Nanocrystalline magnetic alloy thin films

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In this communication the preparation and characterization of nanocrystalline magnetic thin films of Mn doped Zn-Te alloys, prepared on various types of substrates by vacuum deposition techniques have been described. This technology is completely dry and suitable for making nanocrystalline device quality magnetic films on a complicated structure and is preferred for its simplicity. These magnetic thin films can be used as excellent recording media for information storage and handling.

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Magnetism plays an important role in the information communication technology (ICT). Magnetic materials of high coercivity (hard magnets) form the basic structure, i.e., magnetic disks for computer systems and magnetic tapes. Magnetic materials (used as transducer or heads) of extremely small coercivity (soft magnets) are used for recording and retrieval of information in the magnetic recording process\textsuperscript{1,2}, while hard magnetic materials are used as the media in magneto-optic recording. Magnetic hysteresis, reversal process and domain patterns in hard magnetic materials is utilized as thin film-recording media. Thin film recording media are normally inorganic magnetic materials based coatings, possessing high flux densities\textsuperscript{3,4}. Due to the growing requirements for micro, miniaturization of magnetic data storage, handling and micro electromechanical sensing (MEMS) devices, the technologists are developing new techniques for reduction of the size of individual components therein. A MEMS device frequently consists of a sensor (electronic, optical), an actuator, and a processor and invariably comprises of storage and a recording component, which is usually a magnetic memory device. In this context the size of the magnetic component has to be considerably reduced to a few hundreds angstroms to be accommodated on a single chip of micron dimensions. The nano-crystalline alloy thin films of magnetic materials have shown excellent promise towards fabrication of components, materials and devices for information storage and recording media. This is required to downsize the power requirements to operate the MEMS devices. It has now become possible to store information on a single chip that comprises of magnetic storage and recording devices and integration of other active and passive electronic component. The above configuration leads to fabrication of miniaturized magneto-optic, electromagnetic devices for use as integrated gyraters, sensors and actuators, vibrators and weak magnetic field detectors for use in strategic remote sensing, commercial and medical applications, CT scan and MRI. The basic technology behind these applications is the preparation of a suitable magnetic thin film having requisite characteristics. The advances in development of new and tailor-made materials for magneto-optorecording and storage are characterized by the coexistence of electric and magnetic polarization and their modification upon application of optical radiation or vice versa. In the magneto-optoelectronic (MOE) materials an electric polarization is induced on application of external magnetic field in presence of external optical radiation or the changes in magnetization are induced due to external electric field/optical radiation. A dramatic increase in research activities on nanostructured magnetic materials and their industrial applications has created a great demand for a new approach in the field of development of magnetic materials. The need for nanostructured tailor-made

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compositions of magnetic materials, their preparative methods, processing into nanoscale multilayers, thin films, particles, wires and dots, characterization has led to many innovations. The shaping of these materials in the form of micro/nanostructures, measurement of physical properties and potential industrial-oriented applications such as magnetic data storage, magnetic sensors, magnetic tunnel junctions, thin films, particles, wires and dots, characterization has come up as the current field of research. The magnetoelectric/optic effects in thin films depends on the macroscopic crystal state, which requires the intensification of the magnetic permeability and magnetization by manipulations in the composition, shape and size of the device. The nano thin films of magnetizable alloys with suitable magnetic component have a large surface to volume ratio and offer a good structure. The smart structures comprising of a configuration involving magnetic component devices can be prepared from elemental substances through binary, ternary and quaternary alloys. The device forms range from magnetic heads to nanocrystalline ultra thin films of magnetic materials deposited on various types of substrates including polymers. There have been considerable advances in preparation and characterization of micro- magnetic materials. The most commonly used form of thin films is high performance nanocrystalline recording films with single crystal grains, which are continuous throughout the film thickness and strongly coupled by magnetostatic interactions and possible inter regular exchange coupling. In longitudinal thin film recording media, the thickness of the magnetic films is less than 1000 Å and the average magnetization lies predominantly in the film plane. The currently available devices for magnetic recording and data storage devices are made of iron, nickel and cobalt and their various compositions, which involve expensive and sophisticated processing. These devices are normally used in the form of high purity powders, single crystals or stoichiometric bulk or thin films. Recent efforts are directed towards realization, synthesis and preparation of tailor-made alternative materials and devices for magnetic, magneto-optic and magneto-electric alloys of Zn, Te with calculated amount of various dopants. A stoichiometrically balanced composition of Zn-Te and Mn has been found as a suitable materials for fabrication of devices for magneto-electrical, magneto-optical and magneto-photo sensitive devices. These compound semiconductors have a wide optical energy band gap of about 2.26 eV. This allows the maximum absorption of the recording beam. We hereby describe our investigations on preparation and characterization of Zn-Te-Mn alloy magnetic thin films.

**Experimental Procedure**

The Zn-Te, Mn films were prepared by vacuum evaporation on various substrates. The base material for vacuum evaporation was prepared by mixing a calculated amount of Zn-Te-Mn. The mixture was heated to a temperature of 700°C in vacuum-sealed quartz ampoule. The ampoule was then drop quenched in ice-cold water. The stoichiometry of the material was thus maintained. This is confirmed by the XRD pattern of the bulk powder and that of vacuum deposited thin film. The peaks in the XRD patterns are the evident of strong crystallinity of the vacuum evaporated ternary alloy thin film. The films were carried out by studying the optical absorption and reflection spectra using Hitachi U 3400 spectrophotometer. The energy band gap was determined from reflection spectra using the relation \( \alpha h\nu = A (h\nu - E_g)^n \), where \( h\nu \) is the photon energy, \( \alpha \) is absorption coefficient, \( E_g \) is energy band gap, \( A \) is a constant and \( n = \frac{1}{2} \) for direct band gap materials. A plot between \( \alpha h\nu \) and \( h\nu \) provides information about the energy band gap. The optical absorption coefficient \( \alpha \), which is an important factor in deciding the figure of merit of a magneto-optoelectronic device is proportional to the value of \( (R_{\text{max}} - R_{\text{min}})/(R - R_{\text{min}}) \), at a point where reflection falls from maximum \( R_{\text{max}} \) to minimum \( R_{\text{min}} \) and \( R \) is the reflectance for any intermediate energy photons. The absorption coefficient \( \alpha \) is used in terms of reflectance as \( \frac{\ln(R_{\text{max}} - R_{\text{min}})}{(R - R_{\text{min}})} \).

![Fig. 1—XRD pattern of vacuum deposited Zn-Te-Mn thin film](image)
Results and Discussion

The optical reflection spectra of vacuum deposited Zn-Te-Mn films are shown in (Fig. 2). It is observed that the Zn-Te-Mn film is highly absorbed in the range 800-1200 nm that is suitable for laser writing. It is observed that Zn-Te-Mn films are transparent in the visible region, hence suitng for magneto-optical recording. The energy band gap of the films was determined using the plot between \((\alpha h\nu)^2\) and \(h\nu\) (Fig. 3). The extrapolation of straight line to \((h\nu)^2 = 0\) yields the energy band gap of Zn-Te-Mn as 2.22 eV. Fig. 4 shows the surface topography of the vacuum evaporated Zn-Te-Mn thin films. The film is continuous with uniformly distributed crystallites. Fig. 5 shows the predominantly magnetizable domains of vacuum deposited Zn-Te-Mn thin film upon exposure to 1064 nm under scanning electron microscopy. The corresponding B-H curve of the vacuum deposited Zn-Te-Mn thin film (a) without and (b) with optical irradiation are shown in Fig. 6. It is
seen that high degree of magnetization can be achieved at lower magnetic field in the presence of optical radiation. Using lower magnetic field and without using a bulk of material and efficient magneto-optic devices can be made by varying the stoichiometry of the starting material and hence the film.

Conclusions

It has been shown that ternary alloy magnetic thin film prepared by vacuum evaporation of stoichiometrically prepared alloy mixture of the individual components, these thin films show strong promise for magneto-optical recording devices and MEMS, VLSI design and other applications.

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References