

Description

Field of the invention

This invention relates to thin-film magnetic recording playback heads, particularly to such heads wherein non-inductive means are utilized for sensing localized magnetic field patterns of a magnetic recording medium.

Description of the prior art

With an apparently never-ending quest to increase the storage density on magnetic recording medium has come increased demands not only on the magnetic recording medium per se, but also on the transducers used for both recording and playing back the recorded information. As the recorded bit size has progressively decreased, the recording and playback head gaps in typical ring shaped heads have also decreased until it is now virtually impossible to reduce them further using discrete spacer layers. There has consequently been developed a new class of recording and playback heads utilizing thin-films, in which high permeability materials are formed as thin-film pole pieces, metallic thin-films are formed to provide inductive windings around the thin-film pole pieces, and insulative thin-films are formed to provide both a gap between the pole pieces and to insulate the respective windings where appropriate.

Such thin-film heads were perhaps first disclosed in U.S. Patent 3,344,237 assigned to Minnesota Mining and Manufacturing Company, the assignee of the present invention. Since that initial development, many types of thin-film heads have been developed in various attempts to improve the reliability and signal-to-noise ratio while reducing manufacturing costs, complexity, and the like. Particularly relevant to the present invention are non-inductive thin-film playback heads, such as those utilizing magnetoresistive films. U.S. Patent No. 3,987,485 (Sugaya et al) is exemplary of prior art disclosing such heads, the device there disclosed includes a semi-conductive substrate on which may be deposited, along with the magnetoresistive film, or films for multitrack heads, integrated circuits such as switching circuits and amplifiers which are connected to the magnetic heads. In a somewhat similar fashion, U.S. Patent 3,908,194 (Romankiw) depicts a thin-film magnetoresistive read head integrated with a thin-film inductive write head.

In addition to such magnetoresistive thin-film heads, it is also known to utilize heads including thin-films having magnetostrictive properties. Thus, for example, Brunsch et al, IBM Tech. Disclosure Bulletin, Vol. 21, No. 2, July 1978, pp. 667-668, depicts a thin-film head, with both read and write capabilities, in which magnetostrictive films having permanent anisotropy surround a single turn inductive winding, forming a working gap therebetween, and are in turn mechanically coupled to a piezoelectric substrate. In the head there depicted, read or write signals appear to be coupled from or to the conductor and hence

inductively from or to the gap, while DC or AC voltages are applied to the piezoelectric substrate, causing stress in the magnetostrictive films, which, in turn, rotates the anisotropy to allow the signals to be more readily coupled through the gap. Such a head is thus actually an inductive type device in which magnetostriction is utilized in a secondary manner.

A device in which mechanically coupled magnetostrictive and piezoelectric films are used to directly sense localized fields is depicted in Japan Patent Publication No. JA52-88317, published July 23, 1977. The device there set forth is adapted for sensing magnetic field patterns such as may be present in magnetic recording media. The device disclosed therein does not incorporate amplifiers or other electronic circuits as an integral part thereof.

A transducer in which a single composite material having both magnetostrictive and piezoelectric properties is known from Int. J. Electronics, Volume 51, 1981, No. 3 pages 255 to 262. However, there is no suggestion that such a transducer could be utilized as a recording head, or have a construction including discrete coupled thin films.

An example of common mode rejection is found in IBM Technical Disclosure Bulletin, Vol. 17, No. 7 Dec. 1974 page 1862.

The problem with the prior art devices disclosed above is that they are subject to a high level of noise and it is an object of the present invention to provide a magnetically responsive transducer, such as a magnetically responsive playback head, in which the noise rejection is substantially increased.

Disclosure of invention

According to this invention there is provided a thin-film playback head as defined in claim 1.

In a preferred embodiment, the head of the present invention includes a non-magnetic substrate, and especially a semiconductive substrate having as an integral part thereof a solid-state amplifier. In such an embodiment, particularly where the amplifier is a MOSFET type transistor, it is further desirable that the piezoelectric and magnetostrictive thin-film be fabricated directly onto the gate of the MOSFET transistor, thereby minimizing capacitances associated with the connections between the piezoelectric thin-film and the amplifier.

Desirably, a substrate carrying the magnetostrictive thin-film and piezoelectric thin-film is fabricated together with a carrier member adapted to be mounted with the plane of the thin-films substantially normal to the surface of a magnetic recording medium, thereby enabling localized magnetic patterns on the medium and oriented normal to the surface thereof to be impressed on the length of the magnetostrictive thin-film, thus producing a lengthwise stress which is coupled to the piezoelectric thin-film.

If desired, the mechanically coupled magnetostrictive and piezoelectric thin-films may be posi-

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tioned proximate to high permeability thin-film pole pieces configured to optimize detection of either vertically or longitudinally oriented magnetic recordings such that magnetic fields coupled to the pole-pieces induce in the magnetostrictive thin-film a mechanical stress which is coupled to the piezoelectric thin-film, etc. as described hereinabove.

The playback head of the present invention thus satisfies a need existing for a device for reading high density magnetic information stored in memory systems being developed for applications such as a consumer electronic camera. In summary, the essential features of the head thus include integrated magnetostrictive and piezoelectric (IMP) thin-films which operate in conjunction with an amplifier, preferably of a metal-oxide-semiconductor (MOS) type. The resultant head will commonly be referred to herein as an IMP-MOS device.

Brief description of the drawing

Figure 1 is a sectional view of a known IMP-MOS device wherein adjoining magnetostrictive and piezoelectric films are applied directly to the gate of an N-channel MOSFET transistor;

Figure 2 is a combined cross-sectional view and electrical schematic of a further embodiment of an IMP-MOS device of the present invention incorporating a common piezoelectric film together with a magnetostrictive film and also in conjunction with a nonmagnetostrictive film so as to provide common mode noise rejection; and

Figure 3 is a perspective view of an IMP-MOS device of the present invention utilizing both magnetostrictive and non-magnetostrictive films, thereby providing common mode noise rejection such as shown in Figure 2 wherein the device is assembled in a conventional integrated circuit chip carrier to facilitate further mounting.

Detailed description

As set forth herein, the IMP-MOS device of the present invention may be constructed in a variety of configurations including an embodiment wherein the magnetostrictive and piezoelectric films are applied on separate substrates from that of the MOSFET device.

In order to better understand the operation of the present invention, a short description of the operation of a convention MOSFET device such as that in Figure 1 will be useful. The arrangement of Figure 1 overcomes to a limited extent the mentioned disadvantages by requiring the magnetostrictive and piezoelectric film to be deposited directly to the gate of an associated MOSFET transistor. Accordingly, as there shown, the IMP-MOS device 10 includes a substrate 12 of P-type silicon in which two zones have been heavily doped to provide N-type regions 14 and 16, respectively. On top of the substrate and adjoining the N-type regions 14 and 16 are formed insulating SiO_2 regions 18, 20, and 22, respectively, and on top thereof are deposited metallic contact regions 24, 26, and 28 respec-

tively, thereby completing a conventional MOS-FET transistor. Appropriate potentials may be applied to the device such as via conductors 30, 32 and 40 secured to the metallic contacts 24, 26 and 28, respectively.

The IMP-MOS device is completed by deposition of a piezoelectric film 34 onto the gate contact 26 and by subsequent deposition of a magnetostrictive film 36 onto the piezoelectric film 34. Electrical potentials may be applied to the magnetostrictive film via lead 38 and to the underlying gate electrode 26 via lead 40.

When a potential of suitable magnitude and polarity is applied to the lead 40, a conductive channel is formed between the two N-type regions 14 and 16. Application of a voltage between electrodes 30 and 32 results in a current flow between these two electrodes; the magnitude of which is determined by the polarity and magnitude of the potential applied to the lead 40. In the present invention, the magnetic field is detected and transduced into an electrical signal, resulting in a modulated potential on the gate electrode 26 in the following manner: A magnetic field applied in the plane of the magnetostrictive element 36 produces a fractional length change in this element. As the magnetostrictive film is tightly coupled to the piezoelectric film 34, this constriction will produce a corresponding strain or length change in the piezoelectric film 34. This strain in turn results in a voltage on the gate electrode 26 of the MOS transistor and this modulation of the gate voltage of the transistor results in a change in the electrical current through the leads 30 and 32.

Equivalent devices to that shown in Figure 1 may be made using either N-channel or P-channel silicon substrates, operating in either an enhancement or depletion mode. If such a device is operated in the depletion mode, no further biasing of the gate electrode is necessary, and appropriate potentials need only be applied to the source and drain electrodes via a potential source, and if desired, appropriate potentials may be applied to the piezoelectric layer for poling via a lead secured to the magnetostrictive layer.

In one example, a device similar to that set forth in Figure 1 was constructed in the following manner. A P-channel enhancement mode MOS-FET transistor was fabricated from an N-type silicon substrate utilizing conventional MOSFET technology, wherein the gate electrode was prepared having dimensions of approximately 25 by 1,000 micrometers. A prototype combination of magnetostrictive and piezoelectric films was formed as follows: A film of commercially available 25-micron thick polyvinylidene fluoride (PVF_2) was metallized with a thin film of aluminum on both sides and subsequently poled by heating the PVF_2 to a temperature in excess of its Curie point and allowing it thereafter to cool while in an electric field. The thus poled film was then mounted via a transfer adhesive to a water cooled rotating substrate in a vacuum chamber of an ion beam deposition system. The PVF_2 was

then maintained near room temperature through a subsequent deposition operation. A magnetostrictive thin film of approximately 500 nanometers of nickel was subsequently ion beam sputtered onto the PVF₂ from a 98%+ pure nickel foil target. After the deposition, the nickel coated PVF₂ film was removed and cut into strips approximately 1 by 6 millimeters in cross section. Next, a thin layer of silver conductive epoxy was applied to the side of the PVF₂ opposite to that on which the nickel film was deposited. The strip was then glued onto the gate of the MOSFET transistor described above, assuring good electrical contact between the bottom layer of the PVF₂ and the metallized gate. The top layer of the PVF₂ (that having the nickel film sputtered thereon) served as the outer electrode of the transducer structure and was connected to the substrate ground. DC voltage is applied between the source and drain by connecting a source of potential and drain resistor in series with the MOSFET, while a bias voltage is applied to the gate to bias the MOSFET into the saturation region, and also to provide a reasonable value of conductance. The AC output of the amplifier is taken from the drain resistor through a coupling capacitor. The value of the drain resistor typically about 10 k-ohms, was selected to give high amplifier gain for a reasonable source-drain supply voltage.

In another example, an alternative construction to that described hereinabove was prepared using a blend of PVF₂ and PMMA as the piezoelectric film. In such an embodiment, the polymer blend was first cast onto the gate electrode from a solution in a conventional manner. A thin gold layer was subsequently sputtered onto the PVF₂-PMMA blend to form an outer electrode, primarily to be used for poling purposes. The PVF₂-PMMA film was then poled in situ by applying an intense electrical field gradient thereto, such as by maintaining a 6 KV field across the film for about 10 seconds. For convenience, the MOSFET wafer was then mounted in a conventional integrated circuit chip carrier and wire bonded to bonding pads therein in a conventional manner. A length of 0.75 millimeter wide amorphous Fe₈₀B₂₀ magnetostrictive ribbon was then glued over the gold film on the PVF₂-PMMA layer with a rigid epoxy so as to provide good strain coupling.

Figure 2 sets forth a preferred embodiment of the present invention wherein additional components are provided for suppressing unwanted effects of extraneous stimuli other than that of the main magnetic signals of interest. In such an embodiment, a pair of sensing elements as nearly geometrically identical as possible are provided, with only one of the sensing elements receiving the stimulus of interest, but with both the sensing elements equally receiving all background stimuli. A "bridge" configuration is then often used for devices requiring outside power supplies for operation. For example, FET's, which are voltage variable resistors, would be so configured. The present device being magnetoelectric in nature, does not require an external power

supply in order to function, such that a pair of devices will suffice. Accordingly, the device set forth in Figure 2 incorporates a common mode noise rejection feature. As there shown, the device 232 includes a common substrate 234 within which are fabricated two separate MOSFET transistors each shown generally extending over two separate regions 236 and 238, respectively, of the substrate. Each of the MOSFET transistors would be conventional in nature, having the requisite doped regions, metal oxide layers and source, gate, and drain electrodes. Further, as shown in Figure 2, a base electrode 240 may be deposited onto a third region of the substrate and a piezoelectric film 242 deposited thereover. Finally, the common mode noise rejection capability is provided by depositing onto different portions of the piezoelectric film 242 a magnetostrictive film 244 and a similarly configured non-magnetostrictive film 246, such as may be provided from a thin-film aluminum, or the like. Contacts from each of the respective films 244 and 246 are then made via leads 248 and 250 to the respective gate electrodes 252 and 254 of the respective MOSFET transistors. Appropriate sources of potential and biasing resistors 256 and 258, and 260 and 262, respectively, will also be provided for energization of the two separate MOSFET sections. Similarly, bias supplies will also be provided as appropriate. The output from the two respective MOSFET sections will then typically be coupled to a differential amplifier 264 to provide an appropriate differential output signal. Accordingly, in such a device, a ZnO thin-film such as element 242 would be sputtered onto the conductor 240 and a film of FeSi deposited as the magnetostrictive film 244, while an aluminum film is sputtered as layer 246. The second film 246 is desirably dimensionally identical to that of the magnetostrictive film and should be positioned close to it.

In an alternative embodiment, common mode noise rejection may be obtained even though both the films 244 and 246 are magnetostrictive in nature. In such an embodiment, only one of the films would be exposed to a signal field, with appropriate shielding provided if desired to minimize cross-talk. The transducer then electrically consists of two capacitors sharing a common piezoelectric dielectric and ground electrode. While the two capacitors are electrically identical, only one of which responds to the stimulus of interest. Hence, the difference between the outputs of the two will represent a magnetically induced signal with common mode noise rejected. Similarly, such a structure may also be built with the respective magnetostrictive and non-magnetostrictive films fabricated directly on the gates of the two separate MOSFETs.

In an alternative construction, a common mode noise rejection may similarly be achieved using a single MOSFET device by connecting magnetically active and magnetically-inactive transducers in series with the gate of the MOSFET. Thus, for example, such a device may be fabri-

cated using a single silicon substrate on a first portion of which is fabricated a conventional MOSFET transistor similar to that set forth in regions 236 and 238 in Figure 2. On the same substrate but within another region, may then be fabricated overlying films of magnetostrictive and piezoelectric materials as follows: An insulative film may first be applied, over which a common conductive electrode film may be deposited. On top of the conductive film may then be applied a common piezoelectric film, such as a sputtered thin-film of zinc oxide. Over separated portions of the piezoelectric film may be applied similarly configured magnetostrictive films and non-magnetostrictive films, such as a thin-film of aluminum. Assuming the silicon substrate to be grounded, the aluminum film may similarly be grounded, while the magnetostrictive film is coupled to the gate electrode of the MOSFET transistor. In such an embodiment, the lower electrode is left floating such that the piezoelectric film essentially forms two capacitors in series, the first capacitor being formed by the piezoelectric film between the aluminum film and the lower electrode, and the second capacitor being formed between the electrode and the magnetostrictive film.

A preferred arrangement for mounting the IMP-MOS device of the present invention is set forth in the perspective view of Figure 3. As there set forth, one such device 304 may include a conventional ceramic chip carrier 306 which carrier is arranged to have an internal recess and to be open at one end 308. Such chip carriers typically have a plurality of bonding pads positioned about the periphery of the carrier for enabling electrical connections to be made to the various portions of a semiconductor substrate positioned therein. Thus, as set forth in Figure 3, a silicon substrate 310 may be mounted with an appropriate thermally conductive adhesive within the carrier 306, one end of the substrate terminating substantially parallel with the open end of the carrier 308. Over the entire silicon substrate 310 may be sputtered a thin film 312 of gold approximately 500 nanometers thick. Over the gold film may also be sputtered a piezoelectric thin-film of ZnO 313, ranging between 1.5 and 2 micrometers thick. In order to provide a common mode noise rejection configuration like that set forth in Figure 2, over the ZnO film may be deposited a magnetostrictive film 314 and a non-magnetostrictive film 316. Preferably, the magnetostrictive film may be a thin-film of an iron-silicon alloy such as $\text{Fe}_{72}\text{Si}_{28}$, having a thickness of approximately 500 nanometers and a cross-sectional area of approximately 1×5 millimeters. Similarly, the non-magnetostrictive film 316 may be a sputtered film of aluminum having a thickness of approximately 300 to 500 nanometers, and of similar physical dimensions. As shown schematically by leads 318 and 320, respectively, the magnetostrictive and non-magnetostrictive films 314 and 316 may be coupled to the electrodes of integrated MOSFET transistors 322 and 324. The MOSFETs are bonded to another

portion of the zinc oxide piezoelectric film 313 via a suitable thermally conductive adhesive. In a typical case, the periphery of the chip carrier 306 will include bonding pads (not shown) such that connections to appropriate biasing potentials and input and/or output signals may be made to the MOSFETs. Such a chip carrier with the respective film terminating proximate the open end of the carrier may be utilized to detect perpendicularly encoded localized magnetic field patterns within a magnetic recording medium. As a localized bit comes proximate the magnetostrictive and metallic films 314 and 316, respectively, differential stress will be induced within the magnetostrictive film to provide an appropriate signal from the MOSFETs as the medium is caused to move thereby.

As described herein, the amplifier which forms an integrated part of the device of the present invention is desirably a MOSFET type transistor and provides the first stage of amplification, as well as impedance matching, to the magnetostrictive-piezoelectric portion of the device. In order to yield the optimum output for the sensor as a whole, the integrated transistor should have a small gate capacitance and a high transconductance. MOSFET type transistors are thus attractive choices for the present application due to their high input impedance and electrical isolation which make it well matched to the magnetostrictive-piezoelectric sensor. However, it should also be noted that alternative amplifier constructions such as JFET's and the like would also be suitable. In any event, the MOS transistors desirably used in the present devices can be fabricated by standard IC processes. Either N-channel or P-channel devices may be used. However, N-channel devices are particularly attractive as they generally yield higher transconductances than do equivalent geometry P-channel type devices. Also, either enhancement or depletion mode devices can be used, depending upon the particular applications intended.

An important consideration for the amplifier of the present invention is that the capacitance at the gate of the transistor be as low as feasible. This desirability results from the nature of the magnetostrictive-piezoelectric transducer which generates a fixed charge which must be distributed over its own capacitance as well as over all parallel capacitances, including that of the MOSFET gate. Minimizing the parallel capacitance results in the maximum output signal.

It is also recognized that various piezoelectric materials may be suitably utilized in the thin-film piezoelectric layer. Among such materials are ZnO, PVF_2 , CdS, and PZT ceramics. In each case, the piezoelectric thin-film is applied in a manner which results in a high piezoelectric coefficient. Optimum thicknesses and methods of application will depend upon the particular material selected. For example, ZnO and CdS may be sputtered onto the gate of the MOSFET. However, on the other hand, PVF_2 may either be glued from a thin sheet form or cast from a solution and poled in situ on

the gate of the transistor. An important consideration is that there must be good electrical contact between the piezoelectric material and the gate electrode. Also, for optimum transducer action, the material selected must have high resistivity and good electro-mechanical coupling constant.

Finally, with respect to the magnetostrictive thin-film, such a layer is desirably deposited in intimate contact with the piezoelectric film. As therewith, a number of materials may be used as magnetostrictive elements. Among these are FeSi, FeB, Ni, FeSiTb, FeNi, etc. Again, optimum thicknesses and application techniques will depend upon the particular material selected, there being a variety of techniques available for providing the coupling between the magnetostrictive and piezoelectric films. The magnetostrictive material may be sputtered, evaporated, plated, or even adhered with a thin epoxy layer onto the piezoelectric material. Of course, the mechanical and electrical characteristics of the device will depend on the particular deposition or application method employed.

It is the magnetostrictive film that actually couples to a magnetic field. Consequently, its properties are perhaps the most critical. The basic material characteristics required are relatively low coercivity, so that the film magnetization can be easily switched, and a relatively high magnetostriction coefficient. The particular properties of the magnetostrictive layer can be tailored somewhat to match the properties of the piezoelectric layer and the MOSFET being used. However, in general, it is desirable to have the highest possible induced strain per unit applied field, consistent with achieving magnetic saturation at an acceptably low field intensity. The physical dimensions of the film determine the spatial field resolution and bandwidth of the sensor. Thin film, photolithographically patterned elements will display maximum bandwidth and resolution.

While various specific constructions and circuit configurations have been set forth in conjunction with the figures discussed herein, it will be readily apparent to those skilled in the art that many variations and alternatives are feasible. Thus for example, the various circuit connections, grounds, etc., may be inverted, off-set by suitable D.C. potentials, and equivalent amplifiers and the like provided. Likewise, the various constructional configurations may be inverted, additional films included and alternative pole piece geometries substituted, etc. Also wide variations in the thickness and other dimensions of the respective films utilized in the IMP-MOS device will occur depending upon the specifications desired.

Claims

1. A transducer responsive to changes in localised magnetic fields comprising a substrate (234), a thin-film of a piezoelectric material (80,

242) on said substrate and upon a first portion of which is located a thin-film of a magnetostrictive material (82, 244), whereby the output potential of the piezoelectric material is responsive to the localised magnetic field present in the magnetostrictive material, characterized by:

the transducer being a thin-film magnetostrictive playback head comprising a thin film of material (246) having the same area as the thin-film of a magnetostrictive material (82, 244), and being mechanically coupled to a second portion of said piezoelectric thin-film (80, 242) and not responsive to said localized fields, wherein said external fields induce strains in said magnetostrictive thin-film (82, 244) which result in non-equilibrium charge densities on at least one surface of said first portion of said piezoelectric film which are directly proportional to the intensities of said external fields while said fields do not induce corresponding strains in said non-responsive thin film of material such that any non-equilibrium charge densities resulting on at least one surface of said second portion of said piezoelectric film are unrelated to said external fields,

electrodes extending over at least said first and second portions of a surface of said piezoelectric thin-film (80, 242), for coupling from each of said portions electrical potentials corresponding to charge densities thereon, said substrate (234) being formed of a semiconductive material having fabricated therein at least one solid state common mode noise rejection amplifier as an integral part thereof and having contacts (252) immovably secured thereto and to which appropriate electrical potentials and signals from said electrodes may be coupled thereby providing a low impedance output signal corresponding to said induced charge density in which background stimuli are rejected, whereby the elements of the head in combination enable said localised external magnetic fields on a said magnetic recording medium positioned adjacent said magnetostrictive thin-film to be directly sensed independently of the speed of changes in the speed at which the head is moved relative to the medium and the resulting stresses induced only in said magnetostrictive thin-film due to such fields as coupled only to said first portion of said piezoelectric thin-film, the corresponding potentials being coupled to said at least one amplifier resulting in an output signal which is directly representative of said localized field patterns and which has low impedance, low noise characteristics, in contrast to the high impedance signal associated with the non-equilibrium charge density.

2. A transducer according to claim 1, characterised by said non-responsive thin-film of material being of a non-magnetically responsive material.

3. A transducer according to claim 1, characterised by said non-responsive thin-film of material being a magnetostrictive material



the gate of the transistor. An important consideration is that there must be good electrical contact between the piezoelectric material and the gate electrode. Also, for optimum transducer action, the material selected must have high resistivity and good electro-mechanical coupling constant.

Finally, with respect to the magnetostrictive thin-film, such a layer is desirably deposited in intimate contact with the piezoelectric film. As therewith, a number of materials may be used as magnetostrictive elements. Among these are FeSi, FeB, Ni, FeSiTb, FeNi, etc. Again, optimum thicknesses and application techniques will depend upon the particular material selected, there being a variety of techniques available for providing the coupling between the magnetostrictive and piezoelectric films. The magnetostrictive material may be sputtered, evaporated, plated, or even adhered with a thin epoxy layer onto the piezoelectric material. Of course, the mechanical and electrical characteristics of the device will depend on the particular deposition or application method employed.

It is the magnetostrictive film that actually couples to a magnetic field. Consequently, its properties are perhaps the most critical. The basic material characteristics required are relatively low coercivity, so that the film magnetization can be easily switched, and a relatively high magnetostriction coefficient. The particular properties of the magnetostrictive layer can be tailored somewhat to match the properties of the piezoelectric layer and the MOSFET being used. However, in general, it is desirable to have the highest possible induced strain per unit applied field, consistent with achieving magnetic saturation at an acceptably low field intensity. The physical dimensions of the film determine the spatial field resolution and bandwidth of the sensor. Thin film, photolithographically patterned elements will display maximum bandwidth and resolution.

While various specific constructions and circuit configurations have been set forth in conjunction with the figures discussed herein, it will be readily apparent to those skilled in the art that many variations and alternatives are feasible. Thus for example, the various circuit connections, grounds, etc., may be inverted, off-set by suitable D.C. potentials, and equivalent amplifiers and the like provided. Likewise, the various constructional configurations may be inverted, additional films included and alternative pole piece geometries substituted, etc. Also wide variations in the thickness and other dimensions of the respective films utilized in the IMP-MOS device will occur depending upon the specifications desired.

Claims

1. A transducer responsive to changes in localised magnetic fields comprising a substrate (234), a thin-film of a piezoelectric material (80,

242) on said substrate and upon a first portion of which is located a thin-film of a magnetostrictive material (82, 244), whereby the output potential of the piezoelectric material is responsive to the localised magnetic field present in the magnetostrictive material, characterized by:

the transducer being a thin-film magnetostrictive playback head comprising a thin film of material (246) having the same area as the thin-film of a magnetostrictive material (82, 244), and being mechanically coupled to a second portion of said piezoelectric thin-film (80, 242) and not responsive to said localized fields, wherein said external fields induce strains in said magnetostrictive thin-film (82, 244) which result in non-equilibrium charge densities on at least one surface of said first portion of said piezoelectric film which are directly proportional to the intensities of said external fields while said fields do not induce corresponding strains in said non-responsive thin film of material such that any non-equilibrium charge densities resulting on at least one surface of said second portion of said piezoelectric film are unrelated to said external fields,

electrodes extending over at least said first and second portions of a surface of said piezoelectric thin-film (80, 242), for coupling from each of said portions electrical potentials corresponding to charge densities thereon, said substrate (234) being formed of a semiconductive material having fabricated therein at least one solid state common mode noise rejection amplifier as an integral part thereof and having contacts (252) immovably secured thereto and to which appropriate electrical potentials and signals from said electrodes may be coupled thereby providing a low impedance output signal corresponding to said induced charge density in which background stimuli are rejected, whereby the elements of the head in combination enable said localised external magnetic fields on a said magnetic recording medium positioned adjacent said magnetostrictive thin-film to be directly sensed independently of the speed of changes in the speed at which the head is moved relative to the medium and the resulting stresses induced only in said magnetostrictive thin-film due to such fields as coupled only to said first portion of said piezoelectric thin-film, the corresponding potentials being coupled to said at least one amplifier resulting in an output signal which is directly representative of said localized field patterns and which has low impedance, low noise characteristics, in contrast to the high impedance signal associated with the non-equilibrium charge density.

2. A transducer according to claim 1, characterised by said non-responsive thin-film of material being of a non-magnetically responsive material.

3. A transducer according to claim 1, characterised by said non-responsive thin-film of material being a magnetostrictive material

14

which is magnetically screened from said localized fields.

4. A transducer according to claim 1, 2 or 3 characterized by said magnetostrictive thin-film (244) extending over a portion of said piezoelectric thin-film (242),

i) said non-responsive thin-film of material is electrically conductive, and

ii) a second solid state amplifier (238) is included with said substrate, inputs to said second amplifier being coupled to one of said electrodes extending over one surface of said piezoelectric layer and to said non-strain sensitive conductive layer (246), whereby undesired non-magnetic stimuli, both time-varying and steady state, applied to both portions of said piezoelectric thin-film may be suppressed in said amplifiers operating in a differential mode while allowing stimuli present only in one portion thereof to be readily detected.

5. A transducer according to claim 1, 2 or 3 characterized by

a solid state amplifier (236) forming an integral portion of a section of said semiconductive substrate,

a metallic thin film conductor (240) applied to another portion of said substrate, and electrical connections (248) between said conductor thin-film and magnetostrictive thin-film and inputs to said amplifier.

6. A transducer according to claim 1, 2 or 3 characterized by said head further comprising carrier means (306) for supporting said substrate and a thin-film thereon, said carrier means (306) being open at one end (308) and having said substrate (310) and said magnetostrictive thin-film (314) terminating substantially co-planar with said open end, and wherein said carrier means and elements supported therein are adapted to be mounted with the plane of said thin-films substantially normal to the surface of a magnetic recording medium, thereby enabling localized magnetic field patterns on said medium and oriented normal to the surface thereof to be impressed on the length of the magnetostrictive thin-film extending away from said recording medium surface to thereby impart a lengthwise stress which is coupled to said piezoelectric thin-film.

7. A transducer according to claim 1, 2 or 3 characterized by said magnetostrictive thin-film extending over a portion of said piezoelectric thin-film, wherein

(i) said non-responsive thin-film of material is electrically conductive material,

(ii) means are provided for electrically isolating a lower electrode of said piezoelectric thin-film, common to both said first and second portions, from said substrate,

(iii) means are provided for connecting said non-responsive electrically conductive material to a suitable reference potential, and

(iv) means are provided for coupling an input to said solid state amplifier from said magnetostrictive thin-film, whereby undesired non-magnetic

stimuli, both time-varying and steady state, applied to both portions of said piezoelectric thin-film may be suppressed, while allowing stimuli present in only one portion thereof to be readily detected.

Patentansprüche

1. Auf Veränderungen in lokalen magnetischen Feldern ansprechender Wandler mit einem Substrat (234), einer auf dem Substrat vorgesehenen, dünnen Schicht (80, 242) aus einem piezoelektrischen Werkstoff und einer auf einem ersten Teil derselben vorgesehenen, dünnen Schicht (82, 244) aus einem magnetostruktiven Werkstoff, so daß das Ausgangspotential des piezoelektrischen Werkstoffes auf das in dem magnetostruktiven Werkstoff vorhandene, lokale magnetische Feld anspricht, dadurch gekennzeichnet, daß

der Wandler ein magnetostruktiver Dünnschicht-Wiedergabekopf ist, der eine aus einem Werkstoff bestehende, dünne Schicht (246) besitzt, die mit der dünnen Schicht (82, 244) aus einem magnetostruktiven Werkstoff flächengleich und mit einem zweiten Teil der piezoelektrischen dünnen Schicht (80, 242) mechanisch verbunden ist und auf die genannten lokalen Felder nicht anspricht, wobei die genannten externen Felder in der magnetostruktiven dünnen Schicht (82, 244) zu Verformungen führen, die auf mindestens einer Oberfläche des genannten ersten Teils der piezoelektrischen Schicht zu ungleichgewichtigen Ladungsdichten führen, die den Feldstärken der genannten externen Felder direkt proportional sind, die genannten Felder in der nicht ansprache-fähigen Schicht aber nicht zu entsprechenden Verformungen führen, so daß auf mindestens einer Oberfläche des zweiten Teils der piezoelektrischen Schicht auftretende, ungleichgewichtige Ladungsdichten mit den genannten externen Feldern nicht in Beziehung stehen,

daß sich mindestens über den ersten und den zweiten Teil einer Oberfläche der piezoelektrischen dünnen Schicht (80, 242) Elektroden erstrecken, über die von jedem der genannten Teile elektrische Potentiale abgenommen werden können, die den auf diesen Teilen vorhandenen Ladungsdichten entsprechen, daß das Substrat (234) aus einem Halbleiterwerkstoff besteht, in dem mindestens ein in dem Substrat integrierter, gleichtaktunterdrückender Festkörpervverstärker ausgebildet ist, der mit unbeweglich daran befestigten Kontakten (252) versehen ist, an die geeignete elektrische Potentiale und Signale von den Elektroden angelegt werden können, so daß ein niederohmiges Ausgangssignal erhalten wird, das der genannten induzierten Ladungsdichte entspricht und in dem Hintergrundreize unterdrückt sind, so daß die Elemente des Kopfes in Kombination es ermöglichen, daß die lokalen externen magnetischen Felder auf einem genannten magnetischen Aufzeichnungsträger, der sich im Bereich der magnetostruktiven dünnen Schicht befindet, unabhängig von der Geschwindigkeit oder von Veränderungen der Geschwindigkeit,



mit der der Kopf relativ zu dem Aufzeichnungsträger bewegt wird, direkt erfaßbar sind und diese Felder nur mit dem ersten Teil der piezoelektrischen Schicht verkettet sind, so daß sie nur in der magnetostriktiven dünnen Schicht zu mechanischen Spannungen führen und die an den mindestens einen Verstärker angelegten, entsprechenden Potentiale zum Erzeugen eines niederohmigen, rauscharmen Ausgangssignals führen, das den lokalen Feldmustern direkt entspricht, während der ungleichgewichtigen Ladungsdichte ein hochohmiges Signal zugeordnet ist.

2. Wandler nach Anspruch 1, dadurch gekennzeichnet, daß die nicht ansprachefähige dünne Schicht aus einem magnetisch nicht ansprachefähigen Werkstoff besteht.

3. Wandler nach Anspruch 1, dadurch gekennzeichnet, daß die nicht ansprachefähige dünne Schicht aus einem magnetostriktiven Werkstoff besteht, der gegenüber den lokalen Feldern magnetisch abgeschirmt ist.

4. Wandler nach Anspruch 1, 2 oder 3, dadurch gekennzeichnet, daß sich die magnetostriktive dünne Schicht (244) über einen Teil der piezoelektrischen dünnen Schicht (242) erstreckt und

i) die nicht ansprachefähige, dünne Schicht aus einem elektrisch leitenden Werkstoff besteht und
ii) in dem Substrat ein zweiter Festkörperverstärker (238) vorgesehen ist, an den Eingänge über eine der Elektroden angelegt werden, die sich auf einer Oberfläche der piezoelektrischen Schicht und auf der nicht durch Verformung ansprachefähigen, leitenden Schicht (246) erstreckt, so daß sich zeitlich verändernde und stationäre, unerwünschte nichtmagnetische Reize, die auf beide Teile der piezoelektrischen dünnen Schicht einwirken, in den im Differenzverfahren arbeitenden Verstärkern unterdrückbar sind, während in nur einem Teil derselben vorhandene Reize ohne weiteres erfaßbar sind.

5. Wandler nach Anspruch 1, 2 oder 3, gekennzeichnet, durch:

einen Festkörperverstärker (236), der in einem Teil des Halbleitersubstrats integriert ist;

einem metallischen Dünnschichtleiter (240), der an einem anderen Teil des Substrats angebracht ist, und zwischen dem Dünnschichtleiter und der magnetostriktiven dünnen Schicht und Eingängen des Verstärkers vorgesehene, elektrische Anschlüsse (248).

6. Wandler nach Anspruch 1, 2 oder 3, dadurch gekennzeichnet, daß der Kopf ferner zum Tragen des Substrats und der darauf befindlichen, dünnen Schichten eine Trägeranordnung (306) aufweist, die am einen Ende offen ist und auf der das Substrat (310) und die magnetostriktive dünne Schicht (314) im wesentlichen in der Ebene des offenen Endes enden, und daß die Trägeranordnung und die darauf angeordneten Elemente derart montierbar sind, daß die Ebene der dünnen Schichten im wesentlichen normal zu der Oberfläche eines magnetischen Aufzeichnungsträgers angeordnet ist, so daß auf dem Aufzeichnungsträger vorgesehene, normal zu dessen Oberfläche orientierte, lokale Magnetfeldmuster in die sich

von der genannten Oberfläche des Aufzeichnungsträgers weg erstreckende, magnetostriktive dünnen Schicht in deren Längsrichtung einprägbare sind, um in dieser eine mechanische Längsspannung zu erzeugen, die auf die piezoelektrische dünne Schicht übertragen wird.

7. Wandler nach Anspruch 1, 2 oder 3, dadurch gekennzeichnet, daß

(i) die nicht ansprachefähige, dünne Schicht aus einem elektrisch leitenden Werkstoff besteht,

(ii) Mittel zum elektrischen Isolieren einer auf der piezoelektrischen dünnen Schicht vorgesehenen und deren erstem und zweitem Teil gemeinsamen, unteren Elektrode von dem Substrat vorgesehen sind,

(iii) Mittel zum Anlegen eines geeigneten elektrischen Bezugspotentials an die nicht ansprachefähige, elektrisch leitende dünne Schicht vorgesehen sind, und

(iv) Mittel zum Anlegen eines Eingangssignals von der magnetostriktiven dünnen Schicht an den Festkörperverstärker vorgesehen sind, so daß sich zeitlich verändernde und stationäre, unerwünschte nichtmagnetische Reize, die auf beide Teile der piezoelektrischen dünnen Schicht einwirken unterdrückbar sind, während in nur einem Teil derselben vorhandene Reize ohne weiteres erfaßbar sind.

Revendications

1. Transducteur sensible aux variations de champs magnétiques localisés, comprenant un substrat (234), un film ou couche mince d'une matière piézoélectrique (80, 242) appliqué sur ledit substrat et sur une première partie duquel est placé un film ou couche mince d'une matière magnétostrictive (82, 244), de sorte que le potentiel de sortie de la matière piézoélectrique répond au champ magnétique localisé présent dans la matière magnétostrictive, caractérisé en ce que:

le transducteur est une tête de lecture magnétostrictive à couche mince comprenant un film mince de matière (246), ayant la même surface que le film mince de matière magnétostrictive (82, 244), qui est mécaniquement lié à une deuxième partie dudit film mince piézoélectrique (80, 242) et est insensible auxdits champs localisés, de sorte que lesdits champs extérieurs induisent des déformations dudit film mince magnétostrictif (82, 244) qui ont pour effet des densités de charge non équilibrées, sur au moins une surface de ladite première partie dudit film piézoélectrique, qui sont directement proportionnelles aux intensités desdits champs extérieurs, tandis que ces champs n'induisent pas de déformations correspondantes dans ladite autre matière de sorte que des densités de charge non équilibrées, se produisant sur au moins une surface de ladite deuxième partie dudit film piézoélectrique, ne sont pas liées auxdits champs extérieurs,

des électrodes s'étendant sur au moins lesdites première et deuxième parties d'une surface dudit film mince piézoélectrique (80, 242), pour le couplage, à partir de chacune desdites parties, de



potentiels électriques correspondant aux densités de charge sur ces parties, ledit substrat (234) étant constitué d'une matière semi-conductrice dans laquelle est fabriqué au moins un amplificateur statique à réjection de bruit en mode commun faisant partie intégrante du substrat et comportant des contacts (252) fixés de façon immuable et auxquels des potentiels électriques appropriés et des signaux venant desdites électrodes peuvent être reliés, de manière à fournir un signal de sortie de faible impédance correspondant à ladite densité de charge induite dans laquelle les stimuli de fond sont rejetés, grâce à quoi les éléments de la tête en combinaison permettent la détection directe desdits champs magnétiques extérieurs localisés sur un dit support d'enregistrement magnétique en position adjacent audit film mince magnétostrictif indépendamment de la vitesse ou des variations de la vitesse à laquelle la tête est déplacée par rapport au support et des contraintes résultantes induites seulement dans ledit film mince magnétostrictif du fait de ces champs qui sont couplés seulement à ladite première partie dudit film mince piézoélectrique, les potentiels correspondants étant appliqués audit au moins un amplificateur qui donne un signal de sortie directement représentatif desdites configurations de champs localisées et qui a une faible impédance et des caractéristiques de bruit faible, contrairement au signal de haute impédance associé à la densité de charge non équilibrée.

2. Transducteur suivant la revendication 1, caractérisé en ce que ledit film mince de matière non sensible est en une matière non magnétiquement sensible.

3. Transducteur suivant la revendication 1, caractérisé en ce que ledit film mince de matière non sensible est en une matière magnétostrictive qui est magnétiquement protégée desdits champs localisés.

4. Transducteur suivant la revendication 1, 2 ou 3, caractérisé en ce que ledit film mince magnétostrictif (244) s'étend sur une partie dudit film mince piézoélectrique (242), dans lequel

i) ladite matière non sensible est électriquement conductrice et

ii) un deuxième amplificateur statique (238) est inclus avec ledit substrat, les entrées à ce deuxième amplificateur étant reliées à l'une desdites électrodes s'étendant sur une surface de ladite couche piézoélectrique et à ladite couche conductrice non sensible à la déformation (246), de sorte que les stimuli non magnétiques indésirables, à la fois variables dans le temps et permanents, appliqués aux deux parties dudit film mince piézoélectrique, peuvent être supprimés

dans lesdits amplificateurs fonctionnant en mode différentiel, tout en permettant la détection facile des stimuli présents seulement dans une partie du film mince piézoélectrique.

5. Transducteur suivant la revendication 1, 2 ou 3, caractérisé par:

un amplificateur statique (236) formant une partie intégrante d'une section dudit substrat semiconducteur,

un conducteur à film mince métallique (240) appliqué à une autre partie dudit substrat, et des connexions électriques (248) entre ledit film mince conducteur et le film mince magnétostrictif et les entrées audit amplificateur.

6. Transducteur suivant la revendication 1, 2 ou 3, caractérisé en ce que ladite tête comprend en outre un support (306) pour supporter ledit substrat et ledit film mince, ledit support (306) étant ouvert à une extrémité (308) et ledit substrat (310) et ledit film mince magnétostrictif (314) se terminant sensiblement dans le plan de ladite extrémité ouverte, et en ce que ledit support et les éléments supportés dans celui-ci sont prévus pour être montés de sorte que le plan desdits films minces est sensiblement perpendiculaire à la surface d'un support d'enregistrement magnétique, ce qui permet d'imprimer des configurations magnétiques, localisées sur ledit support d'enregistrement et orientées perpendiculairement à sa surface, sur la longueur du film mince magnétostrictif opposée à ladite surface de support d'enregistrement, afin de communiquer une contrainte longitudinale qui est transmise audit film mince piézoélectrique.

7. Transducteur suivant la revendication 1, 2 ou 3, caractérisé en ce que ledit film mince magnétostrictif s'étend sur une partie dudit film mince piézoélectrique, dans lequel

i) ladite matière non sensible est une matière électriquement conductrice,

ii) des moyens sont prévus pour isoler électriquement une électrode inférieure dudit film mince piézoélectrique, commune à la fois aux dites première et deuxième parties, par rapport audit substrat,

iii) des moyens sont prévus pour connecter ladite matière électriquement conductrice non sensible à un potentiel de référence approprié, et

iv) des moyens sont prévus pour relier une entrée audit amplificateur statique à partir dudit film mince magnétostrictif, de sorte que les stimuli non magnétiques indésirables, à la fois variables dans le temps et en régime établi, appliqués aux deux parties dudit film mince piézoélectrique, peuvent être supprimés, tout en permettant la détection facile des stimuli présents seulement dans une partie de celui-ci.

