COMPOSITIONS COMPRISING CYSTALLINE-LIKE TRANSITION METAL MATERIAL AND METHODS OF USE THEREOF

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. application Serial No. 08/621,363 filed March 25, 1996, which is a continuation-in-part of U.S. Application Serial No. 08/228,782, filed April 18, 1994 and issued as U.S. Patent No. 5,501,808.

FIELD OF THE INVENTION

This invention relates to materials having a crystalline-like structure which comprise transition metals that exhibit unique electronic properties.

BACKGROUND OF THE INVENTION

Photomagnetic compounds have been known for some time, they are also referred to as magneto-optical (MO) materials. Enz et al. (1970) *Philips Tech. Rev.* 31:33; Enz et al. (1971) *J. Phys.* (Paris) Colloq: Pt. 2 1–703; and Verdaguer (1996) *Science* 272:698. The changes in magnetic properties that generally occur are either an increase or decrease in intrinsic magnetization, where the compounds can exist in a ferromagnetic, paramagnetic or diamagnetic state.

Beginning in the late 1980's, MO materials were utilized in devices that store and retrieve magnetic information. The materials are considered to be magneto-optical but in reality use thermal heating supplied by a laser to affect the magnetic properties of the material. The principle is to raise the surface to a temperature above the Curie point where the magnetic domains can be easily aligned with an applied magnetic field. Kryder (1993) *Annu. Rev. Mater. Sci.* 23:411. The information stored in the magnetically aligned domains is retrieved by a second polarized low power laser that is altered by an effect known as the polar Kerr rotation. The polarization angle of the light is rotated when reflected from the magnetically polarized surface. A drawback of this type of MO system is that the effective area in which information can be stored, known as the areal density is much larger than the width of the laser beam due to thermal propagation into the medium.

Also, the speed at which the magnetic property can be altered is limited to the speed of sound in the material, which is generally much slower than typical electronic excitations.

MO disk drives are a growing technology that are finding their way into computers as a form of high capacity erasable storage. When they were introduced into the marketplace in 1989, a removable 5" disk had a storage capacity of 650 megabytes of information. MO disks are also extremely stable in a magnetic field. However, 5" disks "proved unwieldy for personal use." Kryder (1993). Despite this and other drawbacks of the MO disk, it enjoyed sales of an estimated $261 million in 1991 and was projected to grow at a 26% rate over the 6 subsequent years.

The MO drive has a few qualities that distinguish it from typical magnetic storage. The MO drive can be thought of as a cross between a floppy disk drive and a fixed hard disk drive. The MO drive is like a floppy drive because its disk is removable and like a hard drive because large amounts of data can be stored. This combination provides for a cost-effective way of storing large amounts of data. For example, a 3" MO drive can hold 127 megabytes of data. A further advantage of the MO drive is that it is virtually impervious to the effects of a magnetic field at room temperature. This is an effect that neither floppy disks nor fixed hard disks can offer. Briefly, this effect is due to the use of a thin film whose coercivity is strongly temperature dependent. In addition to all these benefits, the MO drive has enhanced stability. MO disk drives show promise of having at least a ten year life span on the media, and twenty years can be expected. Also, anisotropy can be expected to suffer no more than a 10% reduction in 70 years of annealing at 50°C. All of these properties (high storage capacity, unaffected by a magnetic field and long-term stability) made the MO disk an appealing new technology.

The MO drive also has some drawbacks that have prevented it from replacing conventional hard disk drives. The MO drives do not perform as well as fixed hard disk drives. They have access times of 50 to 100 msec instead of the 10 to 15 msec for hard disk drives. MO drives also have data rates of about 1 megabyte per second instead of the 2 or 3 megabytes per second that hard disk drives have. These drawbacks along with the fact that MO drives are still rare have made it difficult for MO drives to gain widespread acceptance and popularity.

Given the advantages and disadvantages of the MO disk drive as explained above, the MO disk cannot replace either the floppy disk or the hard disk. The MO drive is too

expensive and too rare to be used in place of a floppy disk while too slow to be used in place of a hard disk. Even still, the MO disk has found its place in the field of data storage. The MO drive is best suited for storage of data that is large or infrequently used. In this way, a set of data can be written to the MO disk and literally put on the shelf until it is needed again.

A thin film can be any film between a few Ångstroms and a few microns. Deposition of thin films is a complicated science and in practicality, more of an art. Most deposition processes require very high vacuum, as much as 10-10 Torr for some applications. There are a number of different deposition methods available, depending on the application. For deposition of the rare earth - transition metal films used in MO drives, sputtering has been found to work well.

Because of the strict vacuum requirements that thin films have, there is a great deal of sophistication required from vacuum technologies. Not only must leaks be sealed, but the vacuum chamber must be clean so that contamination does not evaporate off and get deposited on the film. Gas leakage through the chamber wall as well as evaporation of the chamber wall must also be considered at higher vacuums.

Sputtering is a technique where a target is put under vacuum with a substrate and bombarded such that atoms from the target are ejected and deposited on the substrate. The target is bombarded with high energy particles (e.g., 1 keV Ar ions) that shake atoms off of the target and into the vacuum. Once in the vacuum, the atoms from the target deposit on the substrate, as well as the chamber walls. One major advantage to sputtering is that it allows for the deposition of films having the same composition as the target. Other techniques do not necessarily have this advantage because different atoms evaporate at different rates and diffusion rates are high at the high temperatures used by other techniques. Hence, a target can be made with a specific composition and sputtered with the assurance that the right composition will be deposited on the substrate.

The basic theory behind the MO drive is the use of a substance that has very temperature sensitive magnetic properties. This substance must have a curie temperature well above room temperature. The curie temperature is the temperature where a material changes between ferromagnetic and paramagnetic. Below the curie temperature, the substance is ferromagnetic and has a magnetic susceptibility of (~106), meaning that it is very difficult to change the magnetic field associated with the substance. Above the curie

temperature, the substance is paramagnetic and has a magnetic susceptibility of (~10-6), meaning that the magnetic field of the substance will change easily according to the surrounding magnetic field. This change from ferromagnetic to paramagnetic is used by the MO drive to write and erase with the use of a laser and a magnetic field.

Writing to an MO disk can be seen schematically in Figure 1A. All of the domains are initially set in the "upward" direction. Hence, only the "downward" direction domains need to be written. The process begins with applying a magnetic field to the disk in the downward direction. The field applied is significantly less than that needed to effect the film at room temperature so the film remains unaffected. Then, a diode laser of micron size is pulsed onto the film's surface. In the areas where the laser is pulsed, the film is heated by about 300°C. This is enough to raise the temperature of the film above the curie temperature where the film is easily altered. At this point, the magnetization of the lased domain changes to the downward direction, that is, the direction of the applied field. When the pulse stops, the film cools and freezes in the downward magnetization. A downward domain may be used to represent a 1 in binary memory, while the upward domains may be used to represent a 0. In practice, two domains are needed for each bit. The second domain is always a 0 and is used for comparison so that the 1 will be recognized without ambiguity.

Overwriting information in the MO drives available today is done by a two step process. First, the old information is erased. This is done by setting the magnetic filed in the upward direction and running the laser continuously as the disk is rotated. Then, the magnetic field is set to the downward direction and the new information is written, as before, by pulsing the laser. Thus, two passes are required to overwrite information. This inherent inefficiency slows the MO drive and is a major drawback of the MO drive. However, single-pass overwriting would require that the magnetic field be modulated at the data rate. Furthermore, the magnetic head would have to be small and very close to the recording film so that the domains that are cooling would not be affected. This would eliminate a major advantage of the MO drive, its large head-to-media spacing.

Reading the magneto-optic media also uses the laser in the drive, but at a reduced intensity so that no significant heating takes place. The magnetic field could be read with a magnetic head, but that would require a very small head that is very close to the media. As mentioned above, such a setup would eliminate a key advantage of the MO drive. Figure

1B shows a schematic of how data are read off a magneto-optical disk. The diode laser emits a reduced beam that passes through a polarizer and is focused onto the disk. According to the polar Kerr MO effect, the plane of depolarization is rotated a small angle ±(K), depending on the magnetization of the domain reflecting the beam. The reflected light is then split by a beam splitter and sent through a second plane polarizer called the analyzer. The analyzer can then be positioned such that the beam reflected by an upward magnetization is canceled out completely. This could register a 0 when no signal is detected by the photodetecter. The beam reflected from a downward magnetization would then pass through the analyzer, at least in part, and be detected by the photodetecter. This could then register a 1. Thus, the binary pattern on the MO disk is read using the polar Kerr magneto-optic effect.

In an effort to fit more data on a disk, short wavelength media is being investigated. It is a relatively simple task to develop a laser that emits at 400 nm for use in place of the 800 nm standard. The difficulty comes in finding a material that will hold the necessary magnetic field in such a small domain. The most promising materials under investigation are garnets, although there are still problems to be resolved.

Garnets have many attractive properties that make them appear promising for future MO applications. While their MO effects are small near the 800 nm range, the effects become large around 400 nm. Garnets are also very stable against corrosion and long-term annealing. They are even resistant to annealing at temperatures of several hundred degrees centigrade. These properties make the garnets a very attractive choice for short wavelength media.

Unfortunately, there are two major problems with garnets that are not yet resolved. Since garnets are so resistant to annealing at high temperatures, the substrates must also be as durable because the garnets must be deposited at even higher temperatures. This rules out the plastic substrates used for the current MO disks. Most substrates are too expensive for a low cost storage media, except for one: glass. Because of its low cost and high durability with respect to temperature and corrosion, glass may very well be the only substrate that garnets can use, at least for the time being. The other major problem with garnets is that they have a poor signal-to-noise ratio. Garnets tend to have grain sizes of around 400 nm which causes domain walls to follow the grain boundaries. This causes large fluctuations in domain size and a large amount of noise. Some work indicates that

grain sizes have been made as low as 30 nm. This would indicate that the problem of domain walls following grain boundaries may soon be solved.

A recent conclusion is that MO disk drives are a growing technology that are finding their place in the mass storage arena. Because of their large storage capacities and relatively slow read/write times, they are best suited for large amounts of data that are not used very frequently. There is a lot of technology involved in the deposition of thin films, but there is still quite a bit to be learned in that area as well. The MO drive works on the basis of a large magnetic field turning a small domain when it is heated above its curie temperature by a laser.

Overwriting old data requires two passes of the writing head, one to erase the data and another to write in the new data. This double pass is one of the reasons that MO drives are slower than more conventional magnetic hard disks. Reading data from a MO disk involves a plane polarized, low intensity laser beam that is rotated by the magnetization of the domain being read (polar Kerr effect). It has been predicted that future MO drives win probably have garnets on a glass substrate using a laser with a wavelength of 400 nm.

Optical switches or optical switching is an important future goal of the computer industry. Islam (1993) *Byte* 17:183. The definition of an optical switch is a device that allows one light signal to affect a property of second light signal. There are several types of optical switches that have been developed most of which are electro-optical; these are switches that require an external electrical potential in order to function. McIntyre et al. (1990) *SPIE Proc. Ser.* 1378:162. Recently, a few optical switches have been developed which require only light to operate and are the most desirable in the proposed optical computer industry. Unfortunately, these switches, which are based on light-induced chemical or structural alterations in the switch material, are by nature slow and so their usefulness is limited. Islam (1993); and Wood et al. (1989) *SPIE Proc. Ser.* 1105:154.

Photocopying is generally accomplished by using a material that develops an electrostatic charge when irradiated with light. Mercer (1967) *"Photography and Photocopying"* 3rd ed. MacDonald and Evans, London, pp. 29-34. An electrostatic ink is then applied to the areas which have been exposed to light forming an image. A drawback of this design is that most materials respond to electrostatic charge and this can lead to transfer of unwanted static charge to the other parts of the machine. This can in turn affect the functioning of the photocopier. The use of photomagnetic materials in place of the

electrostatic compounds currently in use limits this problem since most materials do not respond to magnetic fields.

The development of new materials with intrinsic parameters which affect electronic properties has become increasingly more important and has begun to encompass a variety of scientific disciplines. Covalent crystalline materials containing delocalized pi systems are known to exhibit interesting electronic properties when combined with other characteristics such as partially filled electronic energy levels and certain types of electron-phonon coupling. See, for example, Kittel, *Introduction to Solid State Physics*, 6th Ed., John Wiley & Sons, Inc., New York (1986), pp. 338–340. Examples of materials that have these properties are intercalated graphite and n-doped polyacetylenes described by Zhu et al., *Nature*, 355:712–714 (1992), p-doped polyaniline described by MacDiarmid et al., *Synth. Met.*, 18:285 (1987), sulfur nitride (SN) described by Labes et al., *Chem. Rev.*, 79:1 (1979), and intercalated C_{60} described by Haddon et al., *Nature*, 350:320–322 (1991). These materials can exhibit a range of parameters from semiconductor to metallic-like conductivities and many are superconducting. For example, the intercalated C_{60} material can have a superconducting conversion temperature (T_c) as high as 45 K.

Some copper oxide containing compounds have been found to have a T_c value as high as 125 K, which is believed to be due to planes of copper and oxygen that extend through these materials. See Cava, *Sci. Amer.*, 263:42–49 (1990). Copper and oxygen atoms positioned within a plane form only 90° and 180° angles for bonding. Such bonding may have an important impact on the electronic system since the d and p electron orbitals for the atoms are orthogonal to each other. The performance of the copper oxide containing compounds has raised interest in investigating materials with a structure and dimensionality similar to a copper-oxygen plane. Materials which geometrically mimic a planar structure are Hofmann clathrates and the best known of these is $Ni(CN)_2NH_3C_6H_6$ disclosed by Iwamoto, *Inclusion Compounds*, 1:29-42, Academic Press, London (1984). However, the material's electronic properties are not very interesting. It is a very good insulator and has the predicted negative resistance versus temperature slope for insulators. There is no evidence of pi delocalization over the crystal structure. It is believed the delocalized pi system in these compounds is limited and extends only over the units of $[Ni(CN)_4]^{2-}$. Other compounds with structures which mimic a Cu-O plane are "Prussian Blues" described by Shriver et al., *Inorg. Chem.*, 4:725-730 (1965). These compounds

differ in the respect that the networks are three-dimensional, consisting of octahedral transition metals interlinked by linear cyanide units. These compounds are not clathrates and contain counter ions such as alkali metals in the lattice. Delocalization in these compounds is also limited and is believed to extend only over the units of $[M(X)(CN)_6]^{-6+x}$, wherein X is the oxidation state of the transition metal and is in general +2 or +3. It is desirable to provide compounds wherein the pi delocalization is extended further than that of the copper oxide-planes to obtain novel electronic properties.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide devices comprising and methods of use containing photomagnetic material that increases local magnetization after being irradiated with light.

The devices and methods of use include optical computers and computer disks, both with read-write capability and random access memory; light weight motors; magnetic analog films, tapes or substrates; digital films, tapes or substrates; optical switches; photocopiers and sensors.

There is provided by the present invention the use of preferred planar compounds comprising transition metals selected from the group consisting of Ni(II), Pd(II), Pt(II), Au(III), Ir(I), Rh(I), and three dimensional compounds comprising transition metals selected from the group consisting of Fe(II), Fe(III), Co(II), Co(III), Cr(III), Mn(II), Mn(III), Mo(II), Os(II), Rh(III), Ru(III) and Ir(III), wherein the infrared spectra of these compounds have a fingerprint peak within the range of 595-655 cm^{-1} for the metal-carbon stretch. In preferred embodiments, the compounds are ferromagnetic, comprise nickel, iron or cobalt, have a density below 5 g/cm^3 and show enhanced ferromagnetism when exposed to light or thermal energy. Planar compounds such as those comprised of nickel have a density below 5 gm/cm^3. Three dimensional compounds such as those comprising Fe or Co have a density below 3 gm/cm^3.

BRIEF DESCRIPTION OF THE DRAWINGS

Various other objects, features and attendant advantages of the present invention will be more fully appreciated as the same becomes better understood when considered in conjunction with the accompanying drawings, in which like reference characters designate the same or similar parts throughout the several views, and wherein:

Figure 1 depicts the prior art magneto-optical read-write mechanism. Figure 1A is a schematic depiction of the method used to write to an MO disk. Figure 1B is a schematic depiction of the method used to read an MO disk.

Figure 2 is a schematic of top view of a magnetic tape or substrate onto which particles of PM and NFM have been blended uniformly into a tape or substrate.

Figure 3 is a schematic of cross section of PM coated onto a layer of NFM such as in a floppy disk or computer disk.

Figures 4A and 4B depict the mechanism of action of storage of information in the device depicted in Figure 3. In Figure 4A an applied magnetic field traverses the PM and NFM layers. Note that the NFM domains are randomly oriented at right angles to the applied magnetic field. Note that the applied magnetic field is less than $B_{critical}$. This is the blank storage medium. In Figure 4B, the λ_{res} is applied to one NFM domain, producing a region of induced magnetism (or, enhanced local magnetic field) at the domain, raising B_{local} above $B_{critical}$ and causing polarization of the domain.

Figure 5 is a schematic of an optical switch. The polarization (P) of light signal (B) is altered by light signal (A).

Figure 6 is a representation of the partial atomic structure of a planar compound for use in the present invention.

Figure 7 is a representation of the partial atomic structure of a 3-D compound for use in the present invention.

Figures 8A-C are representations of possible stacking arrangements for planar compounds for use in the present invention.

Figure 9 is a representation of the atomic structure of a planar compound for use in the present invention with cations shown.

Figure 10 is an infrared spectrum of a compound for use in the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As used herein, "photomagnetic material (PM) refers to any material that changes its magnetic properties when exposed to light of a particular wavelength and intensity.

As used herein, "resonance wavelength" (λ_{res}) refers to the wavelength of light that maximizes a photo-induced effect.

As used herein, "normal ferromagnetic material" (NFM) refers to any material that can be permanently magnetized.

As used herein, "optical switch" refers to and optical switch in a true optical computer and refers to a device capable of allowing one light signal to change a property of a second light signal. Such properties include, but are not limited to, phase, polarization, and frequency. Preferably, the change is one that is readily measurable.

The invention encompasses applications including, but not limited to, (1) lightweight ferromagnetic applications, computer and data storage technology; (2) recording technology; (3) photocopying devices, (4) optical switches; (5) magnetic analog film; and (6) electronic devices and sensors.

It is now possible to improve on previous devices incorporating MO materials by using materials that have a true photomagnetic property. The areal density of these materials is limited only by the width of the laser beam, the wavelength of light and small effects due to the scattering of light at the substrate surface. This can lead to effective storage areas a few orders of magnitude smaller than what can be currently achieved with current MO systems. A second improvement is the speed at which information can be stored by the material. This can be realized when PM materials are chosen that have mechanisms that are electronically based. Electronic excitations induced by the absorption of light generally occur on a sub-nanosecond time scale making the alteration in magnetic properties of these materials several orders of magnitude less than currently used compounds.

The use of electronically based photomagnetic effect materials to accomplish optical switching makes possible the use of optical computers since the switches would intrinsically operate on subnanosecond time scales.

With respect to the photomagnetic effect, PMs are suitable for use in optical computers. The compositions described herein are the preferred PMs as they are one of the few known materials with the potential capability of converting light information into

magnetic information. Although information can be transmitted optically, it must still be stored magnetically. Thus, the optical computer industry has been searching for materials capable of acting as the interface between light-based systems and magnetic data storage systems.

In addition, the fact that the PMs respond magnetically to light creates the potential for "read-write" CDs that can be written on with laser light, then erased and re-used. Current read-write technology is heat-based and is thus less accurate and disks deteriorate faster than a lower-temperature technology that uses the photomagnetic effect.

The light weight of the PMs means that they are suitable for use in all devices where magnets are presently used and the weight of the device is important. Magnets made containing PMs weigh substantially less than traditional magnets. Thus, magnets made from PMs are suitable for use in the motors of electric cars, aircraft and portable devices where weight is at a premium.

Derivatives of particular photomagnetic materials can be made into normal ferromagnetic materials which are ferromagnetic without the assistance of light. U.S. Pat. No. 5,501,808. These materials have very low physical densities but still have reasonably large magnetic densities. These light weight magnets are suitable for use in machines where weight is a critical factor such as motors for electric cars, aircraft and portable devices.

Recording technology. A potential application is the development of a tape or film impregnated with photomagnetic particles that will respond directly to light and form a magnetic image. In the fields of audio and visual recording, the digital code can be written on the tape with a laser beam, thus increasing the amount of information that can be stored on the tape. Laser beam technology is already well-developed in connection with CD-ROM technology, so adapting it to PM-based technology should not present any great technical obstacles. In addition, in the field of visual recording, an image may be capable of being captured directly in analog form on the PM-impregnated tape, i.e., the image is actually captured magnetically. This is analogous to the traditional motion picture celluloid film process where the image is stored 'in a direct, one-for-one representation on the film by a chemical process. With the PM-based technology, however, the tape has the potential to be re-used and readily edited like magnetic videotape.

Magnetic Information Storage. Recording and accessing information on photomagnetic medium can be accomplished as follows.

As depicted in Figure 2, the PM particles (represented by Xs in Figure 1) are combined with the NFM particles (represented by Os in Figure 2) into a tape or substrate. In an alternate configuration, the PM is coated onto a layer of NFM as depicted in Figure 3.

Information is placed onto the material as follows:

Referring to Figure 4A, the prepared composites are placed in an applied magnetic field ($B_{applied}$) that is less than the critical magnetic field ($B_{critical}$) required to magnetically polarize a NFM domain parallel to the applied field. As shown in Figure 4B, when light at the resonance wavelength (λ_{res}) is applied to a single point on the surface or the entire surface containing PM, the magnetization vector of PM increases. This increases the strength of the local applied magnetic field (B_{local}) according to the relationship $B_{local} = \mu(\lambda_{res})B_{applied}$, where $\mu(\lambda_{res})$ is defined as the photo-induced magnetic permeability of PM. The B_{local} is made greater than $B_{critical}$ and this in turn induces a magnetic polarization vector parallel to the applied field in the NFM domain at that point. The cross hatched area in Figure 4B indicates the region of induced or enhanced local magnetization. Irradiation with λ_{res} causes one NFM domain to align with $B_{applied}$. This domain contains magnetic information. This process occurs at close to the speed of light. This process can be reversed by reversing the applied magnetic field. In Figure 4, the applied magnetic field can be applied at any angle. Likewise, the light beam can be directed at any angle to the PM.

The magnetic information can be accessed by monitoring the polar Kerr rotation of a light source reflected from the surface of the composite. Preferably, the light source is not at λ_{res}, or, if at λ_{res}, it is below the critical intensity.

Forming analog magnetic images is accomplished as stated above except that the gray and color scales can be represented by variations in the magnetization vector at different points on the surface. These variations are induced by variations in light intensity (gray scale) and wavelength of light (color scale) altering the magnitude of $\mu(\lambda_{res})$, which is a function of both these variables. This in turn sets the magnetization vector in the NFM domains at each point forming an analog magnetic image.

Photomagnetic materials can be used in the field of visual recording. Images can be captured directly in analog form on a tape or substrate impregnated with a photomagnetic compound, i.e., the image is actually captured magnetically. This is analogous to the traditional motion picture celluloid film process where the image is stored in a direct, one-for-one representation on the film by a chemical process. With this new technology, however, the tape has the potential to be re-used and readily edited like magnetic videotape.

Photocopying technology. Another application is the development of a new photocopying process. Current photocopying processes use light-sensitive materials combined with electrostatic charge to guide the ink onto the copy surface. Using the same conceptual approach, photomagnetic materials combined with magnetic fields can be used to guide the ink onto the copy surface.

Electronic devices and sensors. Sensors are used in a ubiquitous fashion throughout industry. When used as a light sensor, photomagnetic materials are more versatile than a photodiode. Photomagnetic materials can respond to light intensity, magnetic field strength, temperature and wavelength of light. U.S. Pat. No. 5,501,808. This is in contrast to photodiodes which in general respond only to changes in light intensity and a limited range of wavelengths. When photomagnetic materials are combined with applied magnetic fields, the wavelength of light that they respond to can vary with the intensity of the applied magnetic field. Sensors made with these materials can respond to specific frequencies of light.

Any electronic devices which presently rely on ferromagnets are substantially enhanced by using photomagnetic material. In most electronic devices, the electron speed is about 1% of the speed of light, while optical signals travel at 90% of the speed of light. Thus, using ferromagnets that can respond to optical signals presents obvious speed advantages. The photomagnetic material also presents a new way of detecting light, magnetic fields and/or combinations thereof. As a light sensor, it would be more versatile than a photodiode. Preliminary testing indicates that the threshold frequency of light which produces the photomagnetic effect appears to vary with the strength of an applied magnetic field. The sensor could thus be "tuned" to react to different frequencies of light. This is in contrast to photodiodes, wherein different materials need to be employed for each frequency range.

Optical Switching. Optieal switching can be achieved as follows. As depicted in Figure 5, a layer of PM is placed in an applied magnetic field. A light signal (A) that is at λ_{rcs} is incident on a point on the PM layer while a second *polarized* light signal (B) is reflected from the same point as (A). The induced magnetization $\mu(\lambda_{rcs})$ of the PM causes the polarization of signal (B) to change via the polar Kerr rotation effect.

There are a number of products where it is vital to have the lightest possible electric motor. For example, electric cars need to have very lightweight electric motors in order to conserve energy and run efficiently; any extra weight makes them inefficient and costly to run. For example cars powered by electric motors with magnets made from PMs would be more efficient and able to travel longer distances.

Another example is portable audio and video recording devices. The market demands that these products be as light and compact as possible. Each device, however, has to have an electric motor to roll the video or audio tape through the machine. Because it must contain a magnet, the motor is one of the heaviest components in these devices and PM will reduce that weight substantially.

The two primary applications in the computer/data storage market are: (1) high speed optical computers and (2) laser-mediated data storage. An integral part of the optical computer is a so-called "optical chip" which uses light instead of electronic signals.

Ordinary floppy disks use magnetic storage to store approximately 2 megabytes of data. Optical disks can store up to 600 megabytes of data. The drawback of conventional optical disks (such as CD-ROM disks) is that, unlike magnetic disks, they cannot be erased and re-recorded with new data. Thus, over the past ten years, the data storage industry has been developing MO disks which store the information magnetically like a magnetic disk and can thus be erased and re-written, but which can be read and written on with light, thus permitting the much higher data storage capacities of optical disks.

MO disks are currently being manufactured and sold primarily by Philips and Sony, which also make the drives necessary for reading and writing on such disks.

PMs have applications in the area of MO disks. The current magneto-optical disks work by a heating process which is relatively inefficient. Recording takes place via a high-power writing laser which quickly warms a tiny area on the disks metallic surface, causing the magnetized molecules to line up with the magnet below. On playback, a specially filtered low-power laser beam strikes these molecules and is altered slightly as it bounces

off the disk. The reflected light is then converted into an electronic signal. To erase, the machinery simply reverses the current in the magnet, the writing laser comes back on, and the molecules get flipped the other way.

Because PMs can become ferromagnetic in the presence of the correct frequency of light, and because ferromagnetic materials can in turn enhance the strength of a magnetic field, a magnetic disk surface can be impregnated with PM such that a writing laser will increase the magnetic field in the area where the beam strikes to a critical strength, causing that region, and that region only, to "flip" as in the conventional magneto-optical disk. This process, however, uses no heat, so the inefficiencies of heat transfer (e.g., slow speed, poorer resolution of the beam-affected region, breakdown of materials) are avoided. Reading is accomplished exactly as in the current heat-based technology. Erasing is simpler and more efficient than with the current heat-based systems, since the entire disk is simply exposed to light in the presence of the reversed magnetic field instead of being heated in the presence of the reversed field.

The invention includes the use of compounds with only one transition metal as well as those with mixtures of transition metals having the same coordination characteristics which form either planar or 3-D structures. The molar ratio of the transition metals within the compound can vary widely. A continuous ratio of mixing is possible. Mixed transition metals have been shown in the planar Hofmann clathrates described by Iwamoto, *supra; the* "Prussian Blues" described by Shriver et al., *supra.* and the poly(yne) compounds described by Sonogashira et al., *J. Organomet. Chem.* 160:319-327 (1978). The compounds of the present invention comprise transition metals as described above in a coordinated crystal structure such that a metal-carbon stretch provides a broad fingerprint peak within the range of 595 to 655 cm^{-1} within its infrared spectra. The hydrated form of the crystalline-like compounds of this invention which comprise nickel have a fingerprint peak of about 625 cm^{-1} in the IR spectra and a fingerprint peak of about 7.98 Å in the X-Ray powder diffraction spectra.

The transition metals useful in forming the crystalline-like compounds having a planar structure are those capable of forming square planar complexes such as Ni(II), Pd(II), Pt(II), Au(III), Ir(I) and Rh(I). Such transition metal species provide bonding angles of 90° and 180°. The transition metals contemplated for use in crystalline-like compounds having 3-D networks are capable of forming octahedral complexes with

carbon. These include Fe(II), Fe(III), Co(II), Co(III), Cr(III), Mn(II), Mn(III), Mo(II), Os(II), Rh(III), Ru(III) and Ir(III). These transition metals provide the appropriate bonding angle consistent with copper oxide planes. In forming the transition metal planes or three-dimensional network, the transition metal is reacted with a coordinating compound or ligand to complete the crystalline structure of the compound.

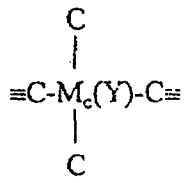
The unit cells for these crystalline-like compounds can be planar or 3-dimensional, depending on the transition metal used. The size of the unit cell also varies with the transition metal(s) utilized. Two axes (a and b) for the unit cell of the planar crystalline structure have a dimension which is a multiple of a value in the range of 4.90 Å to 5.10 Å. The value multiplied depends on the transition metal due to the varying size of the bond lengths. The multiplier, N, is typically from 1-1000, more typically less than 100. Therefore, the range of dimensions for the axes a and b can be represented as 4.9 Å N to 5.1 Å N. The axes a and b do not have to have equivalent dimensions. The distance between the planes can vary from 3.5 Å to 4.5 Å for non-hydrated compounds and 3.5-10Å for intercalated or hydrated compounds. The C axis is some multiple of the distance between planes. For nickel compounds, the dimensions of the two axes a and b are both about 10.13 Å (N = 2) and the distance between planes is believed to be about 6.75 Å with a C-axis of about 13.5 Å.

The unit cell for three dimensional compounds have axes a, b and c with dimensions represented by multiples of a value in the range of 4.9 Å to 5.1 Å, depending on the transition metal. The multiplier, N, is also typically from 1-1000, more typically less than 100. Therefore, the range of dimensions for the axes a, b and c can be represented as 4.9 Å N to 5.1 Å N. The axes a, b and c do not have to have equivalent dimensions.

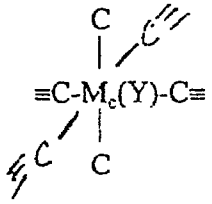
Where more than one transition metal is used and the compound is crystalline, the dimensions of the unit cell are expected to fall within the ranges above. However, with mixed transition metals, the compound's structure may be completely random with respect to the order of transition metals with no definable unit cell.

Not wishing to be bound by theory, it is believed that the transition metal is coordinated with acetylide, C_2^{2-}, segments. This theory is consistent with the products expected from the starting materials utilized in forming the transition metal crystal structures; the size of the unit cell of crystalline-like nickel compounds, as extrapolated

from X-Ray powder diffraction data and the unique electronic properties of the compounds obtained. Pursuant to this theory, a partial unit cell (counter cations not shown) for a four coordinated transition metal bonded to acetylide has the structure shown below:



wherein $M_c(Y)$ = a four coordinated transition metal. An example of a partial unit cell (counter cations not shown) for a six coordinated transition metal bonded to acetylide has the structure shown below:



Not wishing to be bound by theory, it is believed the planar crystalline transition metal compounds of the present invention are of a structure as shown in Figure 6, where only transition metals 5 and acetylene carbons are shown. The counter cations are not shown in Figure 6 and are believed to extend between the planes. The empirical formula for compounds with a structure as shown in Figure 6 is $M(X)_{(4-Y)/X}M_c(Y)C_4$, wherein $M_c(Y)$ is the transition metal, with Y being its ionic state and M(X) being the counter cation with X being its ionic state. M(X) is typically an alkali metal, alkaline earth metal or rare earth metal or stable cation such as a quaternary ammonium ion (NR_4^+) where R is H or any organic moiety. Such a structure will provide a delocalized pi system over a significant portion of the compound. Planar compounds of the formula $M(X)_{(4-Y)/X}M_c(Y)C_{4n}$ wherein n = 1-6 will also provide a delocalized pi system. In such a compound, more than one acetylene group is bonded between the metal atoms.

In the crystalline compounds of the present invention having three dimensional crystal structure, the coordinating compounds or ligands extend between planes. Not wishing to be bound by theory, where the coordinating compound or ligand is an acetylide (C_2^{2-}), it is believed the 3-D crystalline network has a structure as shown in Figure 7. The empirical formula for such a crystalline compound is $M(X)_{(6-Y)/X}M_c(Y)C_6$, wherein $M_c(Y)$ is a transition metal, with Y being its ionic state, and M(X) being the counter cation with X

being its ionic state. Three dimensional compounds of the formula $M(X)_{(6-Y)/X}M_c(Y)C_{6n}$ wherein n=1-6, also provide a delocalized pi system.

As shown in Figures 8A-7C, the planar structures can have many orientations including eclipsed, staggered or centered. The eclipsed form, shown in Fig. 8A, makes the planes superimposed and is a tetragonal unit cell since a=b≠c and the bond angle $\alpha=\beta=\gamma=90°$. The c axis is given as the interplanar distance. This type of geometry has been seen in certain transition metal cyanides as disclosed by Miller et al. (1975) *Prog. Inorganic Chem.* 20:1. The staggered form, shown in Fig. 7B, has many combinations and places the planes at some orientation other than eclipsed or centered. The sequence could be ABA where the A planes are in the same orientation and the B planes are staggered. A special case of staggered is centered, shown in Fig. 7C. In this case, the c axis is twice the interplanar distance.

When the counter cations are considered in the structures given in Figures 6 and 7, the unit cells will remain in the tetragonal crystal system if their arrangement is the same for each unit. When the counter cations have repeat patterns that encompass more than one unit, then the crystal system can change. When the pattern is only along the c axis, the tetragonal system is maintained. If it is along either the a or b axes, then the system can become orthorhombic wherein a≠b≠c; however, $\alpha=\beta=\gamma=90°$.

When considering the crystal structures for the 3-D networks as shown in Figure 7, it is usually seen that the cell unit is cubic without consideration of the counter cations. (a=b=c and $\alpha=\beta=\gamma=90°$). This would be true because the connectivity is the same along three crystallographic axes. When the counter cations are considered, the crystal system can become either tetragonal or orthorhombic, depending on the direction of the counter cation repeat pattern.

Dimeric and oligomeric forms of these proposed compounds have been synthesized by Takahasi et al. *The Institute of Scientific and Industrial Research*, pp, 247-251. The compounds of the present invention are more delocalized and partially ionic in character and thus have stabilities greater than known non-ionic linear transition metal acetylide polymers. The compounds, described herein, like the linear transition metal acetylides, can obtain high molecular weights. However, the compounds of this invention are two-dimensional and three-dimensional in structure with many compounds being ceramic-like.

Compounds of the present invention can be produced by reacting anhydrous transition metal halide with alkali metal and/or alkaline earth metal acetylides (C_2^{2-} = acetylide) in an inert atmosphere following mixing at a temperature of at least 300°C, preferably at the eutectic temperature of the transition metal halide and the alkali metal/alkaline earth metal halide for at least 3 minutes to more than one hour. For example, the eutectic temperature of $NiCl_2$ and $CaCl_2$ is about 600°C. Two or more transition metal halides can be reacted to provide compounds with mixed transition metals. A mixture of black and white powder is obtained from this reaction. The formation of a black powder is noticed as the reaction progresses until a color change is complete. This method was used to prepare the crystal-like compositions of this invention comprising nickel with the following stoichiometry

$$NiCl_2(s) + 2CaC_2(s) \longrightarrow CaNiC_4(s) + CaCl_2(s)$$

A more general formula is as follows:

$$M_c(Y)Z_y + 2M(X)_{2/x}C_2 \rightarrow M(X)_{(4-y)/x}M_c(Y)C_4 + \underline{Y}M(X)Z_x$$

where Z is a halogen.

This method is preferred and preferably, the reaction volume is minimized to minimize sublimation loss of $NiCl_2$. Purification of the product is accomplished by extracting calcium chloride and unreacted nickel chloride with an alcohol. Calcium carbide can also be removed by reaction with an alcohol. The planar structure and the presence of acetylide ligands are consistent with X-Ray powder diffraction analysis.

Other methods are also suitable, such as reacting within a solvent a transition metal tetraacetylide complex of the formula $M(X)_{(4-Y)/X}M_c(Y)(C_2H)_4$ and a transition metal salt of the formula $M(X)_{(4-Y)/X}M_c(Y)Z_4$ in the presence of a catalyst such as a copper (I) salt of the formula Cu(I)Z, $AgClO_3$, AIBN or Bu_3B/O_2, wherein M(X) and $M_c(Y)$ are as defined above and Z is preferably a halide or carboxylate. Two or more transition metal halides and/or two or more transition metal tetraacetylide complexes can be reacted to provide compounds with mixed transition metals.

An additional method for preparing a metal compound having a 3-D crystalline structure comprises reacting within a solvent a transition metal hexaacetylide complex of the formula $M(X)_{(6-Y)/X}M_c(Y)(C_2H)_6$ and a transition metal salt of the formula $M(X)_{(6-Y)/X}M_c(Y)Z_6$ in the presence of a catalyst such as a copper (I) salt of the formula Cu(I)Z (where Z is preferably halide or carboxylate) $AgClO_3$, AIBN or Bu_3B/O_2. In preferred

embodiments, the transition metal is nickel. Two or more transition metal halides and/or two or more transition metal tetraacetylide complexes can be reacted to provide compounds with mixed transition metals.

The tetraacetylide complex can be obtained by a novel method of this invention wherein acetylene is reacted in a solvent with a transition metal salt of the formula $M(X)_{(4-y)/x}M_c(Y)Z_4$ in the presence of a catalyst such as a copper (I) salt, Cu(I)Z (Z = halide) $AgClO_3$, AIBN or BuB/O_2 according to the following reaction

$$M(X)_{(4-y)/x}M_c(Y)Z_4 + 4H_2C_2 \rightarrow M(X)_{(4-y)/x}M_c(Y)(C_2H)_2+4HZ.$$

The hexaacetylide complex can be obtained by a similar reaction scheme with the same catalysts wherein equivalents of acetylene are reacted in a solvent with $M(X)_{(6-y)/x}M_c(Y)Z_6$ to provide $M(X)_{(4-y)/x}M_c(Y)(C_2H)_6$.

Alternatively, the tetraacetylide complex can be obtained by conventional means, such as reacting a transition metal thiocyanate or cyanide with an alkali earth metal salt of acetylide in solvent. The hexaacetylide complexes can be obtained by similar techniques wherein a corresponding transition metal thiocyanate is reacted with an alkali metal salt of acetylide.

These are only some examples of methods for chemically linking to transition metal atoms with acetylenic carbons. The most useful types are copper salt catalyzed reactions (Cu(I)Z) between transition metal complexes and acetylenes. This works well for Pt and Pd but not for Ni since the complexes form precipitates in amine solutions. The choice of Z is preferably limited to halides or possibly saturated carboxylates. The most stable catalyst is copper (I) iodide. These reactions should be carried out in the absence of O_2 since oxygen can cause oxidative coupling between the acetylides.

When transition metals having ferromagnetic properties are used in the crystalline-like compounds of the present invention, these crystal structures also exhibit ferromagnetic behavior. They are of low density, typically below 5 g/cm^3 for planar compounds and below 3 g/cm^3 for 3-D compounds, and also exhibit unusual electronic behavior.

Photoferromagnetic and thermoferromagnetic properties have been found to exist in compounds comprised of nickel. In addition, a nonlinear ferromagnetic response with respect to an externally applied magnetic field has been found.

The compounds containing nickel have been obtained by heating nickel chloride and calcium carbide in an inert atmosphere following mixing and heating under the conditions described in the examples. The nickel compound is hygroscopic and reacts with a large excess of water to produce a mixture of nickel hydroxide, calcium hydroxide and acetylene gas. The hygroscopic formula being $CaNiC_4 \cdot xH_2O$ wherein x is believed to be between 2 and 0. The nickel compound is black with a metallic luster and has a bulk density of approximately 1.34 grams per/ml. The compound catalyzes the decomposition of diethylether.

Ferromagnetism is induced or enhanced by irradiating a sample of the PMs described herein with either fluorescent light or sunlight with an optimum wavelength between 600 and 400 nm. The light is preferably provided by laser so as to adjust the spot size. The spot size is limited only by diffraction effects, wavelength and anomalous scattering effects. These are negligible and easily controllable. Ferromagnetism is induced or enhanced by heating a sample to at least about 20°C, preferably 70°-90°C. Higher temperatures provide a stronger response. The ferromagnetic compounds show a non-linear ferromagnetic response with respect to externally applied magnetic fields with the response increasing with increasing fields. Not wishing to be bound by theory, it is believed that when the conduction band reaches a critical electron density, the exchange interaction induces the ferromagnetic transition. This critical electron density can be reached by either photon excitation or by thermal excitation or both. The energy gap of the material is a function of the applied external magnetic field and decreases as field strength increases since the energy of the conduction electrons are lowered. This applied external field can be coupled with the excitation of electrons with photons or thermal energy. The material is either semiconducting or semimetallic.

Not wishing to be bound by theory, it is believed that the structures and stoichiometry of these compounds is indicative of a superconducting transition within these compounds at some temperature. It is also believed the mixed transition metal compounds will provide electrical properties different from those compounds having only one transition metal. For example, a compound with Fe(II) is expected to be semi-conducting based on a diagram of its molecular orbitals and a compound with Fe(III) is expected to be conducting. A compound with both Fe(III) and Fe(II) would transfer from semiconductive to a metal-like conductor as the proportion of Fe(III) is increased.

Metal-like compounds are expected to have 60-100 mol% Fe(III) and semimetallics are expected to have 0-60 mol% Fe(III).

Without further elaboration, it is believed that one skilled in the art can, using the preceding description, utilize the present invention to its fullest extent. The following preferred specific embodiments of the preferred composition are, therefore, to be construed as merely illustrative and not imitative of the remainder of the disclosure in any way whatsoever.

In the foregoing and in the following examples, all temperatures are set forth uncorrected in degrees Celsius; and, unless otherwise indicated, all parts and percentages are by weight.

The entire disclosures of all applications, patents, and publications, cited above and below, are hereby incorporated by reference.

EXAMPLE

Nickel chloride and calcium carbide in a 1:2 molar ratio in a solid state (anhydrous) were heated with a protective argon purge gas at 1 atm in a quartz reactor. The crucible was open to the purge gas. An electric oven was used to provide a temperature of about 970°C for 24 minutes. During heating, a color change in the starting materials was noticed after two minutes and, following 24 minutes, the color change was complete. Following heating, the reactants were washed with distilled/deionized water for one hour to remove the soluble salt byproducts and unreacted starting materials such as $CaCl_2$ and $NiCl_2$ and also to remove excess CaC_2. The product was then dried for several weeks in a desiccator. The product was anhydrous after heating. The resulting product was plated out to provide a shiny black/white powder with a density of about 1.8 ± 0.5 g/cm^3. The compound remained inert for about one year with no oxidation, even when heated to a temperature of about 70°C. When added to diethylether, the solution bubbled, showing indications of a reaction without a loss of material, suggesting catalysis. The combustion temperature was found to be about 200°C-300°C which yielded a green and white powder.

An IR spectrum and X-Ray diffraction spectrum were taken of the anhydrous product. Diffraction and IR spectra showed the presence of $Ca(OH)_2$, $CaCO_3$ and Ni metal and unusual peaks attributed to one of the inventive compounds in the mixture. The Ni

metal may have been formed by decomposition of $NiCl_2$ since it is known that the ionic salt carbides reduce transition metal halides at temperatures of about 700°C.

The IR Spectra

Figure 10 is the IR spectrum of a compound produced by the method above. The broad band from 3000-3600 cm^{-1} is assigned the OH stretch of $Ca(OH)_2$ and possibly water of hydration. The broad band at 1200-1400 cm^{-1} is assigned to $CaCO_3$ and $Ca(OH)_2$. The two bands at 2924 cm^{-1} and 2875 cm^{-1} correlate with the compound $K_2Pt(C_2CH_3)_2$. However, the bands are due more likely to the analogous species such as $M(X)_{2/X}Ni(C_2R)_4$ on the surface. These compounds are most likely formed by reaction with impure acetylides present in CaC_2. The peak at 2349 cm^{-1} is $C0_2$. The peaks at 1087 cm^{-1} (H1), 875 cm^{-1} (H2) and 712 cm^{-1} (H3) are $CaCO_3$. The jagged bands at 3600-4000 cm^{-1} and 1600-2000 cm^{-1} are free water (12). The peaks at 2500 cm^{-1} (G) and 1000 cm^{-1} (J) have not been assigned at this time. The broad peak at 1625 cm^{-1} (E) is assigned to water of hydration. The presence of water of hydration in the spectrum may indicate the unknown material is hygroscopic, since $Ca(OH)_2$ and $CaCO_3$ do not form hydrates. The band at 625 cm^{-1} is believed to be Ni-C stretching. The approximate location of a nickel acetylenic carbon stretch in free molecules is 585 cm^{-1}, and, therefore, this black powder product does not comprise free molecules.

X-Ray Diffraction

An X-Ray powder diffraction pattern was recorded and an elemental analysis was also done. Confining the powder diffraction file search with the elemental analysis allowed for identification of Ni metal, calcium hydroxide and $CaCO_3$. The intense lines remaining define a compound of the present invention. This showed a low intensity line of 7.98 Å. The elemental analysis showed the presence of Ca, Ni and lesser amounts of Cl and Mg, some Si, Al and S. The spectrum was recorded on an electron microscope equipped for elemental analysis. However, this procedure did not allow for identification of carbon.

Figure 9 shows a representation of the structure of a tetracarbide, the transition metals 5, acetylene carbons 15 and cations are shown but the water molecules are not shown. A tetragonal unit cell with a = b = 10.13 Å, c = 13.25 Å is indexed from the X-Ray diffraction powder pattern taken of the compound formed. The dimensions of the a and b

axes are consistent with the experimental data on the bond lengths and bond angles of nickel acetylides.

The compound was found to be ferromagnetic with the ferromagnetic properties being induced or enhanced upon exposure to fluorescent light or sunlight. The ferromagnetism was demonstrated visually. The compound was also found to have ferromagnetic properties which persist after irradiation as long as 1-3 hours, showing a gradual decay.

The compound is also thermomagnetic. Heating the compound to about 70-80°C induced or enhanced magnetic properties. Thermomagnetism is found at temperatures of 20°C and higher.

Exposing the compound to a magnetic field also enhanced ferromagnetic behavior in response to light and heat. Exposure to high magnetic strengths allowed incandescent light to induce ferromagnetism. Ferromagnetism induced under these conditions is shown with the same test magnets used to show ferromagnetism under fluorescent light. Not wishing to be bound by theory, high magnetic field strengths are expected to reduce the band gap, allowing such frequencies to provide the desired response.

The compound is a black material with a strong metallic luster. It is ferromagnetic on the same order of magnitude as iron, but with a density of 1.34 g/cm^3. This means that it is the lightest known ferromagnetic material, and weighs less than 25% of the weight of better known ferromagnetic materials such as iron.

The preceding examples can be repeated with similar success by substituting the generically or specifically described reactants and/or operating conditions of this invention for those used in the preceding examples.

From the foregoing description, one skilled in the art can easily ascertain the essential characteristics of this invention and, without departing from the spirit and scope thereof, can make various changes and modifications of the invention to adapt it to various usages and conditions.

CLAIMS



WHAT IS CLAIMED IS:

1. A method of recording information on a magnetic medium, the magnetic medium including a number of magnetically polarized local domains and photomagnetic material adjacent to the magnetically polarized local domains, the method comprising the steps of:

placing the magnetic medium in an applied magnetic field; and

applying light to a first location of the magnetic medium to induce magnetization of the photomagnetic material at the first location, wherein the magnetized photomagnetic material is adjacent to a first magnetically polarized local domain,

wherein the magnetization of the photomagnetic material increases the strength of the magnetic field at the first location by a first amount to change the polarization of the first magnetically polarized local domain.

2. The method of claim 1 further comprising the step of:

applying light to a second location of the magnetic medium to induce magnetization of the photomagnetic material at the second location, wherein the magnetized photomagnetic material is adjacent to a second magnetically polarized local domain,

wherein the magnetization of the photomagnetic material increases the strength of the magnetic field at the second location by a second amount to change the polarization of the second magnetically polarized local domain, wherein the first amount differs from the second amount, and the change in the polarization of the first domain differs from the change in the polarization of the second domain.

3. A method of recording information on a magnetic medium, the magnetic medium including a number of magnetically polarized local domains and photomagnetic material adjacent to the magnetically polarized local domains, the method comprising the steps of:

(a) placing the magnetic medium in an applied magnetic field less than the critical magnetic field required to change the polarization of the local magnetic domains;

(b) applying light to a particular location of the magnetic medium to induce magnetization of the photomagnetic material at the particular location, wherein the magnetized photomagnetic material is adjacent to a particular magnetically polarized local domain, the magnetization of the photomagnetic material changing the magnetic polarization of the particular magnetically polarized local domain by increasing the strength of the local magnetic field at the particular location to be greater than the critical magnetic field.

4. The method of claim 3, wherein the applying step changes the magnetic polarization of a particular local magnetic domain to be parallel to the applied field.

5. The method of claim 3, wherein the applying step increases the strength of the local magnetic field B_{local} according to the relationship $B_{local} = \mu(\lambda)B_{applied}$, wherein $B_{applied}$ is the applied magnetic field, and $\mu(\lambda)$ is a photo-induced magnetic permeability.

6. The method of claim 5, wherein μ is a function of a parameter selected from the group consisting of wavelength, temperature, light intensity and applied magnetic field.

7. A magnetic medium comprising:

(a) a plurality of magnetically polarized local domains, and

(b) photomagnetic material adjacent to the magnetically polarized local domains,

(c) wherein the photomagnetic material increases the strength of a magnetic field at a particular magnetically polarized local domain when the photomagnetic material receives light at a location adjacent to the particular local domain.

8. The magnetic medium of claim 7, wherein information is recorded at a particular location on the magnetic medium by (1) placing the magnetic medium in an applied magnetic field less than the critical magnetic field required to change the polarization of the local magnetic domains, and (2) applying light to the particular location of the magnetic medium to induce magnetization of the photomagnetic material at the particular location, the magnetization of the photomagnetic material changing the magnetic polarization of a particular local magnetic domain adjacent to the magnetized photomagnetic material.

9. The magnetic medium of claim 7, wherein the photomagnetic material is a compound of the formula $M(X)_{(4-Y)/X}M_C(Y)C_4$ wherein $M_c(Y)$ is a transition metal selected from the group consisting of Ni(II), Pd(II), Pt(II). Au(III), Ir(I), Rh(I), with Y being its ionic state and M(X) is a counter cation selected from the-group consisting alkali metal. alkaline earth metal and rare earth metals with X being its ionic state; or a compound of the formula $M(X)_{(6-Y)/X}M_C(Y)C_6$ wherein $M_c(Y)$ is a transition metal selected from the group consisting of Fe(II), Fe(III), Co(II), Co(III), Cr(III), Mn(II), Mn(III), Mo(II), Os(II), Rh(III), Ru(III) and Ir(III) with Y being its ionic state and M(X) is a counter cation selected from the group consisting of alkali metal, alkaline earth metal and rare earth metals with X being its ionic state.

10. The magnetic medium of claim 7, wherein the photomagnetic material is a layer of material coated onto a layer of a magnetic material having the magnetically polarized local domains.

11. The magnetic medium of claim 10, wherein the magnetic material is a normal ferromagnetic material.

12. The magnetic medium of claim 7, wherein the photomagnetic material and the magnetically polarized local domains are interspersed magnetic particles in a substrate.

13. The magnetic medium of claim 12, wherein the magnetically polarized local domains are part of a normal ferromagnetic material.

14. A method of optically changing a characteristic of a first light signal, the method comprising the steps of:

(a) placing a photomagnetic material in a magnetic field;

(b) receiving a second light signal at a point on the photomagnetic material to induce magnetization of the photomagnetic material at the point; and

(c) reflecting the first signal from the point on the photomagnetic material.

15. The method of claim 14, wherein the induced magnetization changes the polarization of the first signal via the polar Kerr rotation effect.

16. The method of claim 14, wherein the characteristic is a phase of the first signal.

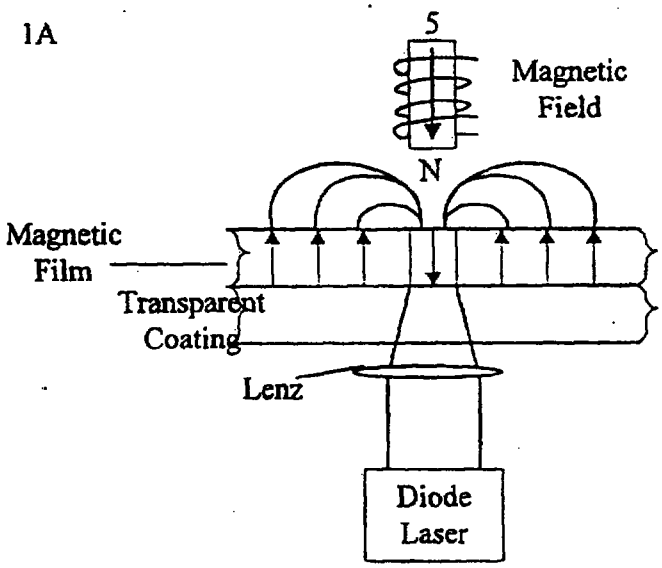
17. The method of claim 14, wherein the characteristic is a polarization of the first signal.

18. The method of claim 14, wherein the characteristic is a change in frequency upon reflection of the first signal.

Figure 1

Prior Art

1A



1B

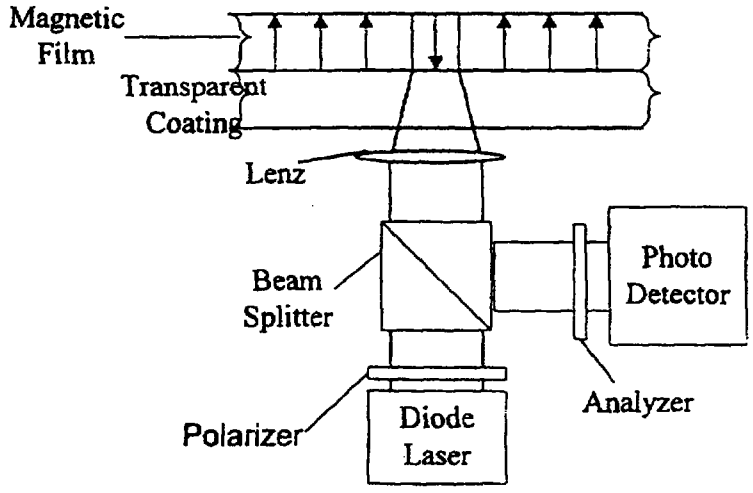


Figure 2

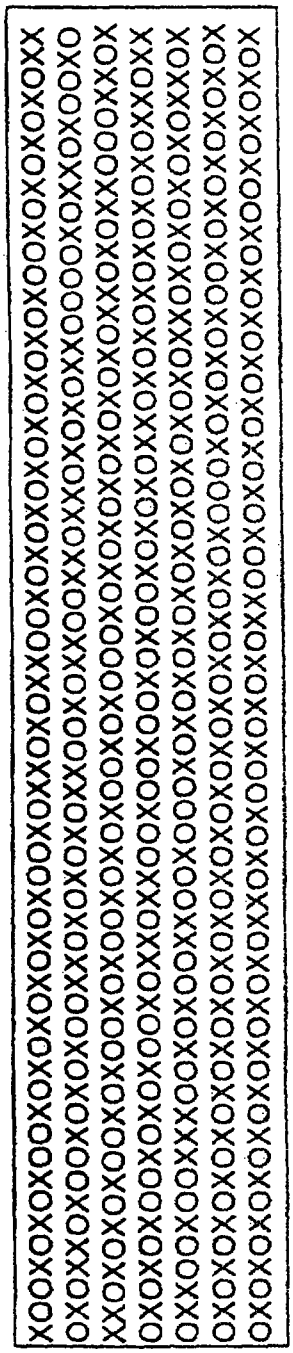


Figure 3

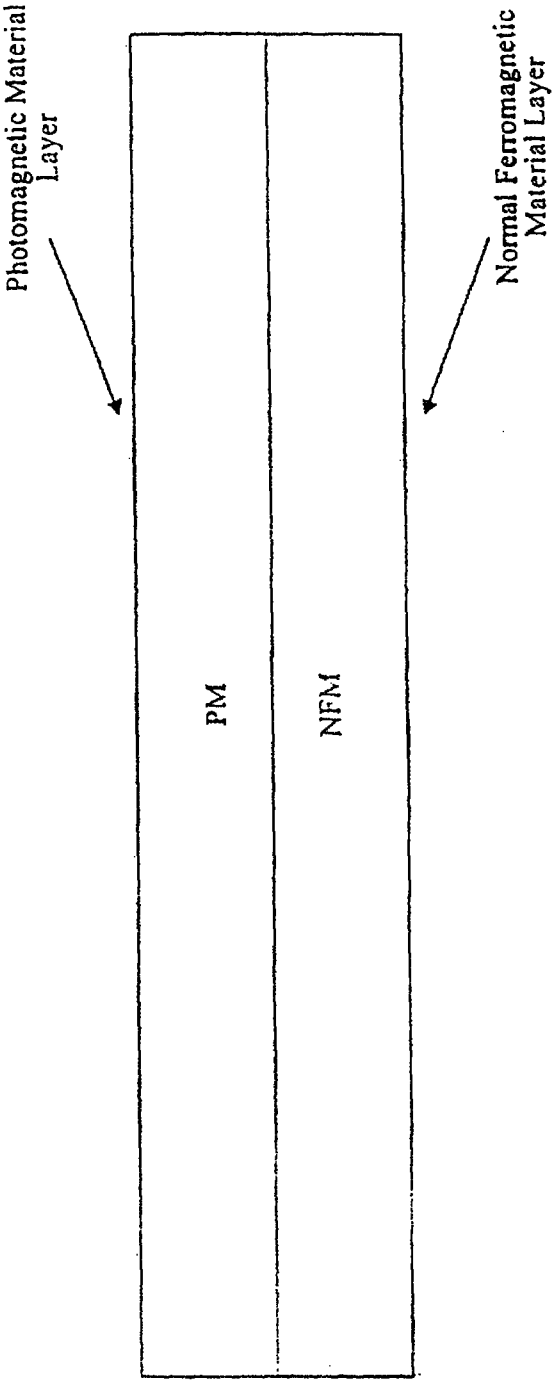
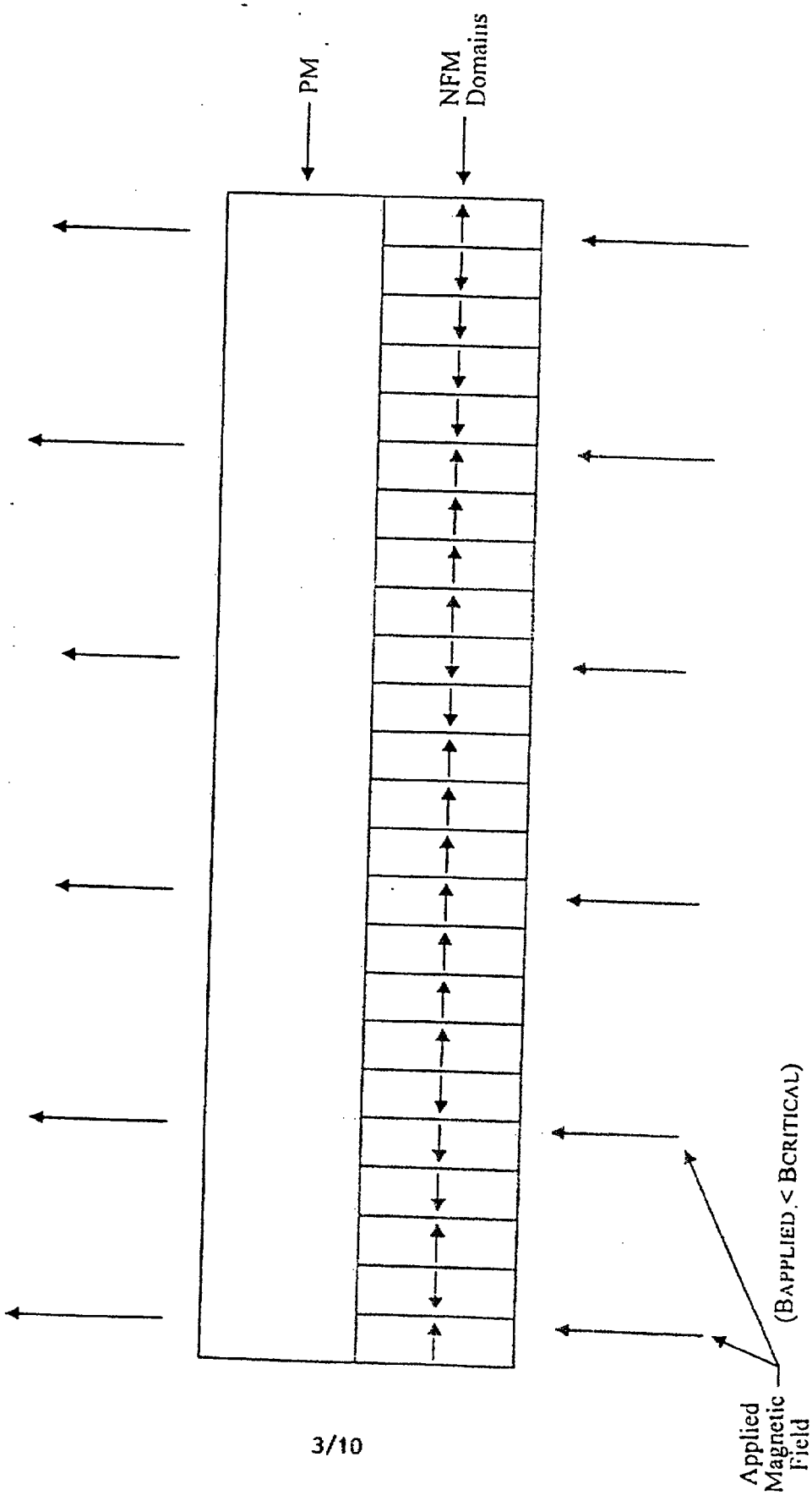


Figure 4A



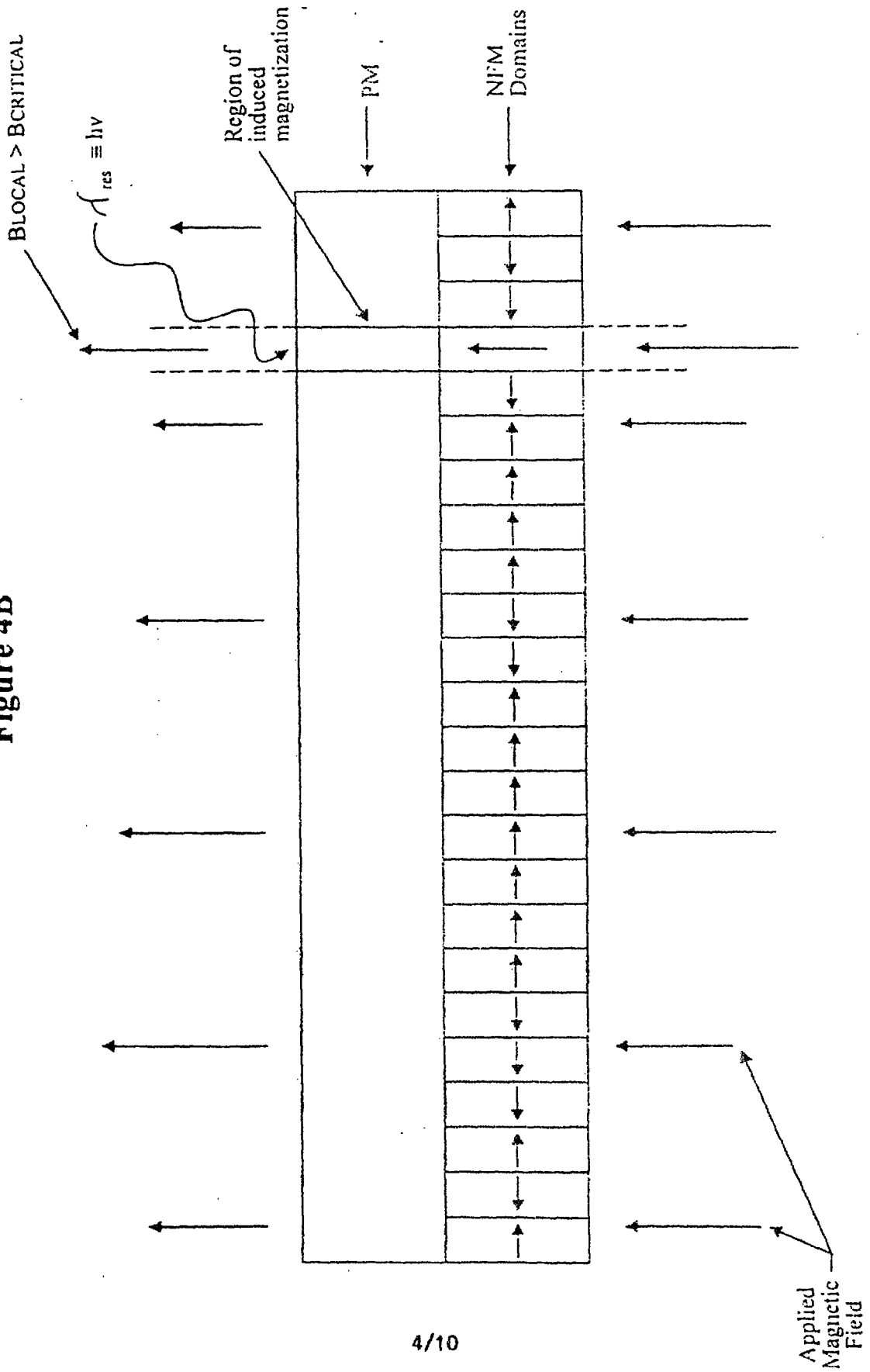
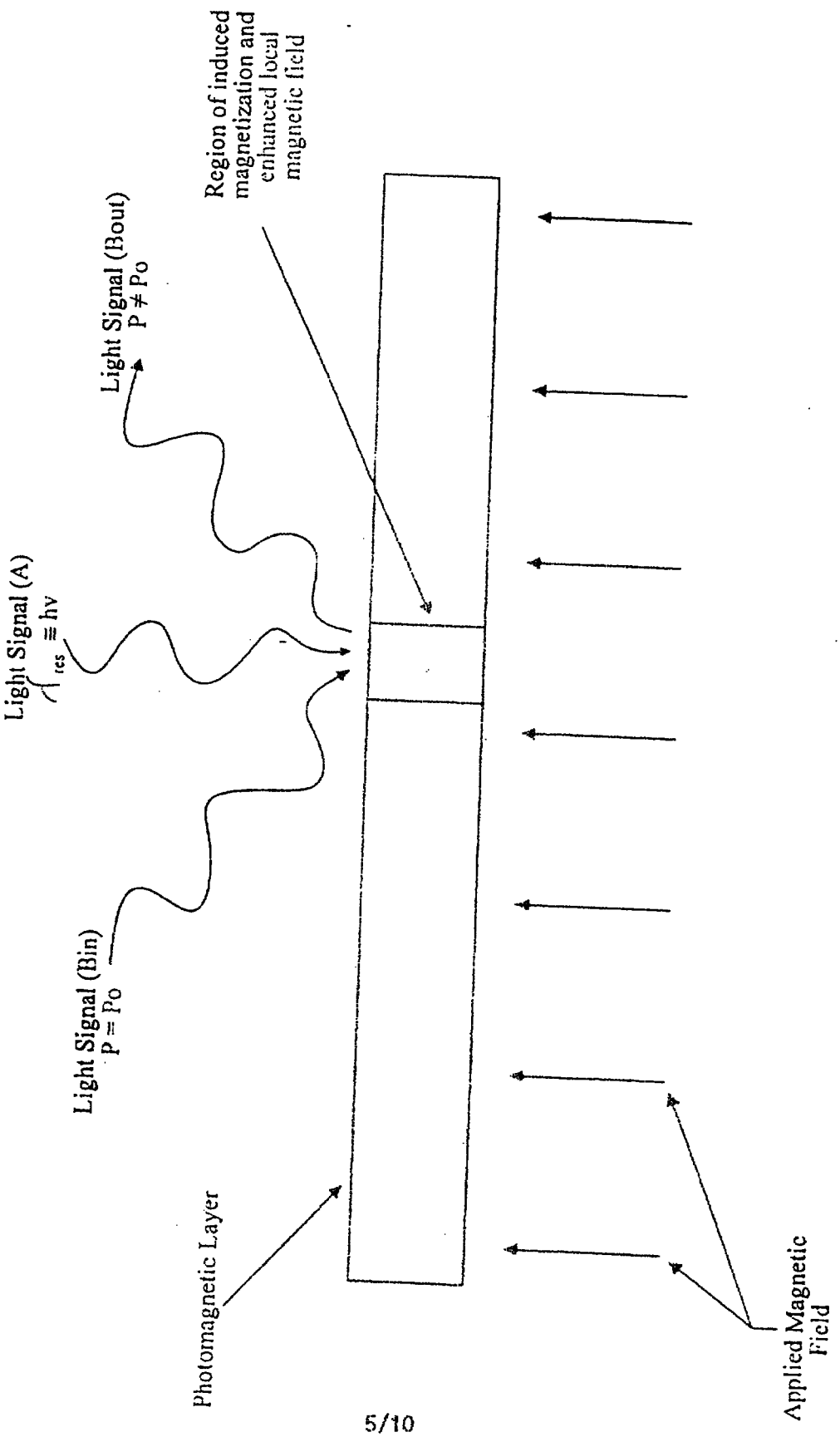

B LOCAL > B CRITICAL
$\lambda_{res} \equiv h\nu$
Region of induced magnetization
PM
NFM Domains
Applied Magnetic Field

Figure 4B

Figure 5


Region of induced magnetization and enhanced local magnetic field
Light Signal (Bout)
P ≠ Po
Light Signal (A)
λres ≡ hν
Light Signal (Bin)
P = Po
Photomagnetic Layer
Applied Magnetic Field

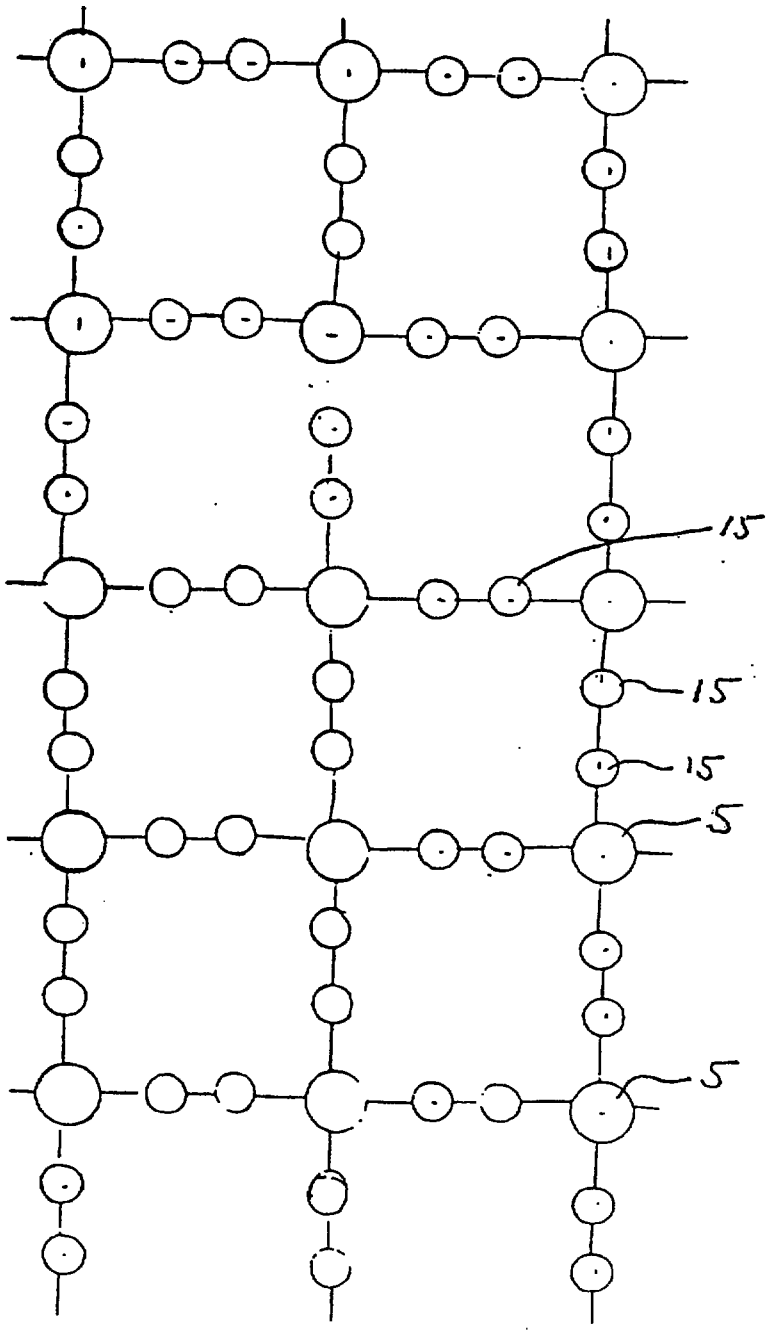


Figure 6

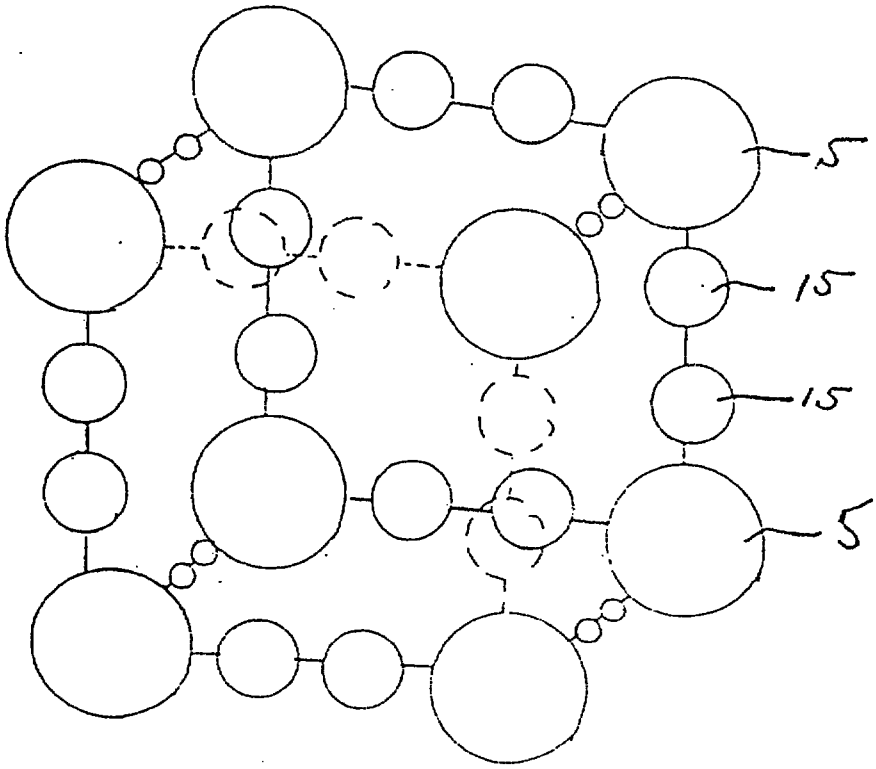


Figure 7

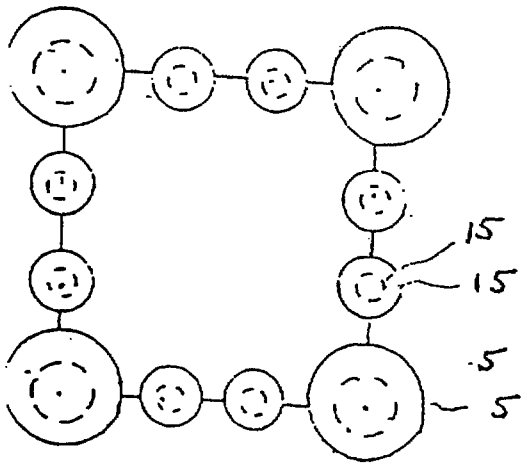


Figure 8A

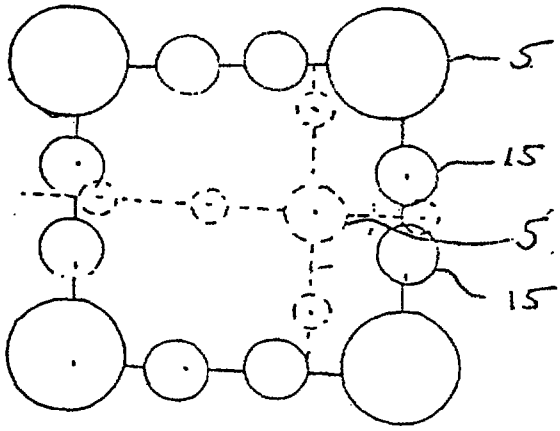


Figure 8B

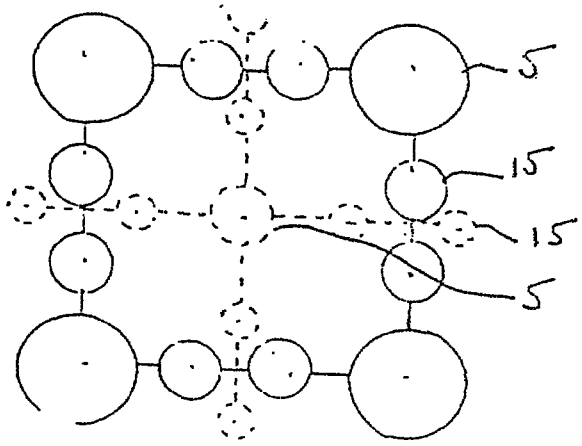


Figure 8C

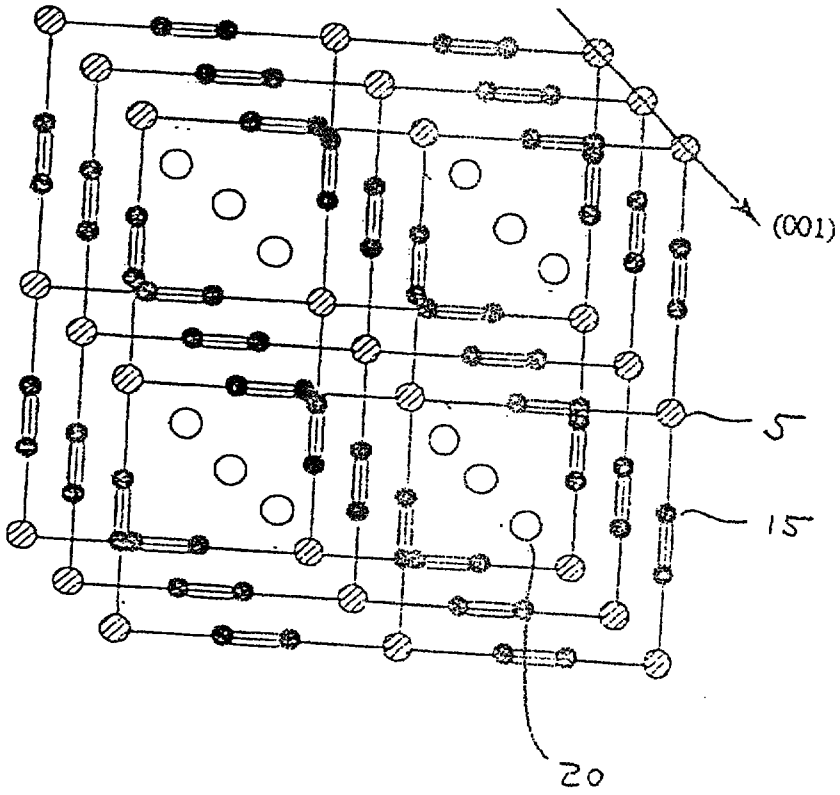


Figure 9

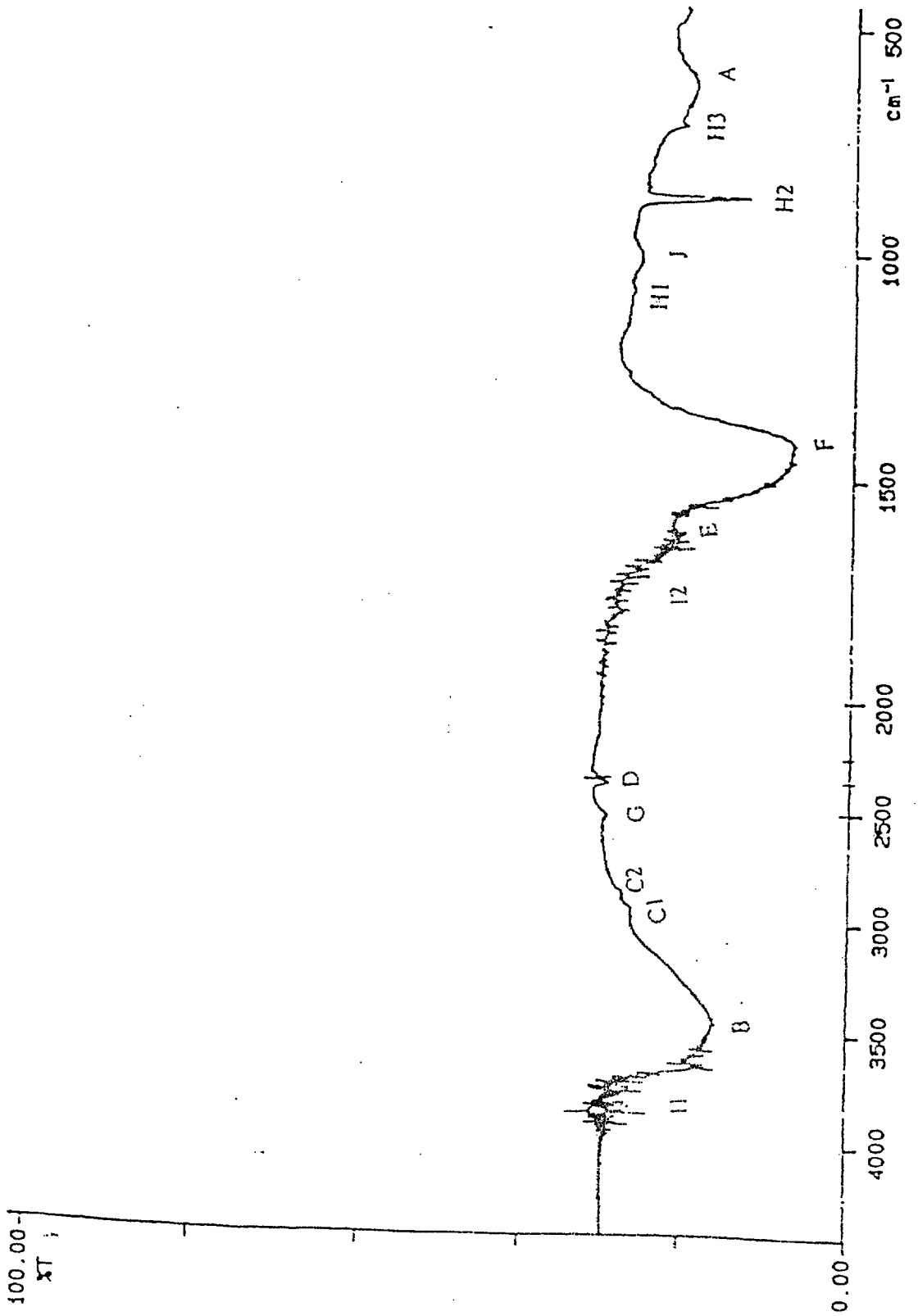

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Figure 10

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980495T-0

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 :
G11B 11/10, G11C 13/06, G03G 5/16, 19/00, G02F 1/09, H04N 1/27

A1

(11) International Publication Number: WO 97/36294

(43) International Publication Date: 2 October 1997 (02.10.97)

(21) International Application Number: PCT/US97/05401

(22) International Filing Date: 25 March 1997 (25.03.97)

(30) Priority Data:
08/621,363 25 March 1996 (25.03.96) US

(60) Parent Application or Grant
(63) Related by Continuation
US 08/621,363 (CIP)
Filed on 25 March 1996 (25.03.96)

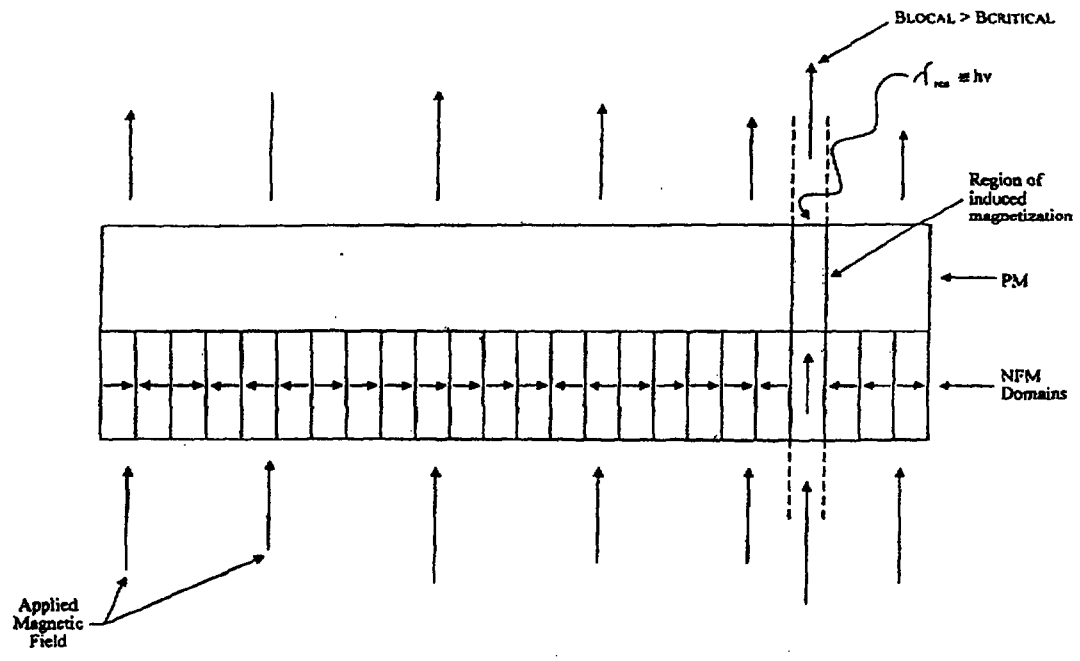
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(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: COMPOSITIONS COMPRISING CYSTALLINE-LIKE TRANSITION METAL MATERIAL AND METHODS OF USE THEREOF



(57) Abstract

The invention encompasses applications including, but not limited to, (1) lightweight ferromagnetic applications, computer and data storage technology; (2) recording technology; (3) photocopying devices; (4) optical switches; (5) magnetic analog film and (6) electronic devices and sensors.