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(54) APPARATUS AND METHOD HAVING TDMR READER TO READER SHUNTS

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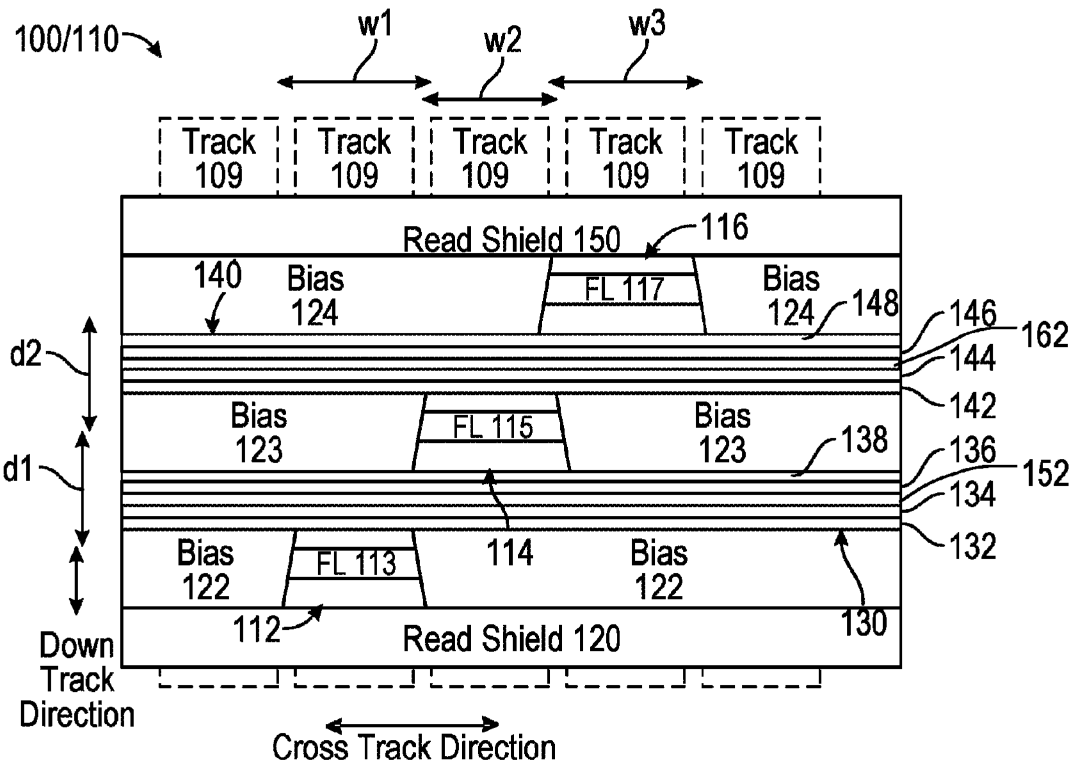
CPC *G11B 5/3163* (2013.01); *G11B 5/1272* (2013.01)

(57) **ABSTRACT**

A method of making a magnetic head is provided. The method includes forming a first read sensor and a first electrical contact formed with a first shunt region. The method further includes forming a first mid-shield layer on the first read sensor, the first mid-shield layer being electrically connected to the first electrical contact. Additionally the method also includes forming a second mid-shield layer over the first mid-shield layer. Further, the method also includes forming a second read sensor over the second mid-shield layer, the second read sensor having a second electrical contact formed with a second shunt region electrically connected to the first shunt region.



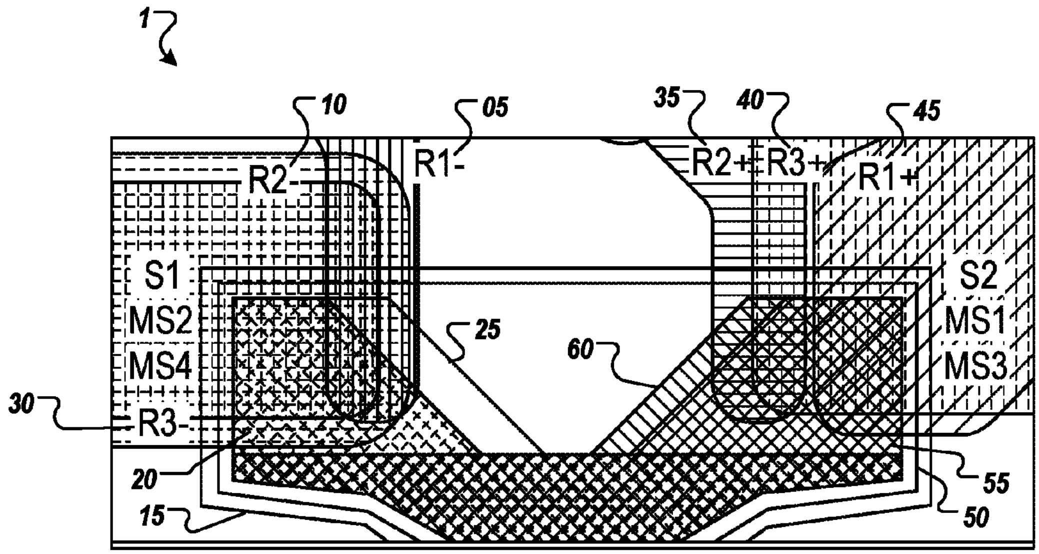


FIG. 1A
(RELATED ART)

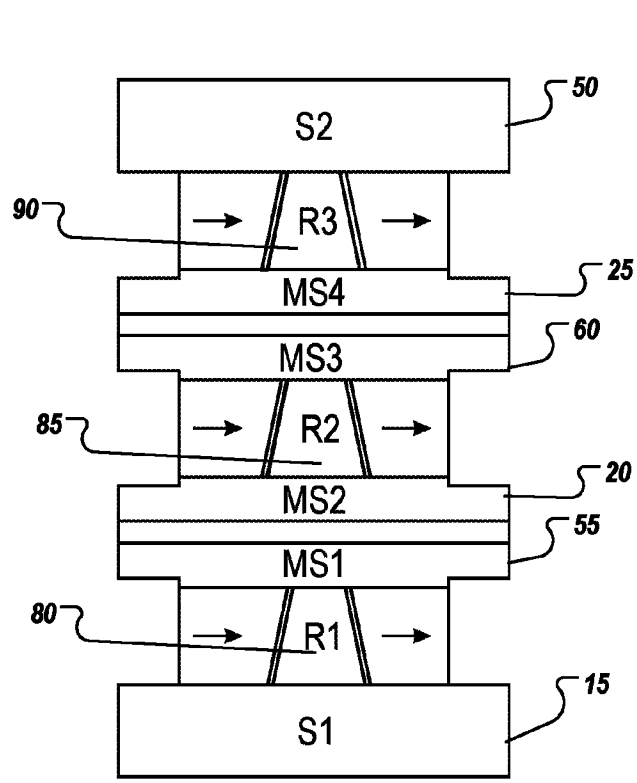


FIG. 1B
(RELATED ART)

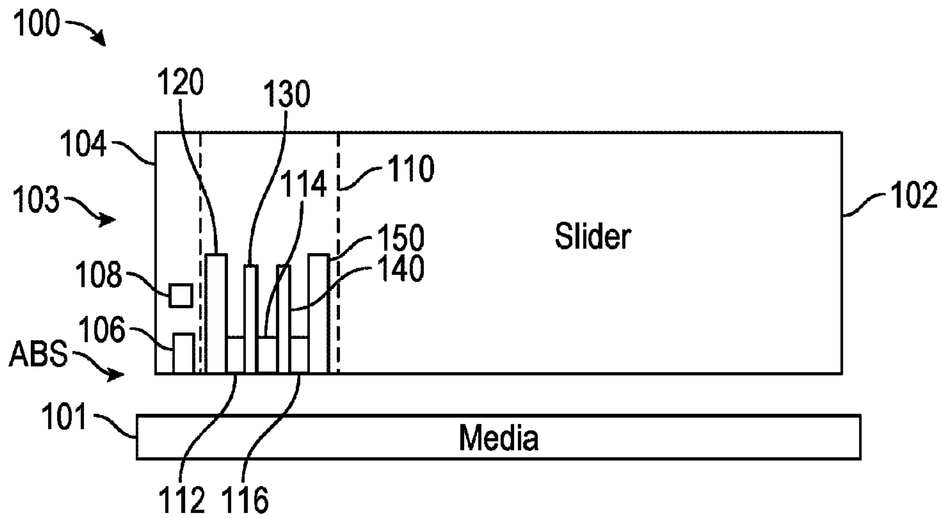

100
120
130
104
114
110
103
102
Slider
150
140
108
106
ABS
101
Media
112
116

FIG. 2

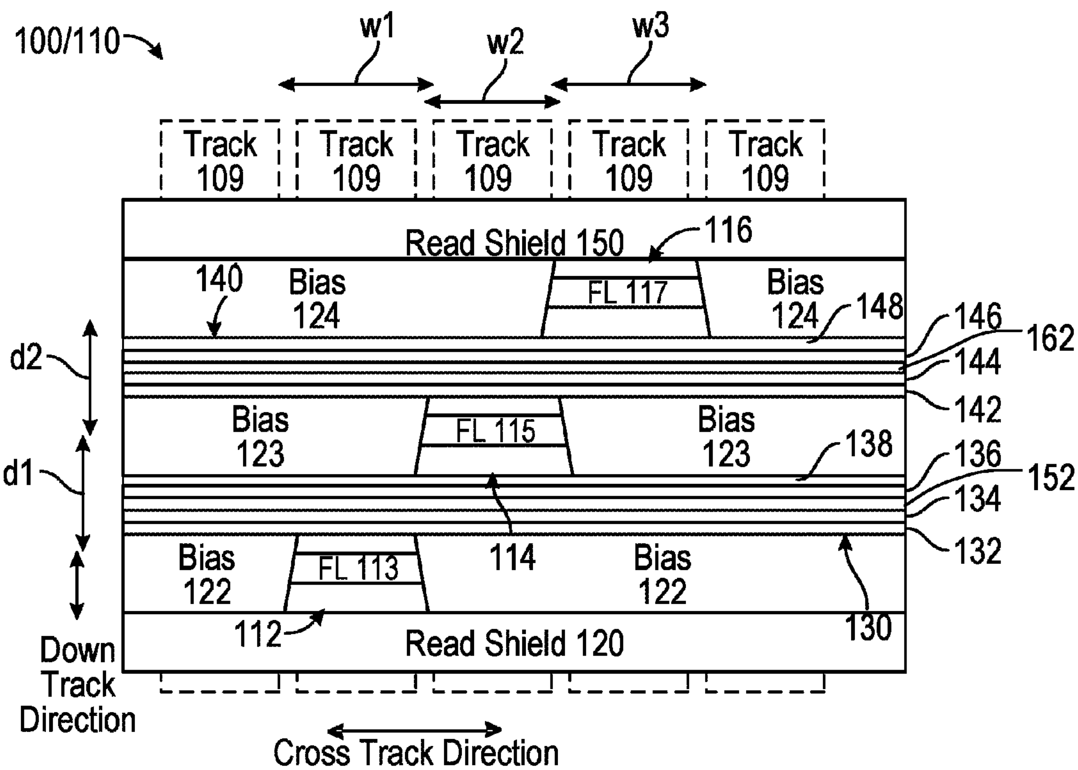

100/110
w1
w2
w3
Track 109
Track 109
Track 109
Track 109
Track 109
Read Shield 150
116
140
Bias 124
FL 117
Bias 124
148
146
162
144
142
d2
Bias 123
FL 115
Bias 123
138
136
152
134
d1
132
Bias 122
FL 113
114
Bias 122
112
Read Shield 120
130
Down Track Direction
Cross Track Direction

FIG. 3

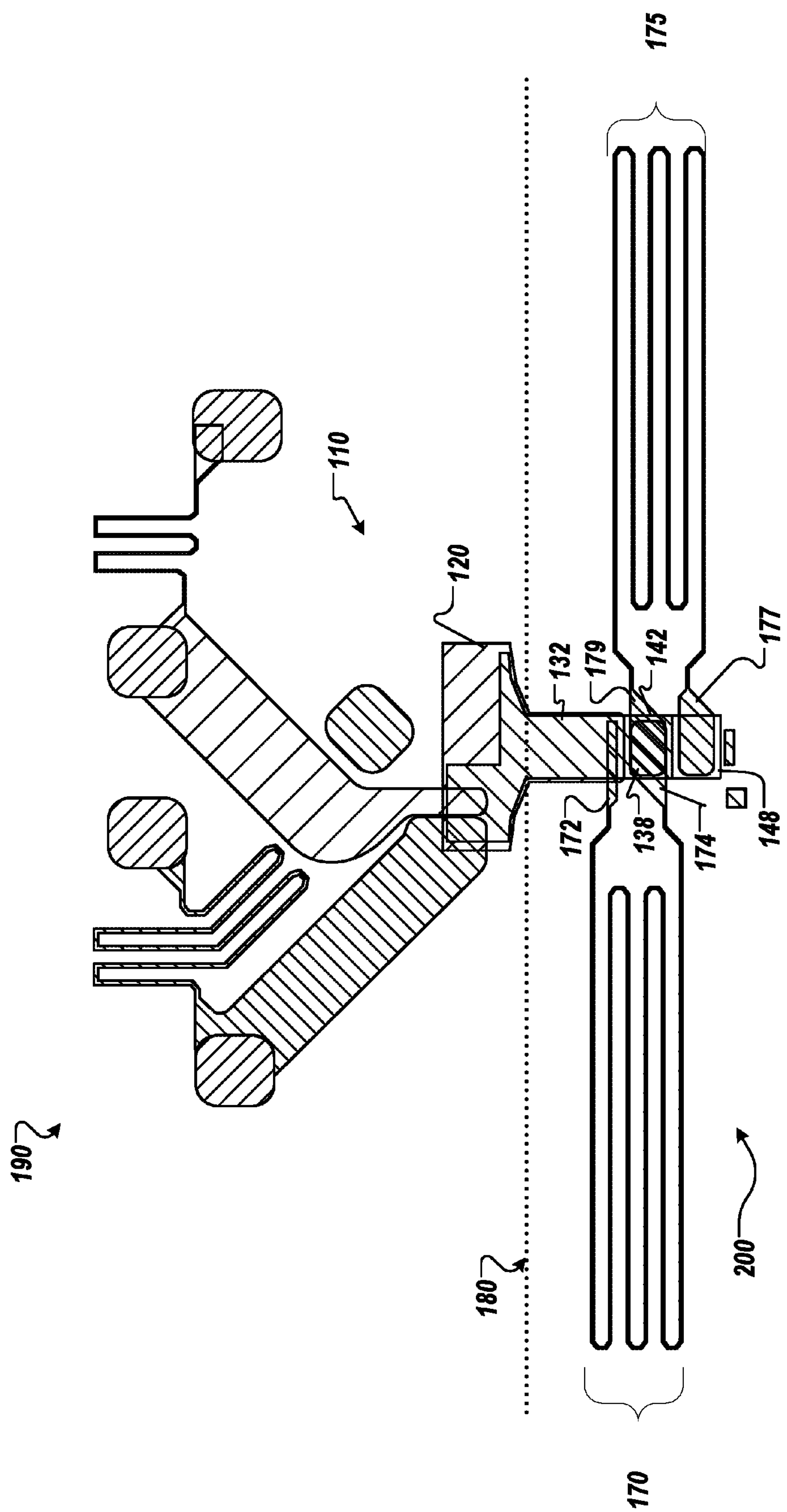


FIG. 4

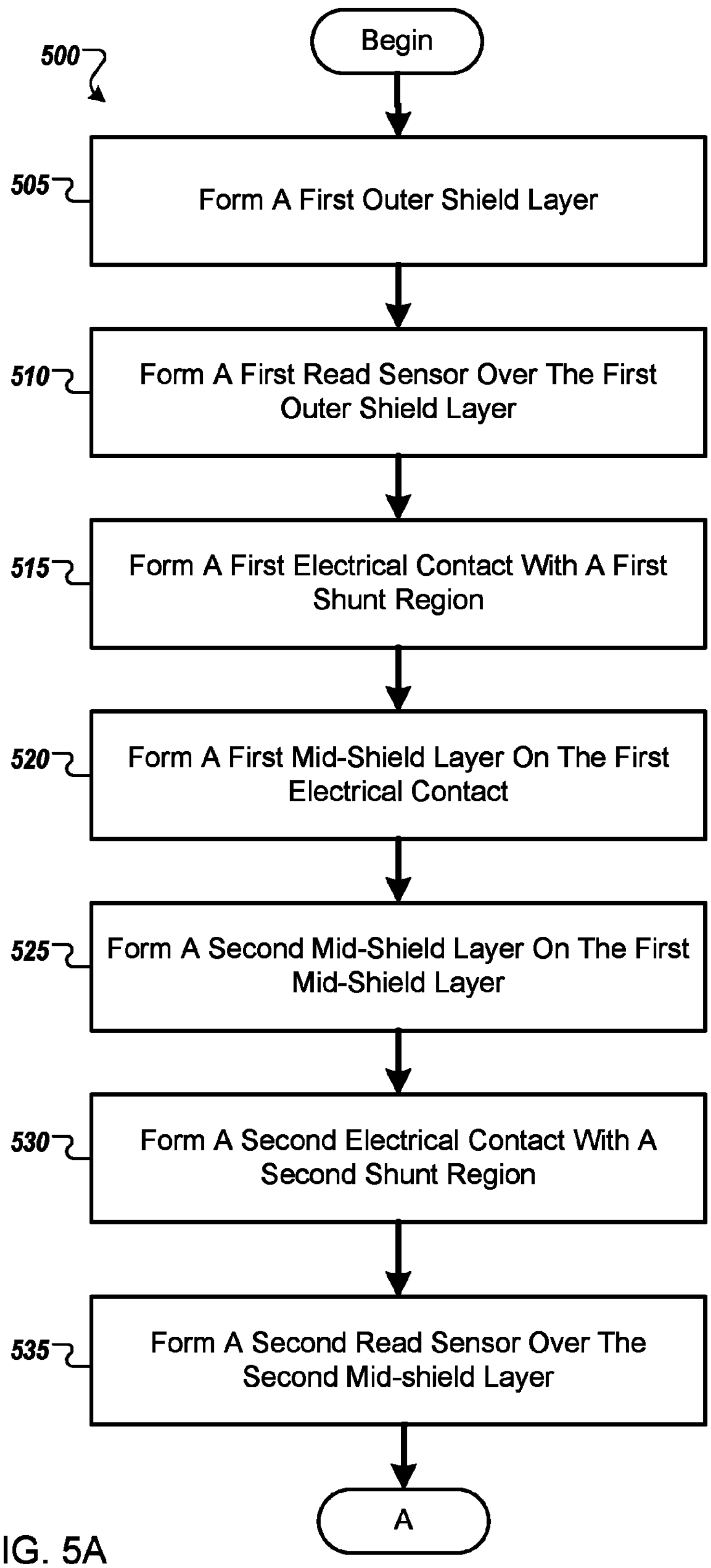

500
Begin
505
Form A First Outer Shield Layer
510
Form A First Read Sensor Over The First Outer Shield Layer
515
Form A First Electrical Contact With A First Shunt Region
520
Form A First Mid-Shield Layer On The First Electrical Contact
525
Form A Second Mid-Shield Layer On The First Mid-Shield Layer
530
Form A Second Electrical Contact With A Second Shunt Region
535
Form A Second Read Sensor Over The Second Mid-shield Layer
A

FIG. 5A

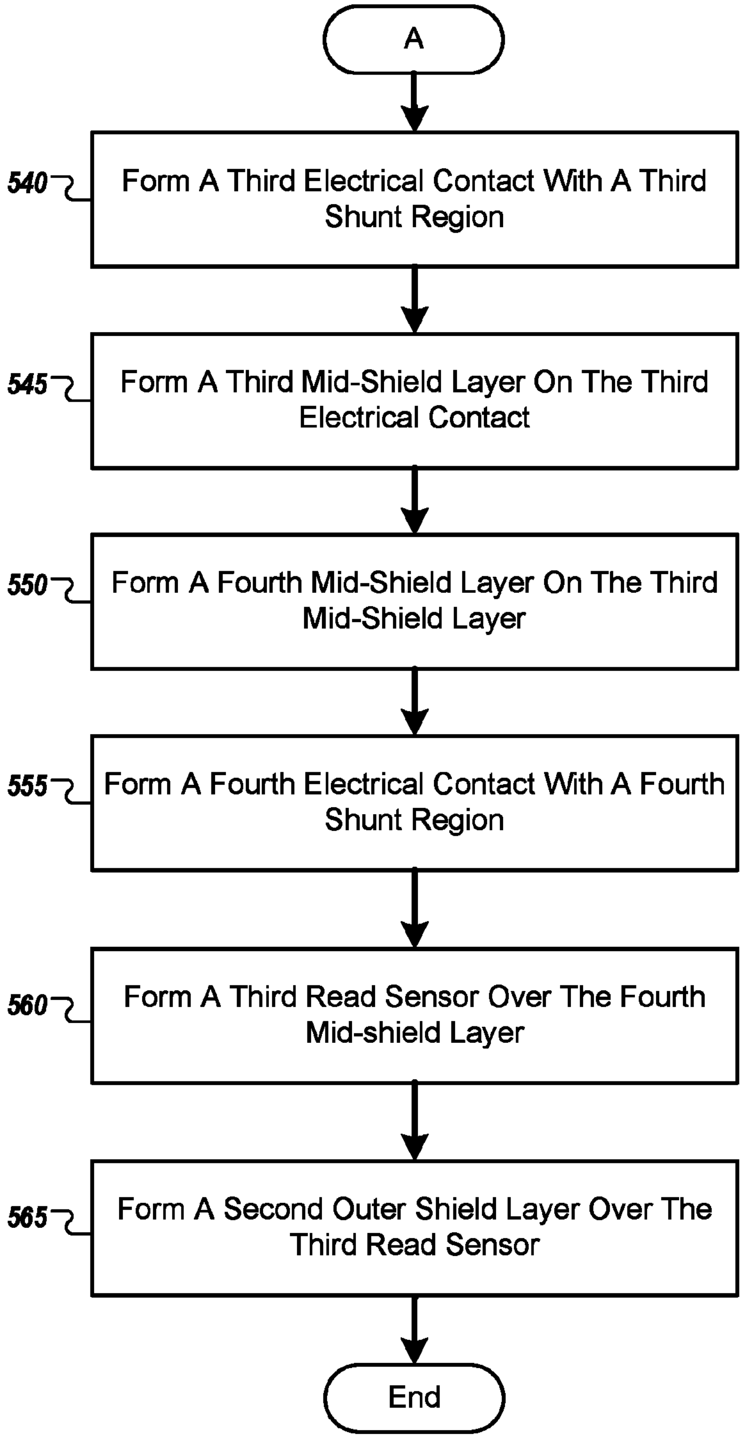

A
540
Form A Third Electrical Contact With A Third Shunt Region
545
Form A Third Mid-Shield Layer On The Third Electrical Contact
550
Form A Fourth Mid-Shield Layer On The Third Mid-Shield Layer
555
Form A Fourth Electrical Contact With A Fourth Shunt Region
560
Form A Third Read Sensor Over The Fourth Mid-shield Layer
565
Form A Second Outer Shield Layer Over The Third Read Sensor
End

FIG. 5B

APPARATUS AND METHOD HAVING TDMR READER TO READER SHUNTS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a divisional of U.S. application Ser. No. 14/579,785, filed Dec. 22, 2014, the contents of which are incorporated by reference.

BACKGROUND

[0002] FIGS. **1**A-**1**B illustrate a related-art two-dimensional magnetic recording (TDMR) transducer **1**. Specifically, FIG. **1**A illustrates a plan view of the related-art read transducer **1** and FIG. **1**B illustrates a schematic view of the related-art two-dimensional read transducer **1**. As illustrated, the related-art read transducer may include the two outer shields (**15**, **50**), four mid-shields (**20**, **25**, **55**, **60**), and three read sensors (**80**, **85**, **90**), each having two terminals for a total of six terminals (**05**, **10**, **30**, **35**, **40**, **45**). The two outer shields include a first outer shield (S**1**) **15** and a second outer shields (S**2**) **50**. The four mid-shields include a first mid-shield (MS**1**) **55**, a second mid-shield (MS**2**) **20**, a third mid-shield (MS**3**) **60**, and a fourth mid-shield (MS**4**) **25**.

[0003] The three read sensors (illustrated in FIG. **1**B) include a first read sensor (R**1**) **80**, a second read sensor (R**2**) **85**, and a third read sensor (R**3**) **90**. The first read sensor (R**1**) **80** includes a negative terminal (R**1**−) **05** and a positive terminal (R**1**+) **45**. The second read sensor (R**2**) **85** also includes a negative terminal (R**2**−) **10** and a positive terminal (R**2**+) **35**. Further, the third read sensor (R**3**) **90** includes a negative terminal (R**3**−) **30** and a positive terminal (R**3**+) **40**.

[0004] By employing multiple sensor array designs, TDMR technology may enable multi-terabit density recording. In principle TDMR operation schemes may require the read sensor array structure of the TDMR transducer be longitudinally aligned along the cross track direction with little or no separation to allow different signals to be obtained at the same data track locations simultaneously during read back process. However, a TDMR transducer **1** may suffer a misalignment between adjacent sensor locations and the actual tracks of interests due to skew angle and radius conditions.

[0005] Providing smaller vertical separation between adjacent sensors may reduce a skew angle causing misalignment. However, this requires very thin insulating films to separate one reader's mid-shield from the next reader's mid-shield. Such thin insulating films may suffer from Electrical Overstress (EOS) or Electrostatic Discharge (ESD) during manufacturing. The chance of EOS or ESD increases as more read sensors are added between the first outer shield (S**1**) **15** and a second outer shields (S**2**) **50**. Accordingly, what is needed is a system and method for improving the manufacturing of a magnetic recording read transducer, particular for a TDMR.

BRIEF DESCRIPTION OF SEVERAL VIEWS OF THE DRAWINGS

[0006] FIG. **1**A illustrates a plan view of the related-art read transducer **1** and FIG. **1**B illustrates a schematic view of the related-art two-dimensional read transducer **1**.

[0007] FIG. **2** is a schematic view illustrating an exemplary implementation of a disk drive.

[0008] FIG. **3** is an ABS view illustrating a portion of a two-dimensional read transducer manufactured from an exemplary implementation of a microstructure of the present application.

[0009] FIG. **4** is a plan view of the exemplary implementation of the microstructure of the present application.

[0010] FIGS. **5**A and **5**B are flow charts illustrating an exemplary implementation of a method for manufacturing a magnetic head according to the present application.

DETAILED DESCRIPTION OF THE EXEMPLARY IMPLEMENTATIONS

[0011] FIGS. **2**-**3** depict side and Air Bearing Surface views of a storage drive or disk drive **100**. For clarity, FIGS. **3** and **4** are not to scale. For simplicity not all portions of the disk drive **100** are shown. In addition, although the disk drive **100** is depicted in the context of particular components other and/or different components may be used. For example, circuitry used to drive and control various portions of the disk drive **100** is not shown. For simplicity, only single components are shown. However, multiples of one or more of the components and/or their sub-components might be used.

[0012] The disk drive **100** includes media **101**, a slider **102**, a head **103** including a write transducer **104** and a read transducer **110**. The media **101** includes tracks **109**. The write transducer includes at least a write pole **106** and coil(s) **108** for energizing the pole **106**. Additional and/or different components may be included in the disk drive **100**. The slider **102**, and thus the transducers **104** and **110** are generally attached to a suspension (not shown). The transducers **104** and **110** are fabricated on the slider **102** and include an ABS proximate to the media **101** during use. Although both a write transducer **104** and a read transducer **110** are shown, in other implementations, only a read transducer **110** may be present.

[0013] The read transducer **110** includes multiple read sensors **112**, **114**, and **116**. The read sensors **112**, **114** and **116** include sensor layers **113**, **115** and **117**, respectively, that may be free layers (FL) in a magneto resistive junction such as a tunneling magneto resistive (TMR) sensor (such as a current-perpendicular-to-plane (CPP) TMR sensor). As may be apparent to a person of ordinary skill in the art, other types of sensors (such as a giant magneto resistive (GMR) sensor) may also be used. Thus, each sensor **112**, **114**, and **116** may include a pinning layer, a pinned layer, a nonmagnetic spacer layer, and a free layer **113**, **115**, and **117**, respectively. For simplicity, only the free layers **113**, **115** and **117** are separately labeled in FIG. **3**. The sensors **112**, **114** and **116** may also include seed layer(s) (not shown) and capping layer(s) (not shown). The pinning layer is generally an AFM layer that is magnetically coupled to the pinned layer. In other implementations, however, the pinning layer may be omitted or may use a different pinning mechanism. The free layers **113**, **115** and **117** are each shown as a single layer, but may include multiple layers including but not limited to a synthetic antiferromagnetic (SAF) structure. The pinned layer may also be a simple layer or a multilayer. Although shown as extending the same distance from the ABS, the pinned layer may extend further than the corresponding free layer **113**, **115**, and/or **117**, respectively. The nonmagnetic spacer layer may be a conductive layer, a tunneling barrier layer, or other analogous layer. Although depicted as a GMR or TMR sensor, in other implementations, other structures and other sensing mechanisms may be used for the sensor.

[0014] The read sensors **112**, **114** and **116** are separated by distances d**1** and d**2** in a down track direction. The down track direction is perpendicular to the cross track direction. The cross track direction and track width direction are the same. In the implementation shown, the distance d**1** and d**2** between the sensors **112** and **114** and between the sensors **114** and **116**, respectively, are the same. However, in other implementations, the distances between the sensors **112**, **114** and **116** may not be the same. It may generally be desirable to reduce the distance between the sensors **112**, **114** and **116** to reduce the skew effect discussed above. In some implementations, the distances d**1** and d**2** may each be at least ten nanometers and not more than four hundred nanometers. The read sensors **112**, **114** and **116** may have various widths, w**1**, w**2**, and w**3**, respectively, in the track width, or cross-track, direction. In some embodiments, the various widths, w**1**, w**2**, and w**3** the widths may be substantially equal. However, in other implementations, different widths may be possible. The widths of the sensors **112**, **114** and **116** may also be based on the track pitch. The track pitch is the distance from the center of one track to the center of the next track. Further, the widths may depend not only on the track pitch, but also on the distance between the sensors **112**, **114** and **116**.

[0015] The read sensors **112**, **114** and **116** may also be displaced along the cross track direction. Therefore, the centers of each of the read sensors **112**, **114** and **116** are not aligned along a vertical line that runs the down track direction. In the implementation shown, none of the read sensors **112**, **114** and **116** are aligned along a vertical line that runs in the down track direction. In other implementations, some or all of the read sensors **112**, **114** and **116** may be aligned. The read sensors **112**, **114** and **116** may also partially overlap in the track width/cross track direction. However, in other implementations, the read sensors **112**, **114** and **116** may be aligned.

[0016] Also shown are bias structures **122**, **123** and **124** that magnetically bias the read sensors **112**, **114** and **116**, respectively. The magnetic bias structure(s) **122**, **123**, and/or **124** may be soft bias structures fabricated with soft magnetic material(s). In other implementations, the magnetic bias structure(s) **122**, **123**, and/or **124** may be hard magnetic bias structures. Other mechanisms for biasing the sensors **112**, **114** and **116** might also be used.

[0017] The read sensors are separated by shields **130** and **140**. The read sensors **112**, **114** and **116** and mid-shields **130** and **140** are surrounded by read shields **120** and **150**. Thus, as used herein, a mid-shield shield may be considered to be an internal shield, which is interleaved with read sensors **112**, **114** and **116** and between the outer, read shields **120**, **150**. The outermost shields **120**, **150** for the read transducer **110** are termed read shields. In the implementation shown in FIGS. **2** and **3**, three read sensors **112**, **114** and **116** and two internal shields **130** and **140** are shown. However, in another implementation, another number of read sensors **112**, **114** and **116** and internal shields **130** and **140** may be present. The shields/read shields **120**, **130**, **140** and **150** generally include soft magnetic material. In some implementations, one or more of the shields **120**, **130**, **140** and **150** may include ferromagnetic layers that are anti-ferromagnetically coupled.

[0018] Current is driven perpendicular-to-plane for the sensors **112**, **114** and **116**. Thus, current is driven through the sensor **112** between the shields **120** and **130**. Similarly, current is driven through the sensor **114** between the shields **130** and **140**. Current is also driven through the sensor **116** between the shields **140** and **150**. Thus, electrical connection is to be made to the shields **120**, **130**, **140** and **150**. However, different currents may be desired to be driven through the sensors **112**, **114** and **116**. Similarly, the resistances of the sensors **112**, **114** and **116** may be desired to be separately sensed. For example, the sensors **112**, **114** and **116** may each be desired to be separately coupled to their own preamplifier (preamp). As a result, the sensors **112**, **114** and **116** are desired to be electrically isolated from each other. Consequently, the shields **130** and **140** are configured to not only magnetically shield the sensors **112**, **114** and **116**, but also to provide electrical isolation. As a result, each middle shield **130** and **140** may include multiple conductive magnetic layers separated by one or more insulating layers. Thus, the shield **130** may include conductive magnetic middle shield layers **134** and **136** that are separated by an insulating layer **152**. In some embodiments, the insulating layer **152** may be considered a magnetic-spacer layer **152**. Similarly, the shield **140** includes conductive magnetic middle shield layers **144** and **146** separated by a magnetic shield layer **162**. However, example implementations are not limited to this configuration, and may include configurations without an insulating layer **152**, **162** formed between the conductive magnetic middle shield layers **134/144**, **136/146**. Further, in some embodiments, the conductive magnetic layers **134/144/136/146** may be formed from a conductive metal and may be referred to as metallic middle shield layers.

[0019] The insulating layer(s) **152** and/or **162** may also be configured to improve the performance of the shields **130** and/or **140**, respectively. For example, a low dielectric constant material may be used for the insulating layers **152** and/or **162**. A low dielectric constant material is one which has a dielectric constant less than eight. For example, SiO and/or SiOC might be used for the insulating layer(s) **152** and/or **162**. As a result, capacitive coupling between the metallic middle shield layers **134** and **136** and/or the metallic middle shield layers **144** and **146** may be reduced. The thickness of the insulating layer(s) **152** and/or **162** may be varied. More specifically, the thickness of the insulating layer(s) **152** and/or **162** may be increased distal from the sensors **112**, **114**, and **116**. In some implementations, the insulating layer **152** and **162** may be on the order of ten nanometers within five microns of the sensors **112**, **114** and **116**. Further from the sensors **112**, **114** and **116**, the thickness may be increased, for example to twenty nanometers. In addition, the material(s) may be changed further from the sensors **112**, **114** and **116**. For example, the insulating layer **152** may include a ten nanometer thick alumina sub-layer having a dielectric constant of approximately six. At least five microns from the sensors an additional sub-layer of silicon dioxide having a thickness of approximately ten nanometers with a dielectric constant of approximately three may be added. Thus, the insulating layer(s) **152** and/or **162** may have varying thicknesses and/or materials.

[0020] Additionally, in each shield **130** and **140**, an electrical contact layer is formed between each sensor **112**,**114**, **116** and respective middle shield layers **134**,**136**,**144**,**146**. For example, electrical contact layer **132** is formed between sensor **112** and middle shield layer **134**. Similarly, electrical contact layer **138** is formed between sensor **114** and middle shield layer **136**. Additionally, electrical contact layer **142** is formed between sensor **114** and middle shield layer **144**. Further, electrical contact layer **148** is formed between sensor **116** and middle shield layer **148**. In the illustrated embodiments, the electrical contact layers **132**, **138**, **142**, **148** are illustrated as separate layers. However, the electrical contact layers **132**, **138**, **142**, **148** are not limited to this configuration, and may be formed as a portion of the respective adjacent middle shield layers **134**, **136**, **144**, **146**.

[0021] In some implementations, the electrical contact layer is formed form the same materials as the neighboring sensors **112**,**114**,**116** and may be formed during the formation of neighboring sensor as discussed in greater detailed below. For example, electrical contact layer **132** may be formed during formation of the sensor **112**. Further, electrical contact layers **138** and **142** may be formed during formation of the sensor **114**. Additionally, electrical contact layer **148** may be formed during formation of the sensor **116**.

[0022] The read transducer **110** may be used in higher density recording, such as TDMR. Through the placement of the sensors **112**, **114** and **116**, the transducer **110** may address skew issues that might otherwise adversely affect performance of the transducer **110**. Consequently, the impedance and response of the transducer **110** may be sufficient for higher frequency performance. Cross talk may thus be reduced. In addition, the effect on the magnetics and other aspects of the transducer **110** because of the reduced overlap may be mitigated by the configuration of the shields **130** and **140**. Performance of the magnetic transducer **110** may thus be improved.

[0023] FIG. **4** is a plan view of the exemplary implementation of the microstructure **190** of the present application. The microstructure **190** includes the read transducer **110** and an interconnection region **200** that may be removed during manufacturing of the read transducer **110**. Specifically, once all of the layers of the read transducer **110** have been formed, the interconnection region **200** may be removed along plane **180** via known manufacturing methods to form the Air Bearing Surface (ABS) of the read transducer. Of course, embodiments of the present application need not have the interconnection region **200** be removed during processing and manufacturing of the read transducer **110**.

[0024] As illustrated, each of the electrical contact layers **132**/**142**/**138**/**148** extend from the read transducer **110** into the interconnection region **200**. Further, a shunt region **172**/**174**/**177**/**179** may be formed on the portions of the electrical contact layers **132**/**142**/**138**/**148** that extend into the interconnection region **200**.

[0025] As illustrated, the upper most electrical contact layer **148** extends furthest into the interconnection region **200** and has the shunt region **177** formed thereon. Additionally, the electrical contact layer **142** extends into the interconnection region **200** less than electrical contact layer **132** and has the shunt region **179** formed thereon. Further, the electrical contact layer **138** extends over the shunt region **179** and has shunt region **174** formed thereon. Further, the lower most electrical contact layer **132** extends least furthest into the interconnection region **200** and has the shunt region **172** formed thereon. The lower most electrical contact layer **132** is the electrical contact layer closest to the lower outer shield **120**. As discussed in the above embodiments, the electrical contact layers **132**, **138**, **142**, **148** are illustrated as separate layers. However, the electrical contact layers **132**, **138**, **142**, **148** are not limited to this configuration, and may be formed as a portion of the respective adjacent middle shield layers **134**, **136**, **144**, **146**.

[0026] Further, an electrical connection **170** is formed between the shunt region **172** and the shunt region **174**. Additionally, and electrical connection **175** is formed between the shunt region **177** and the shunt region **177**. In some embodiments, the electrical connections **170** and **175** may be formed as an electrically conductive layer, which provides minimal resistance and shorts together the respective shunt regions. In other embodiments, the electrical connections **170** and **175** may be formed from an electrically resistive layer that provides a specific level of resistance. For example, each electrical connection **170**, **175** may be formed from the same materials as the read sensors and may provide a defined resistance value. For example, each electrical connection **170**/**175** may have provided an electrical resistance substantially equal to 10 kw plus or minus normal manufacturing tolerances.

[0027] By providing shunt regions **172**/**174**/**177**/**179** with electrical connections **170**/**175** therebetween, Electrical Overstress (EOS) or Electrostatic Discharge (ESD) during manufacturing may be reduced. Further, by provided a defined resistance between the shunt regions **172**/**174**/**177**/**179**, the electrical properties of read transducer **110** may be measured during manufacturing prior to completion.

[0028] Additionally, in some embodiments an electrical connection (not shown) may be provided between the outer read shields **120** and **150** in the interconnection region **200** to electrically short together the outer read shields **120** and **150**. Such an electrical connection or short between the outer read shields **120** and **150** may provide additional protection against EOS and ESD.

[0029] FIGS. **5**A and **5**B illustrate an exemplary implementation of a method **500** for manufacturing the read transducer. For simplicity, some steps may be omitted, interleaved, and/or combined. The method **500** is also described in the context of providing a single recording transducer having two read sensors. However, the method **500** may be used to form a portion or a complete two-dimensional transducer, such as TDMR transducers **110** illustrated in FIGS. **2**-**3** and/or the microstructure **190** of FIG. **4**. Further, the method **500** may also be used to fabricate multiple transducers at substantially the same time. The method **500** may also be used to fabricate other transducers, as may be apparent to a person of ordinary skill in the art. The method **500** is also described in the context of particular layers. A particular layer may include multiple materials and/or multiple sub-layers. The method **500** also may start after formation of other portions of the magnetic recording transducer.

[0030] In **505**, a first outer shield layer **120** is formed. The first outer shield layer **120** may generally be formed from a soft-magnetic material including, but not limited to, Iron alloys, Nickel alloys, or any other soft-magnetic metal that may be apparent to a person of ordinary skill in the art. Further, the application process of the first outer shield layer **120** is not particularly limited and may include any process that may be apparent to a person of ordinary skill in the art including sputtering or any other known process.

[0031] Further, in **510**, a first read sensor **112** is formed on the first outer shield layer **120**. As discussed above, each read sensor **112**, **114**, and **116** may include a pinning layer, a pinned layer, a nonmagnetic spacer layer, and a free layer

113, **115**, and **117**, respectively. The pinning layer is generally an AFM layer that is magnetically coupled to the pinned layer. In other implementations, however, the pinning layer may be omitted or may use a different pinning mechanism. The free layers **113**, **115** and **117** are each shown as a single layer, but may include multiple layers including but not limited to a synthetic antiferromagnetic (SAF) structure. The pinned layer may also be a simple layer or a multilayer. Although shown as extending the same distance from the ABS, the pinned layer may extend further than the corresponding free layer **113**, **115**, and/or **117**, respectively. Further, the formation process of the first read sensor **112** is not particularly limited and may include any process that may be apparent to a person of ordinary skill in the art including sputtering or any other known process.

[0032] After the first read sensor **112** is formed, a first electrical contact layer **132** may be formed over the first read sensor **112** in **515**. The first electrical contact layer **132** may generally be formed from a soft-magnetic material including, but not limited to, Iron alloys, Nickel alloys, or any other soft-magnetic metal that may be apparent to a person of ordinary skill in the art. Further, the application process of the first electrical contact layer **132** is not particularly limited and may include any process that may be apparent to a person of ordinary skill in the art including sputtering or any other known process.

[0033] The first electrical contact layer **132** is formed to extend into the interconnection region **200** illustrated in FIG. **4**. Further during the formation of the first electrical contact layer **132**, the shunt region **172** is also formed using the same materials as the electrical contact layer. In some embodiments, the formation of the first electrical contact layer **132** may formed during the formation of the read sensor **112** and in some embodiments the formation of the first electrical contact layer **132** may be a separate, discrete process from the sensor **112** formation.

[0034] In **520**, a first metallic middle-shield layer **134** is formed over the first electrical contact layer **132**. The first metallic middle-shield layer **134** may generally be formed from a soft-magnetic material including, but not limited to, Iron alloys, Nickel alloys, or any other soft-magnetic metal that may be apparent to a person of ordinary skill in the art. Further, the application process of the first metallic middle-shield layer **134** is not particularly limited and may include any process that may be apparent to a person of ordinary skill in the art including sputtering or any other known process.

[0035] As discussed above, the first electrical contact layer **132** is illustrated as a separate layer. However, the first electrical contact layers **132** is not limited to this configuration, and may be formed as a portion of the adjacent first metallic middle-shield layer **134**.

[0036] In **525**, a second metallic middle-shield layer **136** is formed above the first metallic middle-shield layer **134**. In some implementations, the insulation layer **152** may be formed between the first and second metallic middle-shield layers **134**, **136**. The second metallic middle-shield layer **136** may generally be formed from a soft-magnetic material including, but not limited to, Iron alloys, Nickel alloys, or any other soft-magnetic metal that may be apparent to a person of ordinary skill in the art. Further, the application process of the second metallic middle-shield layer **136** is not particularly limited and may include any process that may be apparent to a person of ordinary skill in the art including sputtering or any other known process.

[0037] In **530**, a second electrical contact layer **138** may be formed over the second middle-shield layer **136**. The second electrical contact layer **138** may generally be formed from a soft-magnetic material including, but not limited to, Iron alloys, Nickel alloys, or any other soft-magnetic metal that may be apparent to a person of ordinary skill in the art. Further, the application process of the second electrical contact layer **138** is not particularly limited and may include any process that may be apparent to a person of ordinary skill in the art including sputtering or any other known process.

[0038] The second electrical contact layer **138** is formed to extend into the interconnection region **200** illustrated in FIG. **4**. Further during the formation of the second electrical contact layer **138**, the shunt region **174** is also formed using the same materials as the electrical contact layer. Additionally the electrical connection **175** may also be formed during the formation of the second electrical contact layer **138**.

[0039] As discussed above, the second electrical contact layer **138** is illustrated as a separate layer. However, the second electrical contact layers **138** is not limited to this configuration, and may be formed as a portion of the adjacent second metallic middle-shield layer **136**.

[0040] Further, in **535**, a second read sensor **114** is formed above the second middle-shield shield layer **136**. In some embodiments, the second electrical contact layer **138** may formed during the formation of the second read sensor **114** in **535** and in some embodiments the formation of the second electrical contact layer **138** may be a separate, discrete process from the sensor **114** formation.

[0041] As discussed above, each read sensor **112**, **114**, and **116** may include a pinning layer, a pinned layer, a nonmagnetic spacer layer, and a free layer **113**, **115**, and **117**, respectively. The pinning layer is generally an AFM layer that is magnetically coupled to the pinned layer. In other implementations, however, the pinning layer may be omitted or may use a different pinning mechanism. The free layers **113**, **115** and **117** are each shown as a single layer, but may include multiple layers including but not limited to a synthetic antiferromagnetic (SAF) structure. The pinned layer may also be a simple layer or a multilayer. Although shown as extending the same distance from the ABS, the pinned layer may extend further than the corresponding free layer **113**, **115**, and/or **117**, respectively. Further, the formation process of the second read sensor **114** is not particularly limited and may include any process that may be apparent to a person of ordinary skill in the art including sputtering or any other known process.

[0042] After the second read sensor **114** is formed, a third electrical contact layer **142** may be formed over the second read sensor **114** in **540**. The third electrical contact layer **142** may generally be formed from a soft-magnetic material including, but not limited to, Iron alloys, Nickel alloys, or any other soft-magnetic metal that may be apparent to a person of ordinary skill in the art. Further, the application process of the third electrical contact layer **142** is not particularly limited and may include any process that may be apparent to a person of ordinary skill in the art including sputtering or any other known process.

[0043] The third electrical contact layer **142** is formed to extend into the interconnection region **200** illustrated in FIG. **4**. Further during the formation of the third electrical contact layer **142**, the shunt region **179** is also formed using the same materials as the electrical contact layer. In some embodiments, the formation of the third electrical contact layer **142** may formed during the formation of the read sensor **114** and in some embodiments the formation of the third electrical contact layer **142** may be a separate, discrete process from the sensor **114** formation.

[0044] In **545**, a third metallic middle-shield layer **144** is formed over the third electrical contact layer **142**. The third metallic middle-shield layer **144** may generally be formed from a soft-magnetic material including, but not limited to, Iron alloys, Nickel alloys, or any other soft-magnetic metal that may be apparent to a person of ordinary skill in the art. Further, the application process of the third metallic middle-shield layer **144** is not particularly limited and may include any process that may be apparent to a person of ordinary skill in the art including sputtering or any other known process.

[0045] As discussed above, the third electrical contact layer **142** is illustrated as a separate layer. However, the third electrical contact layers **142** is not limited to this configuration, and may be formed as a portion of the adjacent third metallic middle-shield layer **144**.

[0046] In **550**, a fourth metallic middle-shield layer **146** is formed above the third metallic middle-shield layer **144**. In some implementations, the insulation layer **162** may be formed between the third and fourth metallic middle-shield layers **144**, **146**. The fourth metallic middle-shield layer **146** may generally be formed from a soft-magnetic material including, but not limited to, Iron alloys, Nickel alloys, or any other soft-magnetic metal that may be apparent to a person of ordinary skill in the art. Further, the application process of the fourth metallic middle-shield layer **146** is not particularly limited and may include any process that may be apparent to a person of ordinary skill in the art including sputtering or any other known process.

[0047] In **555**, a fourth electrical contact layer **148** may be formed over the fourth middle-shield layer **146**. The fourth electrical contact layer **148** may generally be formed from a soft-magnetic material including, but not limited to, Iron alloys, Nickel alloys, or any other soft-magnetic metal that may be apparent to a person of ordinary skill in the art. Further, the application process of the fourth electrical contact layer **148** is not particularly limited and may include any process that may be apparent to a person of ordinary skill in the art including sputtering or any other known process.

[0048] The fourth electrical contact layer **148** is formed to extend into the interconnection region **200** illustrated in FIG. **4**. Further during the formation of the fourth electrical contact layer **148**, the shunt region **177** is also formed using the same materials as the electrical contact layer. Additionally the electrical connection **170** may also be formed during the formation of the second electrical contact layer **148**.

[0049] As discussed above, the fourth electrical contact layer **148** is illustrated as a separate layer. However, the fourth electrical contact layers **148** is not limited to this configuration, and may be formed as a portion of the adjacent fourth metallic middle-shield layer **146**.

[0050] Further, in **560**, a third read sensor **116** is formed above the fourth middle-shield shield layer **146**. In some embodiments, the fourth electrical contact layer **148** may formed during the formation of the third read sensor **114** in **560** and in some embodiments the formation of the fourth electrical contact layer **148** may be a separate, discrete process from the sensor **116** formation.

[0051] As discussed above, each read sensor **112**, **114**, and **116** may include a pinning layer, a pinned layer, a nonmagnetic spacer layer, and a free layer **113**, **115**, and **117**, respectively. The pinning layer is generally an AFM layer that is magnetically coupled to the pinned layer. In other implementations, however, the pinning layer may be omitted or may use a different pinning mechanism. The free layers **113**, **115** and **117** are each shown as a single layer, but may include multiple layers including but not limited to a synthetic antiferromagnetic (SAF) structure. The pinned layer may also be a simple layer or a multilayer. Although shown as extending the same distance from the ABS, the pinned layer may extend further than the corresponding free layer **113**, **115**, and/or **117**, respectively. Further, the formation process of the third read sensor **116** is not particularly limited and may include any process that may be apparent to a person of ordinary skill in the art including sputtering or any other known process.

[0052] In **565**, a second outer shield layer **150** is formed over the third read sensor **116**. The second outer shield layer **150** may generally be formed from a soft-magnetic material including, but not limited to, Iron alloys, Nickel alloys, or any other soft-magnetic metal that may be apparent to a person of ordinary skill in the art. Further, the application process of the second outer shield layer **150** is not particularly limited and may include any process that may be apparent to a person of ordinary skill in the art including sputtering or any other known process. Once the second outer shield layer **150** is formed in **565** the process **500** may end in some implementations. However, in some implementations, the interconnection region **200** may be removed along plane **180** to form the ABS. The removal of the interconnection region **200** may be done through any process that may be apparent to a person of ordinary skill in the art (such as dicing, etching, etc.).

[0053] The foregoing detailed description has set forth various implementations of the devices and/or processes via the use of block diagrams, schematics, and examples. Insofar as such block diagrams, schematics, and examples contain one or more functions and/or operations, each function and/or operation within such block diagrams, flowcharts, or examples can be implemented, individually and/or collectively, by a wide range of hardware, software, firmware, or virtually any combination thereof.

[0054] While certain implementations have been described, these implementations have been presented by way of example only, and are not intended to limit the scope of the protection. Indeed, the novel methods and apparatuses described herein may be embodied in a variety of other forms. Furthermore, various omissions, substitutions, and changes in the form of the methods and systems described herein may be made without departing from the spirit of the protection. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the protection.

What is claimed is:

1. A method of making a magnetic head, the method comprising:

forming a first read sensor and a first electrical contact formed with a first shunt region;

forming a first mid-shield layer on the first read sensor, the first mid-shield layer being electrically connected to the first electrical contact;

forming a second mid-shield layer over the first mid-shield layer; and

forming a second read sensor over the second mid-shield layer, the second read sensor having a second electrical contact formed with a second shunt region electrically connected to the first shunt region.

2. The method of claim **1**, wherein the forming the first read sensor comprises:

forming a read sensor area of the read sensor; and

forming the first electrical contact after the first read sensor has been formed.

3. The method of claim **1**, wherein forming the second electrical contact electrically connected to the second mid-shield layer comprises forming an electrically resistive layer between the first shunt region and the second shunt region.

4. The method of claim **3**, wherein the electrically resistive layer is formed to have an electrical resistance substantially equal to 10 kw.

5. The method of claim **1**, wherein the forming the first read sensor comprises:

forming a first outer shield layer; and

forming the first read sensor over the first outer shield layer; and

wherein the method further comprises:

forming a second outer shield layer over the second read sensor.

6. The method of claim **1**, wherein the forming the first electrical contact comprises forming the first shunt region in a region of the magnetic head to be removed during formation of an air bearing surface;

wherein the forming the second electrical contact comprises forming the second shunt region in the region of the magnetic head to be removed during formation of the air bearing surface; and

further comprising forming the air bearing surface by removing the first shunt region, and the second shunt region.

7. The method of claim **1**, wherein forming the second read sensor further comprises for forming a third electrical contact formed with a third shunt region, and

wherein the method further comprising:

forming a third mid-shield layer on the second read sensor, the third mid-shield layer being electrically connected to the third electrical contact;

forming a fourth mid-shield layer over the third mid-shield layer; and

forming a third read sensor over the fourth mid-shield layer, the third read sensor having a fourth electrical contact formed with a fourth shunt region electrically connected to the third shunt region.

8. The method of claim **7**, wherein forming the second electrical contact electrically connected to the second mid-shield layer comprises forming a first electrically resistive layer between the first shunt region and the second shunt region; and

wherein forming the fourth electrical contact electrically connected to the fourth mid-shield layer comprises forming a second electrically resistive layer between the third shunt region and the fourth shunt region.

9. The method of claim **7**, wherein the forming the first read sensor comprises:

forming a first outer shield layer; and

forming the first read sensor over the first outer shield layer; and

wherein the method further comprises:

forming a second outer shield layer over the third read sensor.

10. The method of claim **7**, wherein the forming the first electrical contact comprises forming the first shunt region in a region of the magnetic head to be removed during formation of an air bearing surface;

wherein the forming the second electrical contact comprises forming the second shunt region in the region of the magnetic head to be removed during formation of the air bearing surface;

wherein the forming the third electrical contact comprises forming the third shunt region in a region of the magnetic head to be removed during formation of the air bearing surface;

wherein the forming the fourth electrical contact comprises forming the fourth shunt region in the region of the magnetic head to be removed during formation of an air bearing surface; and

further comprising forming the air bearing surface by removing the first shunt region, the second shunt region, the third shunt region, and the fourth shunt region.

11. A method of assembling a storage drive comprising:

forming a magnetic head using the method of claim **1**;

mounting the magnetic head on a slider arm; and

mounting the slider arm proximate to a storage medium.

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