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(54) **MAGNETO-RESISTIVE (MR) TRANSDUCER HAVING AN ELECTROSTATIC DISCHARGE (ESD) ELEMENT AND SEPARATION STRUCTURE IN CONTACT WITH MAGNETIC MEDIA**

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(52) **U.S. Cl.** **360/323**

(58) **Field of Classification Search** **360/323**
See application file for complete search history.

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(57) **ABSTRACT**

A magneto-resistive (MR) transducer is capable of reading data signals magnetically recorded on a tape. The transducer includes a head-tape interface (HTI) and a MR sensor adjacent to the HTI. An electro-static discharge (ESD) element is coupled to the MR sensor, which is adapted to provide an electrical path from the MR sensor to a lower potential structure.

18 Claims, 8 Drawing Sheets

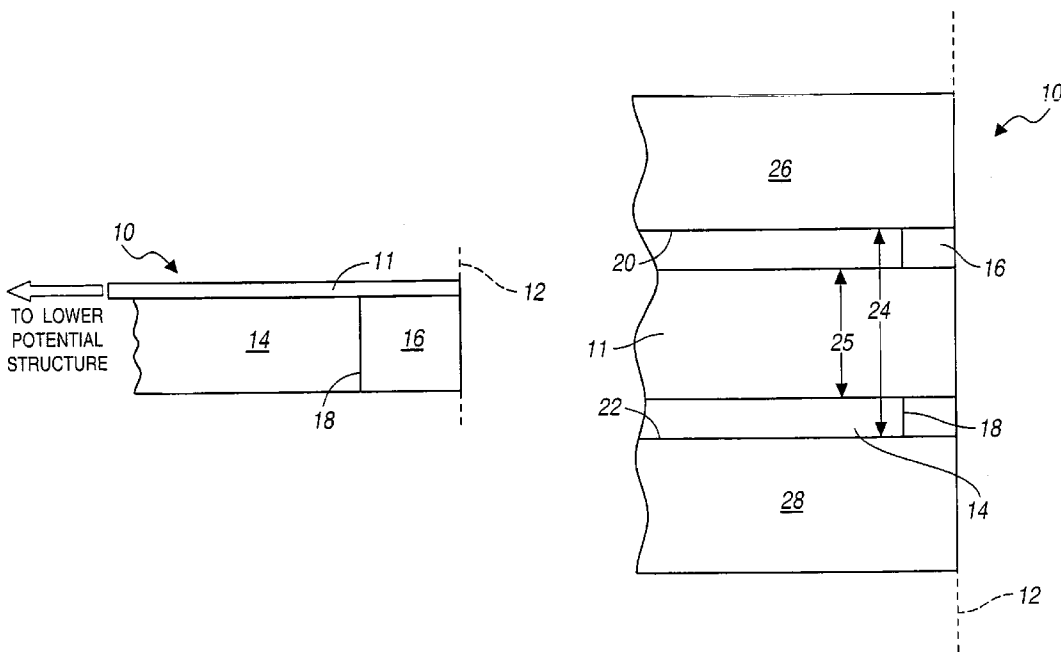


FIG. 2B

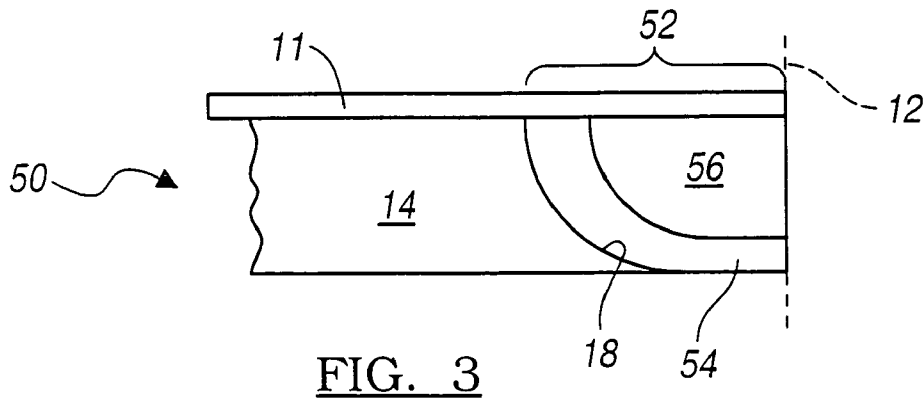
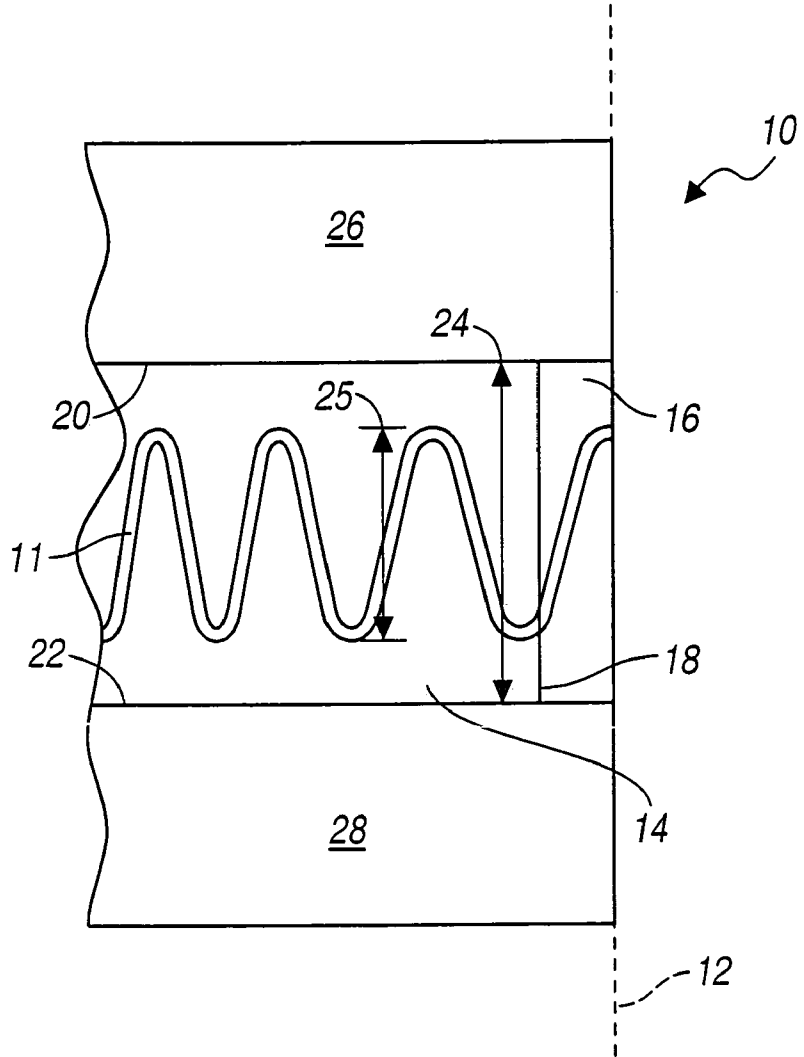


FIG. 3

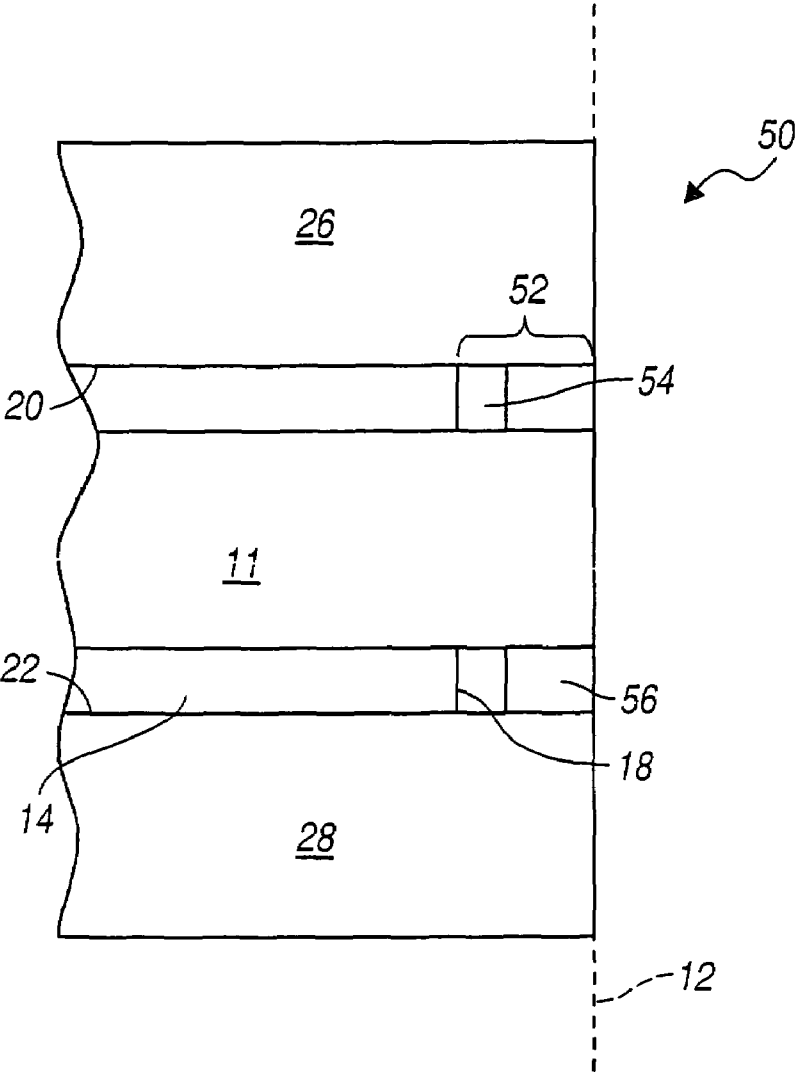


FIG. 4

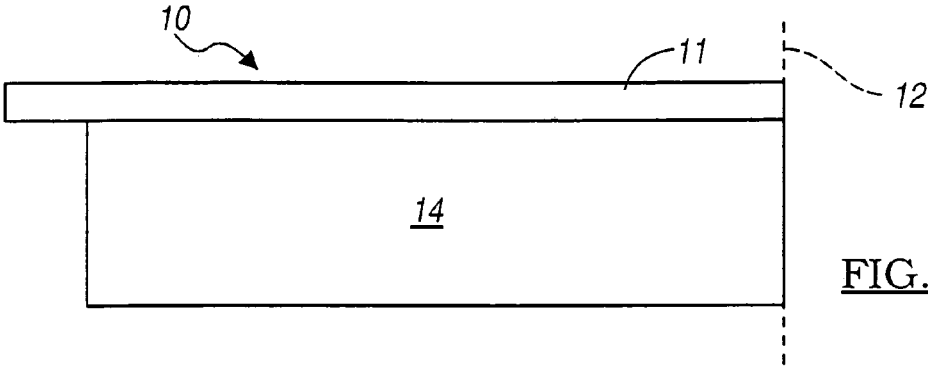


FIG. 5A

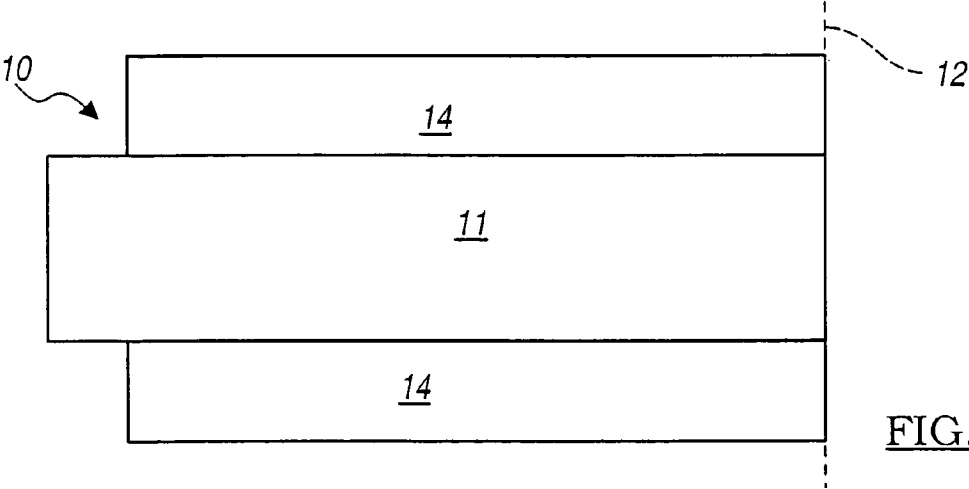


FIG. 5B

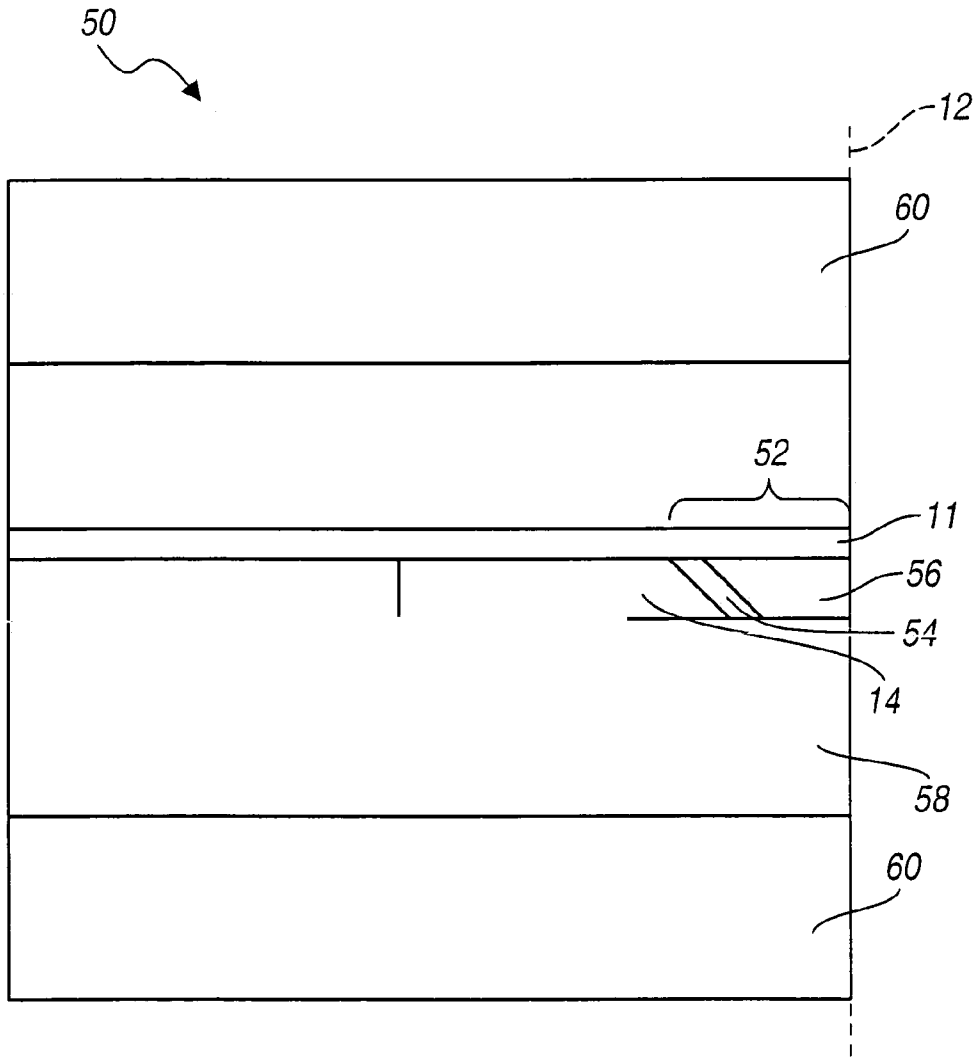
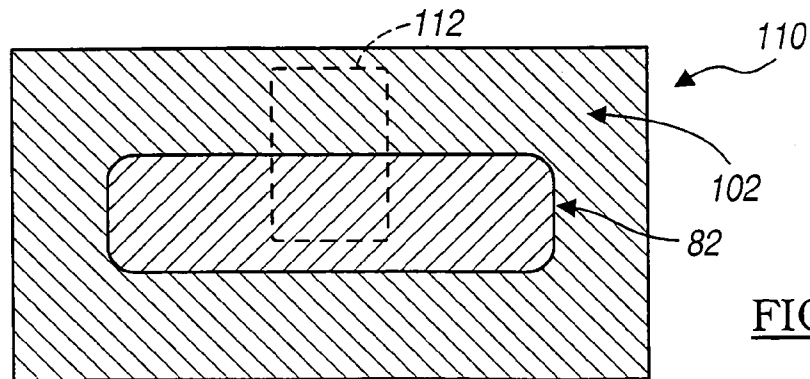
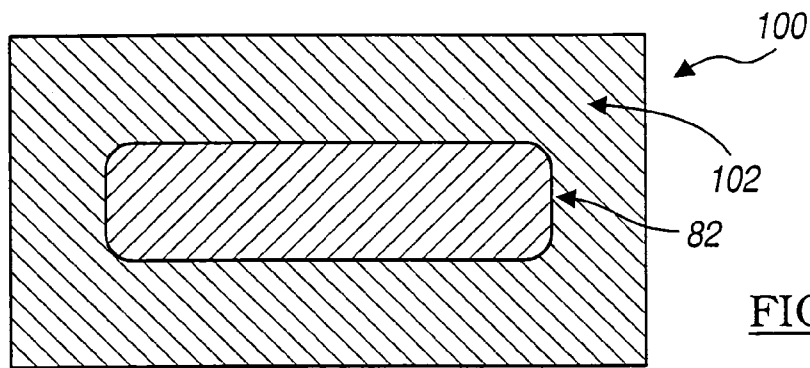
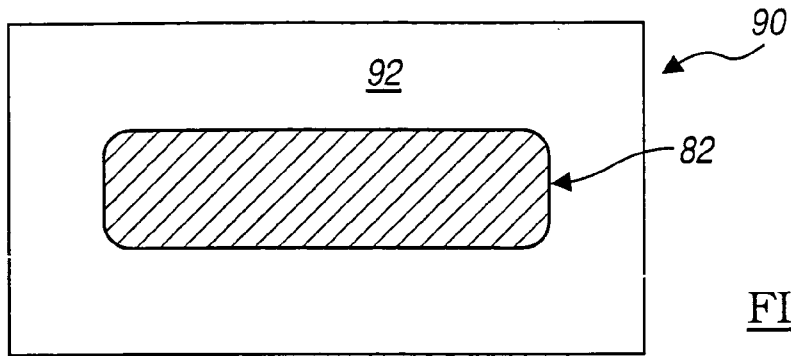
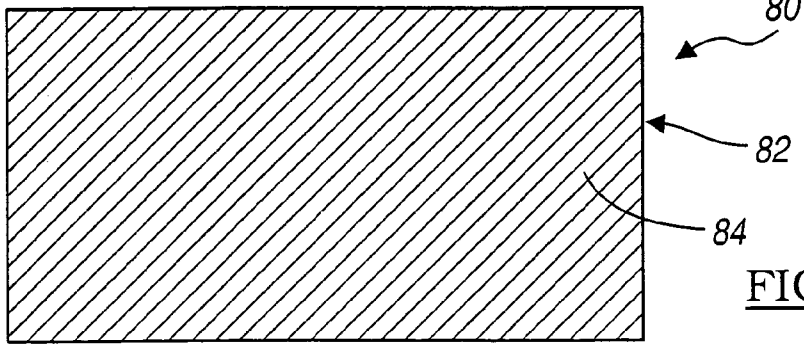
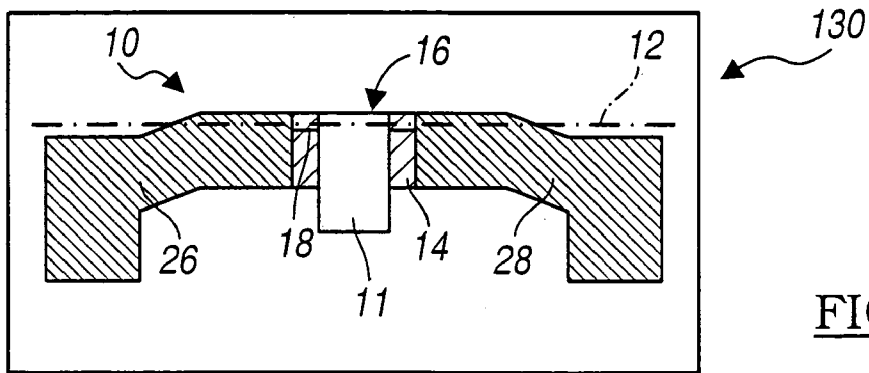
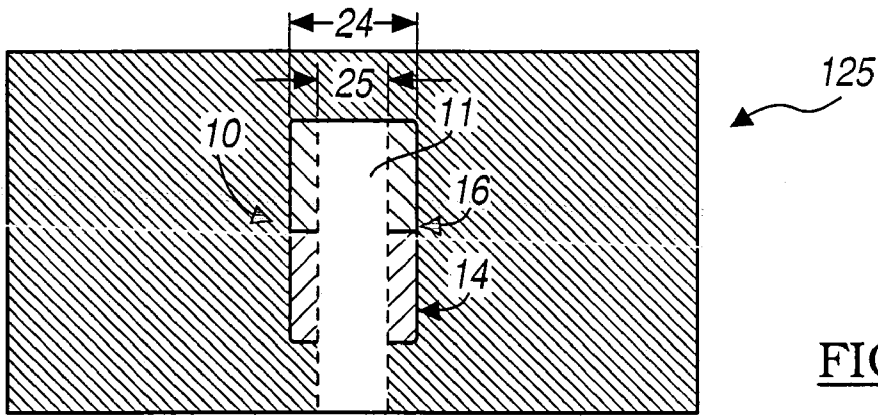
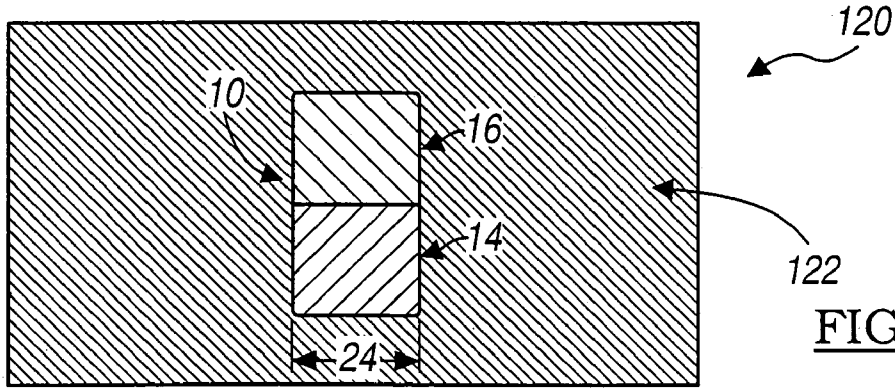
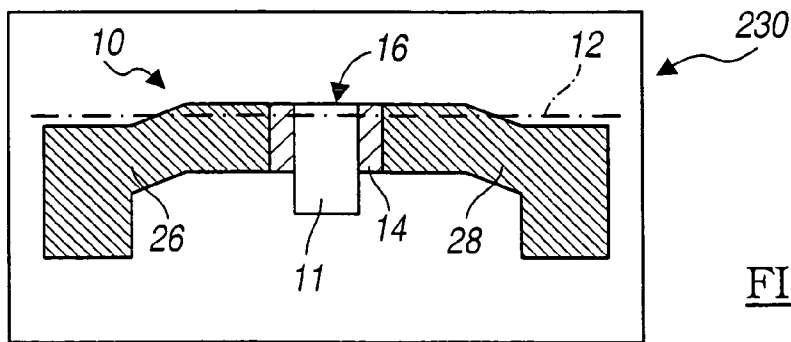
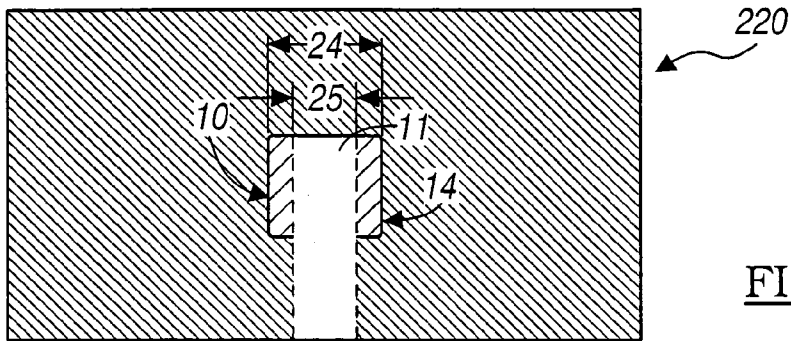
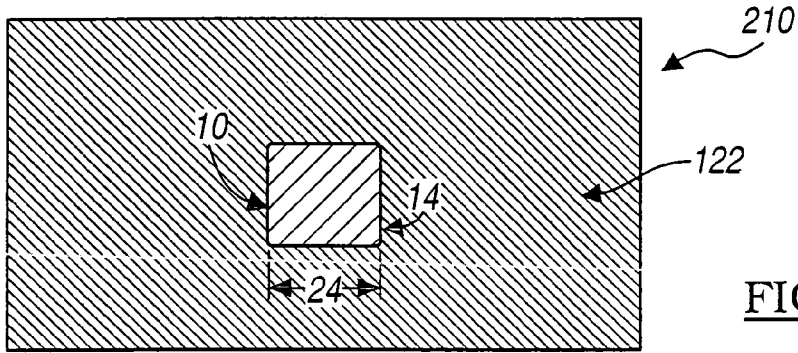
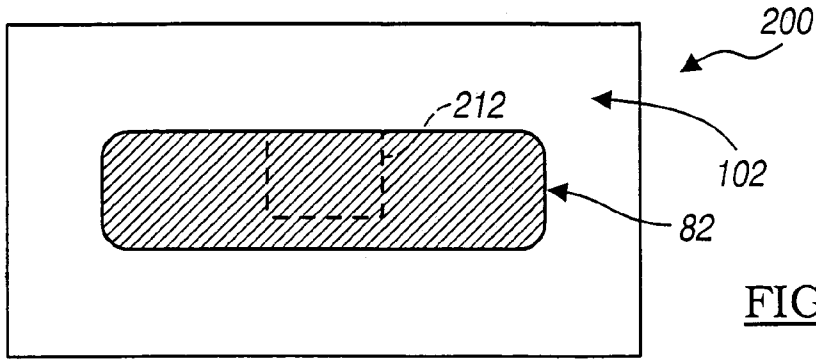


FIG. 6







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**MAGNETO-RESISTIVE (MR) TRANSDUCER
HAVING AN ELECTROSTATIC DISCHARGE
(ESD) ELEMENT AND SEPARATION
STRUCTURE IN CONTACT WITH
MAGNETIC MEDIA**

TECHNICAL FIELD

The present invention generally relates to magneto-resistive (MR) sensors and, more particularly, to a MR transducer having an electro-static discharge (ESD) element.

BACKGROUND

Tape drives are being improved in order to accommodate increased tape cartridge capacities and data rates. Increases in tape cartridge capacities are achievable by increasing the linear data density and the number of data tracks written across the width of tape. Increases in data rates are achievable by increasing the number of parallel data channels and the tape velocity.

Increases in tape cartridge capacities and data rates are limited by the available read back signal-to-noise ratio (SNR). This limitation results because the physical read width in linear flexible media recording systems is proportionally smaller than the physical write width in order to provide the servo system with sufficient margin to correctly position the read sensor within the previously written track during read-back operation. Thus, as the track pitch is reduced, the physical read width is proportionally reduced resulting in a decrease in the read signal and thereby a loss in SNR.

Certain read sensors use the anisotropic magneto-resistance (AMR) effect. The AMR effect causes the intrinsic resistance of an AMR sensor to be a function of the relative angle between the direction of the electric current flow in the sensor and its magnetic moment. The AMR effect has a maximum amplitude of roughly 2.5% of the intrinsic resistance of the sensor. The available signal can be increased somewhat by reducing the thickness of the sensor in order to increase its resistance or by increasing the electric current flow in the sensor. However, the absolute amplitude of the read-back signal is limited by both the maximum current density achievable without damaging the sensor film stack and the temperature rise of the sensor.

These issues can be mitigated by using read-back sensors which use the giant magneto-resistive (GMR) effect. The GMR effect results in sensor resistance changes of more than 10%. However, GMR sensors are formed from extremely thin films (<5 nm) of which several of these films (e.g., Cu, NiMn, PtMn) may have significant corrosion issues. As flexible media systems read with the sensor essentially in contact with the surface of the tape this inevitably exposes the sensor to corrosive agents, in addition to abrasion and smearing of the film stack at the sensor edge exposed to the tape. An additional drawback of GMR based devices is the adverse effects of electro-static discharge (ESD). During an ESD event, a charge build-up is rapidly dissipated through the sensor and other components of the GMR based device. The damage results in catastrophic changes such as device melting or evaporation, and/or the magnetic integrity of the device.

The above disadvantages result in significant processing and reliability issues which currently limit the use of MR

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(including GMR and AMR) read-back sensors in a flexible media environment such as magnetic tape.

SUMMARY

5 A magneto-resistive (MR) transducer is provided for reading data signals magnetically recorded on a tape. In one embodiment, the transducer includes a head-tape interface (HTI), a MR sensor, and a separation structure. An electro-static discharge (ESD) element is coupled to the MR sensor and/or the separation structure and provides an electrical path to a lower potential structure. In yet another embodiment of the MR transducer, the transducer includes the HTI, the MR sensor, and the ESD element absent the separation structure. 10 Accordingly, the ESD element is coupled to the MR sensor and provides the electrical path from the MR sensor to the lower potential structure.

A method of forming a MR transducer, is provided, which includes depositing a MR sensor sheet film over a wafer and protecting a portion of the MR sensor sheet film with photo-resist. The method includes etching away an unprotected portion of the MR sensor sheet film to thereby leave MR sensor material on the wafer. The method also includes depositing a separation structure sheet film over the MR sensor material and the wafer. An additional step of the method is lifting off the photo-resist to remove the separation structure sheet film deposited over the MR sensor material to thereby leave the MR sensor material surrounded by separation structure material on the wafer. The method further includes depositing an electro-static discharge (ESD) element over the MR sensor and the separation structure. 20

Yet another step is protecting with photo-resist a portion of the MR sensor material which is to form a MR sensor and protecting with photo-resist a portion of the ESD element and the separation structure material which is to form a separation structure on an edge of the MR sensor. The method also includes milling away the unprotected portions of the MR sensor material, the ESD element and the separation structure material to thereby leave the MR sensor and the separation structure on the wafer with the separation structure being formed on an edge of the MR sensor. The method includes lapping the separation structure to define a head-tape interface with the separation structure being disposed between the edge of the MR sensor and the head-tape interface such that the separation structure physically separates the MR sensor from the head-tape interface. 25 30 35 40 45

BRIEF DESCRIPTION OF THE DRAWINGS

50 FIG. 1 illustrates a cross-sectional view of a magneto-resistive (MR) transducer in accordance with an embodiment of the present invention;

FIGS. 2A and 2B illustrate a top-down view of the MR transducer shown in FIG. 1 having alternative embodiments of an electro-static discharge (ESD) element; 55

FIG. 3 illustrates a cross-sectional view of a MR transducer in accordance with another embodiment of the present invention;

FIG. 4 illustrates a top-down view of the MR transducer shown in FIG. 3; 60

FIGS. 5A and 5B illustrate a cross-sectional and a top-down view of a MR transducer in accordance with another embodiment of the present invention;

FIG. 6 illustrates a cross-sectional view of a MR transducer in accordance with yet another embodiment of the present invention. 65

FIGS. 7A and 7B illustrate several initial steps in a fabrication process for forming a MR transducer in accordance with an embodiment of the present invention;

FIGS. 7C through 7G illustrate additional steps within the fabrication process following the steps illustrated in FIGS. 7A and 7B for forming a MR transducer having a separation structure and an electro-static discharge (ESD) element in accordance with an embodiment of the present invention; and

FIGS. 8A through 8D illustrate alternative steps of the fabrication process to those steps shown in FIGS. 7C through 7G for forming a MR transducer having an electro-static discharge (ESD) element absent a separation structure in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

By way of example a system and methodology for implementing the present invention is described below. The provided system and methodology may be adapted, modified or rearranged to best-fit a particular implementation without departing from the scope of the present invention.

Referring now to FIG. 1, a cross-sectional view of a magneto-resistive (MR) transducer 10 in accordance with an embodiment of the present invention is shown. MR transducer 10 is to be employed in a magnetic head for reading magnetically recorded data from a magnetic medium such as tape. To this end, MR transducer 10 includes a head-tape interface 12 (i.e., a tape bearing surface) which is to be positioned adjacent to tape for the MR transducer to read data from the tape. It is recognized that MR transducer 10 may be virtually any type of MR transducer, including but not limited to, a giant magneto-resistive (GMR), anisotropic magneto-resistive (AMR) or a tunneling magneto-resistive (TMR) transducer.

MR transducer 10 generally includes an electro-static discharge (ESD) element 11, a MR sensor 14, and a separation structure 16. As is known in the art, MR sensor 14 is formed by a set of layers which form a film stack. Such layers forming the film stack of MR sensor 14 typically include free and pinned metallic ferromagnetic layers containing Ni, Fe, Co or combinations thereof. Separation structure 16 is formed on a front side or edge 18 of MR sensor 14 and physically separates the MR sensor from head-tape interface 12. That is, separation structure 16 is interposed between MR sensor 14 and head-tape interface 12 such that the MR sensor is offset from the head-tape interface. As such, separation structure 16 reduces exposure of MR sensor 14 to direct physical contact with the surface of tape at head-tape interface 12 when MR transducer 10 is reading data from the tape.

Separation structure 16 is formed of materials that are non-magnetic, ferromagnetic, or a combination of both. Separation structure 16 includes one or several films. The material(s) and film(s) defining separation structure 16 are selected such that the separation structure protects MR sensor 14 and its front surface 18 from the tape surface at head-tape interface 12 while not degrading the performance of the MR sensor 14. From the proper selection of the material(s) and film(s) used to define separation structure 16, coupling of the free and pinned layers in the film stack of MR sensor 14 can be minimized while coupling of written transitions from tape at head-tape interface 12 into the MR sensor can be maximized.

Regardless of whether the single film forming separation structure 16 is a non-magnetic or a magnetic material, the separation structure functions as an "isolation film" as it

isolates MR sensor 14 from direct physical contact and exposure to head-tape interface 12.

ESD element 11 enables shunting of charges that build-up on MR transducer 10. As such, ESD element 11 contacts separation structure 16 and MR sensor 14 to provide an electrical path for dissipating charges. ESD element 11 may provide the electrical path from MR transducer 10 to a structure having a lower electrical potential such as a ground point or another structure within the head. In one embodiment, ESD element 11 may be comprised of a relatively high resistance metal having a resistance of about 10 kilo-ohms. In such an embodiment, ESD element 11 may, but not necessarily, form a serpentine resistive path. In an alternative embodiment, where ESD element 11 provides a relatively high resistance path, ESD element 11 may be comprised of an insulator that is doped with metal. In yet another embodiment, ESD element 11 may be comprised of a relatively low resistance metal in accordance with design and performance requirements.

Referring now to FIGS. 2A and 2B, with continual reference to FIG. 1, a top-down view of MR transducer 10 is shown. As shown in FIG. 2A, MR sensor 14 and separation structure 16 share two side surfaces 20 and 22 which are generally normal to head-tape interface 12. Front side 18 of MR sensor 14 has a width 24 between side surfaces 20 and 22. Width 24 defines the physical read width of MR sensor 14. Separation structure 16 also has the same width 24 as MR sensor 14 and is generally formed parallel with head-tape interface 12 between side surfaces 20 and 22. Additionally, ESD element 11 is shown as a layer on top of MR sensor 14 having a width 25. As shown, width 25 of ESD element 11 is less than width 24 of MR sensor 14. However, in one aspect of the invention, so long as the resistance of ESD element 11 has a sufficient magnitude, width 25 may be the same as or greater than width 24. Such embodiments provide improved control of current flowing through separation structure 16. FIG. 2B illustrates an alternative embodiment of MR transducer 10 wherein ESD element 11 forms a serpentine resistive path. In one aspect, the serpentine resistive path enables increased resistance to current flowing throughout the head.

MR transducer 10 further includes a pair of permanent magnet (PM) films 26 and 28. PM film 26 is defined to abut MR sensor 14 and separation structure 16 along side surface 20. PM film 26 is further defined to abut and be formed parallel with head-tape interface 12 as shown in FIG. 2. Likewise, PM film 28 is defined to abut MR sensor 14 and separation structure 16 along side surface 22. PM film 28 is also defined to abut and be formed perpendicular with head-tape interface 12 as shown in FIGS. 2A and 2B. PM films 26 and 28 are patterned PM stabilization films which function to stabilize the performance of MR sensor 14 for reading magnetically recorded data from tape.

Referring now to FIGS. 3 and 4, cross-sectional and top-down views of a MR transducer 50 in accordance with another embodiment of the present invention are respectively shown. MR transducer 50 includes a separation structure 52 which separates front edge 18 of MR sensor 14 from head-tape interface 12. Separation structure 52 generally differs from separation structure 16 of MR transducer 10 shown in FIG. 1 in that separation structure 52 is defined from two films 54, 56 instead of just a single film. More particularly, separation structure 52 includes an under-layer film 54 and an isolation film 56.

Under-layer film 54 is interposed between front edge 18 of MR sensor 14 and isolation film 56. Under-layer film 54 is defined such that a portion of the under-layer film abuts side surface 22 and head-tape interface 12 as shown in FIG. 3. Under-layer film 54 physically isolates isolation film 56 from

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direct contact with MR sensor **14**. Isolation film **56** is interposed between head-tape interface **12** and under-layer film **54**. Isolation film **56** serves to separate MR sensor **14** and its front edge **18** from head-tape interface **12**.

As an example, under-layer film **54** is formed of Cr or Ta as these materials neither propagate anti-ferromagnetic coupling between the NiFe layers (which make up the film stack of MR sensor **14**) and can both be deposited with high resistivity. In either case, isolation film **56** is formed from a magnetically soft ferromagnetic material such as CoZrMo, NiFeMo, or NiFeCr in order to improve the coupling of the magnetic flux from the transitions recorded on the tape into MR sensor **14**. As such, isolation film **56** functions to conduct magnetic flux into MR sensor **14** from magnetic transitions recorded in tape at head-tape interface **12**. The role of under-layer film **54** is not to separate front edge **18** of MR sensor **14** from head-tape interface **12** but it is rather to ensure the correct operation of the MR sensor. Additionally, as shown, MR transducer **50** includes ESD element **11** to protect the structural and magnetic integrity of MR transducer **50** during an ESD event.

Referring to FIGS. **5A** and **5B**, yet another embodiment of MR transducer **10** is shown. In this embodiment, MR transducer **10** is formed without separation structure **16** (FIG. **1**). Accordingly, it is recognized that MR transducer **10** may include ESD element **11** without separation structure **16**.

Now referring to FIG. **6**, an alternative embodiment of MR transducer **50** is illustrated having an alumina gap material **58** and a shield **60**. Alumina gap material provides structural support for shield **60** and electrical isolation between MR sensor **14** and shield **60**. As recognized by one of ordinary skill in the art, shield **60** is configured to block magnetic flux from neighboring tracks and up and downstream magnetic bits located on the tape, which enables improved resolution by MR sensor **14**. As described above, ESD element **11** is configured to provide an electrical path from head-tape interface **12** to a lower voltage structure within the head or a grounding point. Accordingly, in one aspect of the invention, ESD element **11** may provide an electrical path from head-tape interface **12** to shield **60**. In such an embodiment, charges that are built-up on head-tape interface **12** during an ESD event are discharged through ESD element **11** to shield **60**.

Referring now to FIGS. **7A** through **7G** and **8A** through **8D**, a fabrication process for forming a MR transducer having an ESD element is shown in accordance with an embodiment of the present invention. The steps shown in FIGS. **7C** through **7G** illustrate the fabrication process for forming a MR transducer having a separation structure in addition to an ESD element. Alternatively, the steps shown in FIGS. **8A** through **8D** illustrate an embodiment of the fabrication process for forming a MR transducer having the ESD element absent the separation structure. In either embodiment, the views shown in FIGS. **7A** through **7G** and **8A** through **8D** are looking down at a top side of the MR transducer being fabricated. As such, the views shown in FIGS. **7A** through **7G** and **8A** through **8D** are top-down views like the top-down MR transducer views shown in FIGS. **2A**, **2B**, and **4** and **5B**.

It is to be understood that each of FIGS. **7A** through **7G** and **8A** through **8D** may actually cover more than one actual fabrication step. For example, to proceed from FIG. **7A** (MR sensor deposited as sheet film) to FIG. **7B** (MR sensor pattern) photo definition and ion mill (or etch) steps are involved. A separation structure would then be deposited (FIG. **7C**) in situ before any resist strip/lift off step. As such, the sequence of the fabrication process illustrated in FIGS. **7A** through **7G**

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and **8A** through **8D** is to be understood to include additional typical fabrication steps which are evident to those skilled in the art.

A first fabrication step **80** shown in FIG. **7A** includes depositing a MR sensor sheet film **82** on a wafer having a base structure **84**. As is known in the art, base structure **84** for a MR sensor typically includes the following sequence of layers from the bottom to the top: (AlTiC) substrate, insulating under-layer, patterned magnetic shield, and an insulating gap. MR sensor sheet film **82** is deposited over the insulating gap layer of base structure **84**. MR sensor sheet film **82** includes the film stack which forms the MR sensor.

A second fabrication step **90** shown in FIG. **7B** includes defining the MR sensor from the deposited MR sensor sheet film **82**. Second fabrication step **90** is performed by defining the desired shape of the MR sensor with photo-resist through photolithography. The unprotected portion **92** of film stack **82** is then milled away leaving a desired portion of the MR sensor film stack **82** as shown in FIG. **7**.

A third fabrication step **100** shown in FIG. **7C** includes defining an abutted junction (i.e., a separation structure) with separation structure material **102** around the remaining desired portion of MR sensor film stack **82**. With the photo-resist remaining on MR sensor film stack **82** from the second fabrication step **90**, the separation structure material **102** is deposited as a sheet film over the remaining MR sensor film stack **82** and the milled away portion **92**. As will be described below, separation structure material **102** forms a separation structure such as separation structures **16** and **52**. For example, to form separation structure **16**, separation structure material **102** includes one deposition of a film layer which forms separation structure **16**. As another example, to form separation structure **52**, separation structure material **102** includes several depositions of film layers which form under-layer film **54** and isolation film **56** of separation structure **52**. After the separation structure material **102** is deposited, the photo-resist is lifted off leaving the desired portion of MR sensor **82** surrounded by separation structure material **102** as shown in FIG. **7C**.

A fourth fabrication step **110** shown in FIG. **7D** includes photo-defining a desired portion of MR sensor film stack **82** and separation structure material **102** as indicated by dashed line **112**. The remaining portion of MR sensor film stack **82** and isolation junction material **102** are then milled away leaving MR sensor **14** and a separation structure such as separation structure **16** as shown in FIG. **7E**. As shown in FIG. **7E**, MR sensor **14** has width **24** which defines the physical read width of the MR sensor.

A fifth fabrication step **120** shown in FIG. **7E** includes depositing a permanent magnet (PM) stabilization sheet film **122** on base substrate **84** and over the photo-resist still protecting MR sensor **14** and separation structure **16**. PM stabilization sheet film **122** forms abutted junctions with MR sensor **14** and separation structure **16**. After the photo-resist is lifted off, a MR transducer **10** remains as illustrated in FIG. **7E**.

A sixth fabrication step **125** shown in FIG. **7F** includes depositing an ESD element **11** over MR sensor **14** and separation structure **16**. As described above, ESD element **11** may be comprised of a relatively high resistance metal or alternatively, a relatively low resistance material. Additionally, as shown, ESD element **11** has a width **25** that is less than width **24** wherein width **24** defines the physical read width of MR sensor **14**.

A seventh fabrication step **130** shown in FIG. **7G** includes photo-defining and milling away unprotected portions of the ESD element **11**, MR sensor film stack, the separation struc-

ture material, and PM stabilization sheet film **122** to define ESD element **11**, MR sensor **14**, separation structure **16**, and patterned PM films **26**, **28** prior to completion of the reader wafer build and lapping. The dashed line indicates the finished stripe height of MR sensor **14** after lapping which is set to be head-tape interface **12**. As such, head-tape interface **12** is located within separation structure **16** and the distance from head-tape interface **12** to MR sensor **14** is minimized with sensing front edge **18** of the MR sensor not being in contact with the head-tape interface.

As discussed in the foregoing, fabrication of MR transducer **10** shown in FIGS. **5A** and **5B** does not require fabrication of separation structure **16**. Accordingly, FIGS. **8A** through **8D** illustrate fabrication of the MR transducer **10** shown in FIGS. **5A** and **5B**. Prior to steps **200** through **230** occurring (FIGS. **8A** through **8D**), steps **80** and **90** (FIGS. **7A** and **7B**) occur as described above. Accordingly, in the alternative embodiment, following step **90** (FIG. **7B**), step **200** (FIG. **8A**) occurs, which includes photo-defining a desired portion of MR sensor film stack **82** as indicated by dashed line **212**. The remaining portion of MR sensor film stack **82** is then milled away leaving MR sensor **14** as shown in FIG. **8B**. As shown in FIG. **8B**, MR sensor **14** has width **24** which defines the physical read width of the MR sensor **14**.

A next step in the alternative fabrication process includes a step **210** wherein a permanent magnet (PM) stabilization sheet film **122** is deposited on base substrate **84** (FIG. **7A**) and over the photo-resist still protecting MR sensor **14**. As described above, PM stabilization sheet film **122** forms abutted junctions with MR sensor **14**. After the photo-resist is lifted off, a MR transducer **10** remains as illustrated in FIG. **8B**.

Another step in the alternative fabrication process includes a step **220** shown in FIG. **8C**, wherein ESD element **11** is deposited on an area adjacent to MR sensor **14**. As shown, ESD element **11** has a width **25** that is less than width **24** wherein width **24** defines the physical read width of MR sensor **14**.

Yet another step is a step **230** shown in FIG. **8D** that includes photo-defining and milling away unprotected portions of the ESD element **11**, MR sensor film stack, and PM stabilization sheet film **122** to define ESD element **11**, MR sensor **14**, and patterned PM films **26**, **28** prior to completion of the reader wafer build and lapping. The dashed line indicates the finished stripe height of MR sensor **14** and ESD element **11** after lapping which is set to be head-tape interface **12**.

Thus, it is apparent that there has been provided, in accordance with the present invention, a MR transducer having an ESD element and alternatively, a separation structure separating a MR sensor from a head-tape interface, and method of making the same that fully satisfy the objects, aims, and advantages set forth above.

While embodiments of the present invention have been illustrated and described in the general context of MR sensors, it is not intended that these embodiments illustrate and describe all possible forms of the present invention. Accordingly, the present invention is equally applicable to virtually any magneto-resistive sensors including but not limited to giant magneto-resistive (GMR) sensors, anisotropic magneto-resistive (AMR) sensors, and tunneling magneto-resistive (TMR) sensors. As such, the words used in the specification are words of description rather than limitation, and it is understood that various changes may be made without departing from the spirit and scope of the present invention.

What is claimed is:

1. A magneto-resistive (MR) transducer for reading data signals magnetically recorded on tape, the transducer comprising:

5 a MR sensor having a front edge;

a separation structure including at least one film formed of at least one of non-magnetic or ferromagnetic materials, the separation structure is configured to contact the tape and is formed on the front edge of the MR sensor to isolate the MR sensor from contact with the tape; and
10 an electro-static discharge (ESD) element coupled to at least one of the separation structure and the MR sensor and configured to contact the tape, the ESD element being further configured to provide an electrical path to a lower potential structure.

2. A transducer of claim **1**, wherein the ESD element forms a serpentine resistive structure.

3. The transducer of claim **1** wherein the at least one film includes an isolation film and an underlying film and wherein the isolation film is positioned between the tape and the underlying film, and the underlying film is positioned between the isolation film and the MR sensor to isolate the MR sensor from contacting the isolation film.

4. The transducer of claim **3** wherein the isolation film is formed of at least one of chromium (Cr) and tantalum (Ta).

5. The transducer of claim **3** wherein the underlying film is formed of at least one of an alloy of cobalt, zirconium, and molybdenum (CoZrMo), an alloy of nickel, iron and molybdenum (NiFeMo), and an alloy of nickel, iron, and chromium (NiFeCr).

6. The transducer of claim **1** further comprising at least one permanent magnet (PM) film positioned about the MR sensor and configured to contact the tape to stabilize performance of the MR sensor.

7. A magneto-resistive (MR) transducer for reading data signals from a magnetic tape, the transducer comprising:

15 an MR sensor;

a separation structure formed about the MR sensor for contacting the tape and separating the MR sensor from the tape, and

20 an electro-static discharge (ESD) element for contacting the MR sensor, the separation structure, and the tape and for dissipating electrical charges from the tape.

8. The transducer of claim **7** further comprising an insulator for contacting the MR sensor and the tape.

9. The transducer of claim **8** wherein the insulator is formed of an alumina gap material.

10. The transducer of claim **7** wherein the separation structure includes an isolation film and an underlying film and wherein the isolation film is positioned between the tape and the underlying film, and the underlying film is positioned between the isolation film and the MR sensor to isolate the MR sensor from contacting the isolation film.

11. The transducer of claim **10** wherein the isolation film is formed of at least one of chromium (Cr) and tantalum (Ta).

12. The transducer of claim **10** wherein the underlying film is formed of at least one of an alloy of cobalt, zirconium, and molybdenum (CoZrMo), an alloy of nickel, iron and molybdenum (NiFeMo), and an alloy of nickel, iron, and chromium (NiFeCr).

13. The transducer of claim **7** further comprising at least one permanent magnet (PM) film positioned about the MR sensor and configured to contact the tape to stabilize performance of the MR sensor.

14. A magneto-resistive (MR) transducer for reading data signals from a magnetic tape, the transducer comprising:
25 an MR sensor;

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an electro-static discharge (ESD) element configured to contact the MR sensor and the tape and to dissipate electrical charges from the tape; and
at least one permanent magnet (PM) film positioned about the MR sensor and the ESD element and configured to contact the tape and to stabilize performance of the MR sensor.

15. The transducer of claim 14 further comprising a separation structure formed about the MR sensor and configured to contact the tape and to separate the MR sensor from the tape.

16. The transducer of claim 15 wherein the separation structure includes an isolation film and an underlying film and

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wherein the isolation film is positioned between the tape and the underlying film, and the underlying film is positioned between the isolation film and the MR sensor to isolate the MR sensor from contacting the isolation film.

17. The transducer of claim 16 wherein the isolation film is formed of at least one of chromium (Cr) and tantalum (Ta).

18. The transducer of claim 16 wherein the underlying film is formed of at least one of an alloy of cobalt, zirconium, and molybdenm (CoZrMo), an alloy of nickel, iron and molybdenum (NiFeMo), and an alloy of nickel, iron, and chromium (NiFeCr).

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