic precursors to be added in same ratio as that of the stoichiometry required in the required product. Substances like CTAB and sodium conjugates have been reported as very efficient reagents in this versatile mode of synthesis [78, 79]. This method gives the CoPt nanoparticles almost around the size of 5 nanometers.

<table>
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<tr>
<th>Sr. No.</th>
<th>Brief Description of the Method</th>
<th>Nature of product obtained</th>
<th>References</th>
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<tbody>
<tr>
<td>1.</td>
<td>Dihydrogen mediated chemical reduction of organometallic precursors</td>
<td>Lengthy and cumbersome process but yields monodisperse, superparamagnetic particles with almost 1 nm as mean diameter.</td>
<td>[77]</td>
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<tr>
<td>2.</td>
<td>Strong aqueous reduction of metallic salts either as reverse micelle systems or microemulsion based synthesis</td>
<td>Small CoPt particles with diameter less than 5 nanometers are formed; size depends on relative surfactant ratios.</td>
<td>[78-79]</td>
</tr>
<tr>
<td>3.</td>
<td>Room temperature reduction of organometallic precursors without micelle systems</td>
<td>CoPt nanoparticles with varying size distributions are obtained, synthesis depends on control of density of initiating precursors</td>
<td>[80-81]</td>
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4. Polyol systems

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<td></td>
<td>Synthesis of CoPt nanoparticles in an organic medium</td>
<td>[82-83]</td>
</tr>
<tr>
<td>5.</td>
<td>Hybrid method, particularly for core shell based nanoparticle synthesis</td>
<td>Cobalt is formed as core and platinum is formed or deposited as shell in the overall particle.</td>
</tr>
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</table>

Table 2. Synthesis Methods for CoPt nanoparticles.

Several other interesting combinations of precursors with surfactants such as those dealing with colloidal precursors and organic surfactants like those of oleic acid etc. can provide good versatility in the overall output. This method of synthesis provides us with nanoparticles of high coercivity and anisotropy that makes them better option to be used for magnetic data storage applications. Similarly, some studies have suggested that the doping of CoPt nanoparticles with antimony (Sb) can enable good properties to be incorporated into the overall structure of CoPt. In particular, this doping has proved to be useful for incorporating better coercivity values [86]. There is a particular phase during which if the synthesized nanoparticles of CoPt are retrieved and used, they assure for better properties as far as their applications with respect to their usage for magnetic storage applications is concerned. For example, it has been observed that CoPt nanoparticles synthesized using alcoholic reduction method in this characteristic phase have coercivity as high as 7.57 kilounits [82]. Further, when these particles are subjected to annealing or thermal treatment, these showed coercivity values shoot up to an extent of 600 kilounits. These highly diverse, multifunctional and technical trials show that a particular mode of synthesis procedure has to be followed in order to obtain required configuration of synthesized nanoparticles and that particles need to be controlled in their synthesis as the approach involved is bottom-up and there is a significant that particles may form aggregates.

**Phase Transition of CoPt nanoparticles from fcc to fct Form**

Just like in case of FePt nanoparticle synthesis, in CoPt nanoparticle synthesis too, the phase conversion of the as synthesized face centered nanoparticles into tetragonal form is an essential requirement so as to optimize the usefulness of these particles for memory storage applications. Till date attempts aiming at the phase conversion of CoPt nanoparticles have not met with much success but no doubt, they have provided some valuable information. In a study carried out by Kumbhar et al (2001), it has been shown that particles of CoPt obtained via microemulsion technique when annealed at a temperature of 400°C for 4 hours show an increase in coercivity values upto 500 units and this has possibly predicted that a still higher temperature processing can bring about the phase conversion of synthesized particles from cubic to tetragonal form [80]. To add new excitement, it was also predicted by Yu et al (2002) that annealing at a temperature of 550°C can give a coercivity value of 5500 units but it also shows that further increase in temperature has no effect on the coercivity [81]. Similarly, in an attempt, Gibot et al (2005) have reported a coercivity value of 6000 units when the CoPt nanoparticles are thermally annealed and doped with antimony at a temperature of 650°C [88]. They carried out this doping intentionally
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with an objective to lower the transition temperature of CoPt. Along the same lines, the annealing of particles obtained via polyol method shows that if the annealing time is of 1 hour at 700℃, the coercivity values obtained are up to 7570 units. On the other hand if the annealing time is increased to 4 hours, surprisingly the coercivity value is 600 kilo units. In a further surprise, Tzitzioos et al in 2005 have predicted that these modifications in the coercivity values that it is only due to complete conversion of CoPt nanoparticles from cubic to the tetragonal form. They also stressed that the ratio of cobalt to platinum ratio plays a crucial role in dictating its properties and behavior for particular applications [85].

To date, the best possible strategy to obtain particles of high coercivity values suited to data storage applications involves the annealing of 1-2 nanometer spherical nanoparticles with similar sized nanorods obtained through microemulsion method at 665℃ for 30 minutes [80]. This yielded superparamagnetic particles having coercivities as high as 9000 units. The details of core mechanism of particle interactions responsible for exhibition of high coercivity values are yet not fully understood. However, research is underway to find the basic type of nanoparticles responsible for imparting high density data storage attributes.

**Rare Alkaline Earth Metals For Magnetic Storage Applications**

With the continuous efforts dedicated to the exploration of nanomaterials data storage and the use of patterned nanoparticle arrays in most of the conventionally used hard drives and other memory disks, there is still a continuous quest for the nanomaterials which can behave even more robustly as hard magnets and show more pronounced magnetic anisotropy effects. This search of higher magnetic anisotropic materials began more so after the discovery of FePt nanoparticles as memory storage, owing to the hardness and magnetic effects of iron. In significant studies, it has been found that alloys of rare-earth metals with their transition counterparts have the highest magnetic anisotropies [89], which enable them to show further strong tendency to strictly align along the two easy axes of magnetism in a much more reliable manner. In rare-earth metal transition metallic hybrid intermetallic species, the rare earth metals contribute the unpaired f-orbital electrons which are responsible for providing magneto crystalline anisotropy while the d-orbital electrons of transition metals are the source of most of the magnetism exhibited. These materials are right now being explored for the design and functioning as permanent magnets and it is a wide speculation that if they are synthesized in the nanoparticulate form and used as permanent magnets, this breakthrough can have a serious impact on the plight of magnetic recording based storage. An alloy of element samarium (Sm) and transition metal cobalt (Co) SmCo₅ has been one of the best studied and documented material for the design of permanent magnets and it is therefore perceived to be a hot contender for magnetic storage materials. This has a hexagonal closed packed structure with cobalt layers followed by a regular patterned arrangement of cobalt plus samarium. There are two core advantages of this magnetically doping based alloy system. First, it has a high value of magneto-crystalline anisotropy and secondly, a relatively easily and reasonably achieved magnetization extent along the characteristic c-direction of the overall crystallographic structure. In significant studies, this material has been predicted to possess the most suitable magnetic anisotropy and magnetization extents amongst its contemporary counterparts, on the basis of which it is a highly optimized asset for tapping its potential in memory storage devices [89-91]. This alloy has a very high Curie temperature of 1020 K which clearly indicates that it has a very stable magnetic effect exhibition tendency [92-93]. In a further analysis by Ono et al (2002), have accessed the utility value of SmCo₅ and compared it with that of the FePt nanoparticles. In their analysis, they have found that effective magnetic anisotropy values in SmCo₅ nanoparticles are 1.5 times higher than those of FePt and the cost of preparation of these particles is nearly 25
times less, only further stressing the beneficial aspects of SmCo$_5$ [95]. The crucial aspects deserving mention here are the chemically controllable synthesis of SmCo$_5$ so that their stability is not unduly affected. Literature available till recently sites ball milling and melt spinning as the two standard and most popular physical methods for the fabrication of nanostructured SmCo$_5$ based magnetic materials. Unfortunately, these methods provided a limited control over the final sizes of magnetic grains involved [94-95]. That is why; most of the studies concerned to SmCo$_5$ particle synthesis have been focused on chemical methods of synthesis. This is chiefly because these methods are highly controllable to obtain small sized particles that can form patterned arrays. Like that of the FePt nanoparticle synthesis, one of the very popular methods for the synthesis of SmCo$_5$ nanoparticles involves their synthesis via organometallic reduction in the presence of organic solvents. Of note, all such methods yield face centered cubic structured particles instead of application suited hexagonally cubic packed structures [94]. However, considerable phase transition approaches regulating the kinetics of chemically formed SmCo$_5$ have also been reported. Synthesizing under tight control in the form of core-shell arrangements has been proposed which can be performed in multiple permutations and combinations. Reductive annealing based mechanisms have also been used to synthesize nanoparticles with desired crystallographic orientation.

In all, these materials though possess a very good potential to be used as magnetic storage assets but there is still majority of homework left in optimizing these particles for magnetic storage applications and possess higher magnetic anisotropies. Studies aimed at the synthesis in the capped and coated arrangements need to be further optimized by the maintenance of chemical structures, form, properties and physicochemical properties.

**Self-Assembly Based Nanomagnetic Arrays for Magnetic Recording**

In order to use the magnetic nanoparticles for data storage applications, it is most probable expectation that the nanoparticles available should be self-assembled to form regular layers of them on a patterned surface. This will prove to be a big boon for the use of these nanoparticles for data storage applications. For this, we need to control the activity of nanoparticles after they are formed. This so as self-assembly is a naturally governed process and it generally refers to the well-defined arrangement of building blocks without any application of energy from any external source and this is self-driven in nature [98-100]. That means basically that the system components interact among themselves so specifically so as to achieve a configuration with minimum energy and maximum stability. There are various methods available to accomplish this. In fact, this is classified as being one, two or three dimensional on the basis of specific arrangements of the units involved. There have been numerous attempts of self-assembling the FePt nanomaterials so as to form their patterned arrays useful for magnetic storage purpose. The overall assembly in two or three dimensions is stabilized by hydrogen bonding, dipole-dipole interactions or Van-der Waal interactions. An interesting identifying feature of self-assembled system is the fact that the combined forces defining interactions between system components should be comparable to the forces disrupting them. Magnetic nanoparticles, once synthesized have a large number of atoms concentrated on their surface and have high energies. These all critical features need to be controlled in order to enable a properly built self-assembled system. For this, the necessary condition is the presence of some repulsive forces in the system which can compensate for the unusual attraction between component systems [99]. In addition, this surface activity stabilization can be achieved by the use of special molecules on the surface which can change for chemical and physical behavior of the synthesized nanoparticles in the nano configuration. Coating nanoparticles with hydrophobic molecules can
alter their solubilities and make them ready to achieve particular purpose. In one such attempt, the synthesized FePt nanoparticles have been stabilized to form self-assemblies by using organic molecules like oleic acid and oleyl amine. Of note, coating nanoparticle surface with large alkyl chain hydrophobic surfactants has been suggested to be a powerful invasion. Keeping in mind the occurrence of self-assembly in the situations involving the solvent systems, there are three critical features responsible for maintaining overall stability. The first is the interaction between self-assembled substrate molecules and solvent, the second one is the interaction between two neighboring particles and the third feature involves the regulation of interactions between the particles of the self-assembled molecules of these systems with the environment. Complex mechanisms emanating from modifying the surface behaviors of these nanoparticles like those of coating them with hydrophobic organic molecules or polar groups can impart the synthesized nanoparticles to be dispersed and dissolved in particular organic solvents and this way we can carry out better functionality and ultimately the desired arrangement of nanoparticles as suited for magnetic data storage applications. Synthesis of magnetic materials have yielded the magnetically designed nanoparticles within fluid media, giving rise to specially made up magnetic fluids termed as ferrofluids. These fluidomagnetic materials are specialized to achieve the sophisticated applications based on condensed matter physics. The arrangement of chemical entities on the surface of these nanoparticles using highly sensitive, controlled and specifically designed mechanisms has even yielded two dimensional or three dimensional arrangement of self-assembled layers. Studies done by Zeng et al, Chen et al and Shukla et al along the same lines have enabled the synthesis of self-assembled FePt nanoparticles being stabilized by surfactants oleic acid and oleyl amine and the arrangement has yielded well defined superlattices [57, 102-103]. Along the same lines, colloidal monodispersed nanoparticle crystals of FePt have been grown using a triple layer functionalized approach. This method involves the slow diffusion of a stabilizing molecule into the bulk of a concentrated FePt dispersion. This movement occurs in a highly regulated manner through the buffer layer of the third component. In order to optimize the arrangement of particles for optimized assemblies, particles are treated with surfactants before the actual event of self-assembly begins. The structure of this nanoparticle assembly depends critically on the interaction between the particles and this is highly influenced by the particular shape of each nanoparticle [103]. Studies related to optimization of this feature have predicted that if the shape of each of the participating nanoparticle is well-controlled it gives rise to higher packing densities and relatively better inter crystal orientation. In one such attempt, iron oxide based nanoparticles doped with iron have synthesized in cubical and polyhedron shapes [68-70]. They have mentioned in detail that nanoparticle arrays imparting these assembled systems specific shapes can be hugely responsible for their specific applications.

In a specific modification to favor the formation of self-assembled arrangement of nanoparticles, a particular substrate can be functionalized with specific molecules on its surface. This surface modification can be used to drive the assembly on the surface of these intentionally designed systems through surface exchange reactions. This kind of self-assembly is specially termed as molecule-mediated self-assembly and has also been used in synthesis of composite nanostructures [104-106]. Through this method, multifunctional polymers have been routinely used to mediate the assembly of a particular kind of particles. Another inroad into the design of self-assembled system of FePt nanoparticles has been made through the use of polyethylamine. This is an amine based polymer which can bind onto the FePt nanoparticles and can make feasible its attachment to a number of ionic molecules via specific interionic and electrostatic interactions [64, 107-108].
Conclusion and Future Prospects

In a nut shell we can say that considering the advanced scale miniaturization of the memory storage devices, the need for robust development of efficient magnetic storage devices is highly urgent. The features which prove to be significant hurdles in the development of magnetic memory systems for information storage are the higher values of magnetic coercivity and the residual magnetism determined through reminiscence. The chief requirement of nanomaterials for these particular applications is due to the fact that they have higher surface areas and can have the provision of storing higher information per unit of their platform. The most significant task requiring optimization so as to achieve the required purpose is the fact that how nanomaterials should be engineered to have higher values of coercivity and residual magnetism considering their natural tendencies to exhibit nil coercivities and residual magnetism. The minimization of grain size of the constituent particles and the prevention of the prevalence of superparamagnetic limit are some of other thrust areas. Further, the synthesis methods that have been most favorable for these applications are the chemical methods. This is so because these methods are easy to control and are comparatively more versatile. The interphase conversion into desired configurations is also a task that needs optimization. Further, some materials have been reported to be synthesized in good yield while others still have some bottlenecks in their synthesis to be resolved, just like in case of CoPt systems due to different reduction potentials and unease of simultaneous reduction. Considerable benefits have also been observed through the regulated addition of materials in the form of dopants. Further, there is a provision of self-assembly which is more pronounced when the particles are in nanosize.

There is also a need to design competent systems with proper shape, size and structure of nanoparticles involved. These are the riding feature for optimizing the extents of magnetic anisotropies, which are the core essentials of magnetic materials employed for magnetic storage applications. The constant improvements in the design of oxide coated functional molecules that can enable the proper activity of the synthesized nanoassemblies regulating the kinetics of their chemical synthesis and also preventing the aggregation of particles at the surface to behave as distinct assemblies and possess no heterogeneity throughout their structures. There is also a need to do rigorous testing of nanomaterials for their formation into monodispersive thin films. The aspects of thin films working and synthesis should be better and better studied along with proper investigations of dopants that can be made use of in heterogeneous alloy systems. The effect of dopants different host materials and that too in different concentrations is another hot area needing significant contribution.

Though these systems are interesting but considerable command and optimization is must for their application which is the aim for future. So the future is very optimistic for the synthesis and applications of these materials.

References:


