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Giant magnetoresistance based nanopositioner encoder

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Fries

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(54) **GIANT MAGNETORESISTANCE BASED NANOPOSITIONER ENCODER**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 46 days.

This patent is subject to a terminal disclaimer.

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(63) Continuation-in-part of application No. 09/715,339, filed on Nov. 17, 2000, now Pat. No. 6,633,233.

(51) **Int. Cl.**[7] **G01B 7/14**; G01B 7/30; G01R 33/06; H01L 43/08

(52) **U.S. Cl.** **324/207.24**; 324/207.21

(58) **Field of Search** 324/207.11, 207.2, 324/207.21, 207.24, 207.25, 174

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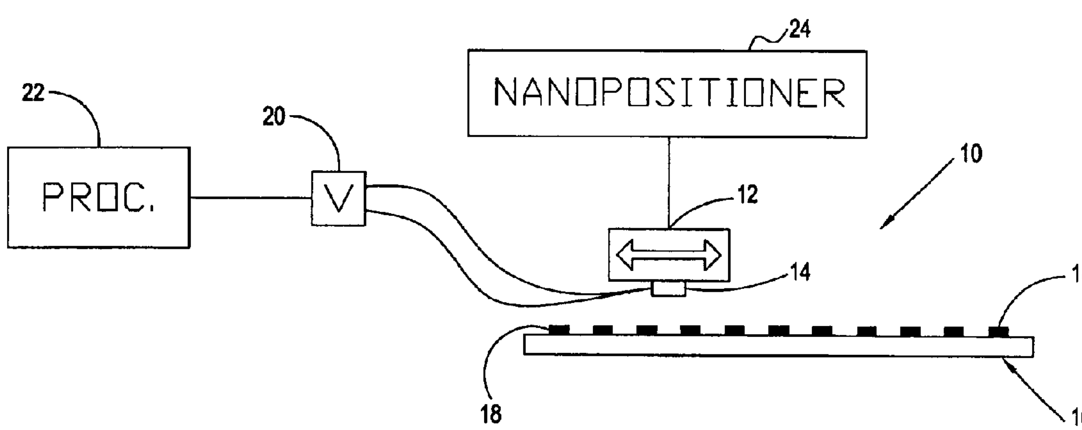
(57) **ABSTRACT**

An encoder (**10**) for a nanopostioner (**24**) includes a strip of magnetic bits (**18**) for producing discrete magnetic fields and a giant magnetoresistor (GMR) (**14**) which changes in electrical resistance in response to changes in the magnetic fields. The GMR (**14**) is connected to a mass (**12**) which moves along a path proximate to the strip of magnetic bits (**18**). A voltage sensor (**20**) is connected to the GMR (**14**) to produce digital signals based on the changes in electrical resistance of the GMR (**14**). A processor (**22**) calculates the position of the nanopositioner (**24**) based on the digital signals.

2 Claims, 1 Drawing Sheet



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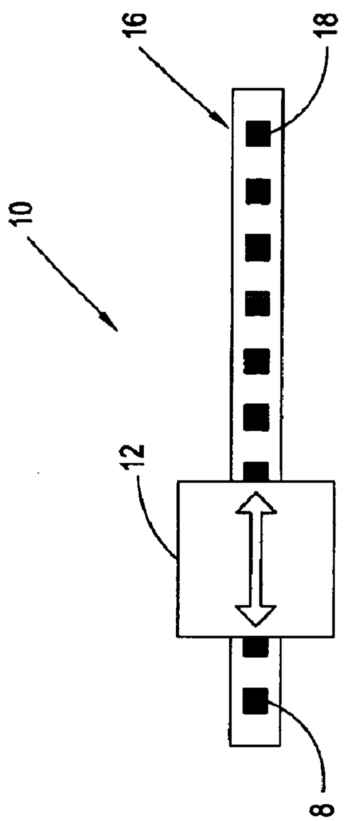

Fig. 1

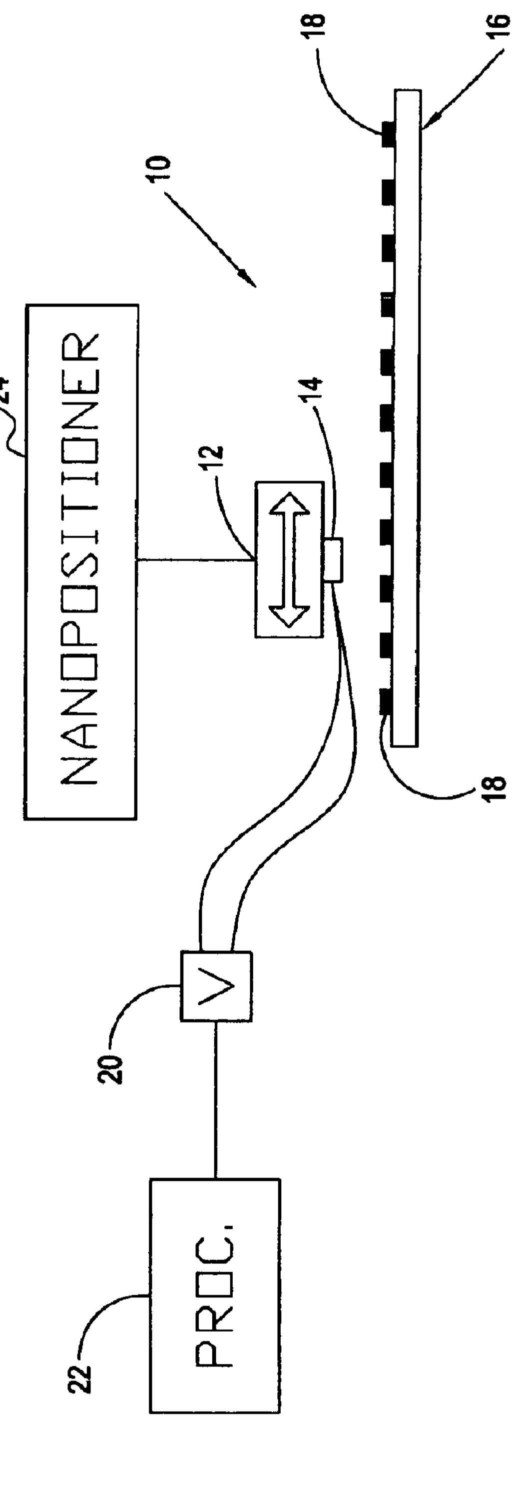

Fig. 2

GIANT MAGNETORESISTANCE BASED NANOPOSITIONER ENCODER

CROSS-REFERENCES TO RELATED APPLICATIONS

The subject patent application is a continuation-in-part of U.S. patent application Ser. No. 09/715,339, filed Nov. 17, 2000, now U.S. Pat. No. 6,633,233, issued Oct. 14, 2003.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The subject invention generally relates to an encoder for determining position. Specifically, the subject invention relates to an encoder for determining the position of a nanopositioner using giant magnetoresistor (GMR) technology.

2. Description of the Related Art

A number of devices and methods are currently used to determine position in nanopositioner systems. For example, a laser interferometer may be used to measure position. However, an output of a laser interferometer is not perfectly linear, leading to significant errors in the position measurement, on the order of 2 to 5 nanometers.

A two-plate capacitive sensor may also be used to measure position. This type of capacitive sensor uses two plates: a fixed plate and a movable plate. The movable plate is connected to an object being positioned. A capacitance is measured between the two plates to determine the position. When used over a small range, a capacitive sensor provides high linearity with resolutions of 0.1 nanometers. However, capacitive sensors are not best suited for nanopositioning applications over a long range, since the capacitance between the two plates approaches zero as the movable plate moves further and further away from the fixed plate.

BRIEF SUMMARY OF THE INVENTION AND ADVANTAGES

The invention provides an encoder that includes a magnetic element that produces a magnetic field and a mass to move along a path which passes through the magnetic field. A giant magnetoresistor (GMR) is operatively connected to the mass for changing in electrical resistance in response to changes in the magnetic field produced by the magnetic element. A voltage sensor is connected to the GMR for sensing the voltage across the GMR. The magnetic element includes a strip of magnetic bits to provide discrete magnetic fields regions disposed linearly relative to one another along the path. The mass and the magnetic bits are supported for movement relative to one another along the path to produce digital signals from the voltage sensor.

The encoder of the present invention is able to provide position measurements with high accuracy. The accuracy of the encoder is not limited by any range of positions to be measured.

BRIEF DESCRIPTION OF THE DRAWINGS

Other advantages of the present invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. **1** is a top view of a giant magnetoresistance based encoder according to the subject invention; and

FIG. **2** is a side view of the giant magnetoresistance based encoder, including a nanopositioner, a voltage sensor, and a processor.

DETAILED DESCRIPTION OF THE INVENTION

Referring to the Figures, wherein like numerals indicate like or corresponding parts throughout the several views, a giant magnetoresistance based encoder is shown at **10**.

The encoder **10** includes a mass **12** to move along a path. In a preferred embodiment, the mass **12** is operatively connected to a nanopositioner **24**. However, one should appreciate that the present encoder **10** may be implemented outside the nanopositioning realm.

The nanopositioners **24** is a device that controls motion at the nanometer level. The nanopositioner **24** is typically used in the fields of scanning microscopy, nano-imprinting, nano-manufacturing, etc. Piezoelectric actuators are commonly used to drive nanopositioning devices. Thus, the nanopositioner **24** may also be referred to as a piezoelectric postioner, a piezo actuator, or a piezonanopositioner.

The encoder **10** further includes a giant magnetoresistor (GMR) **14**. The GMR **14** is operatively connected to the mass **12**. Those skilled in the art appreciate that that the GMR **14** is also commonly referred to as a spin valve sensor. One typical configuration of the GMR **14** includes a layer of a non-metallic element, such as chromium or copper, sandwiched between layers of a magnetic element, such as iron or cobalt. This results in magnetization of the magnetic elements pointing in opposite directions. Due to this phenomenon, the GMR **14** exhibits a change in electrical resistance when exposed to a magnetic field. Those skilled in the art realize that other configurations of the GMR **14** can also be fashioned to achieve the change in electrical resistance during exposure to the magnetic field.

The encoder **10** also includes a magnetic element **16**. The magnetic element **16** is located proximate to the GMR **14** to produce the magnetic field. As described above, the GMR **14** changes in electrical resistance due to changes in the magnetic field produced by the magnetic element **16**. The magnetic element **16** includes a strip of magnetic bits **18**. The magnetic bits **18** provide discrete magnetic field regions disposed linearly relative to one another along the path.

The encoder **10** further includes a voltage sensor **20**. The voltage sensor **20** is operatively connected to the GMR **14** for sensing a voltage across the GMR **14**. The voltage sensor **20** applies a supply voltage to the GMR **14** and senses a return voltage from the GMR **14**. The return voltage will change as the electrical resistance of the GMR **14** changes.

The mass **12** and the magnetic bits **18** are supported for movement relative to one another along the path to produce digital signals from the voltage sensor **20**. The encoder **10** also includes a processor **22** operatively connected to the voltage sensor **20**. The processor **22** determines a position of the mass **12** based on the digital signals. The position of the mass **12** is correlated to a position of the operatively connected nanopositioner **24** for use in controlling the movement of the nanopositioner **24**.

Several procedures may be employed by the processor **22** to determine the position of the mass **12** or the nanopositioner **24** based on the digital signals. In a first procedure the processor **22** counts the number of digital signals received, which corresponds directly to the number of magnetic bits **18** passed by the GMR **14**. Assuming the processor **22** knows a direction of travel of the mass **12** and a distance between the magnetic bits **18**, then the position of the magnetic bits **18** can be easily calculated. In a second procedure, the magnetic bits **18** or groups of magnetic bits **18** have varying magnetic characteristics. The varying magnetic characteristics allows the processor **22** to determine the direction of travel of the mass **12** or the nanopositioner **24**. Calculating the position is then the same as in the first procedure. Other procedures for determining the position of the mass **12** or the nanopositioner **24** are evident to those skilled in the art.

Obviously, many modifications and variations of the present invention are possible in light of the above teachings. The invention may be practiced otherwise than as specifically described within the scope of the appended claims. In addition, the reference numerals in the claims are merely for convenience and are not to be read in any way as limiting.

What is claimed is:

1. An encoder **(10)** for determining position comprising:

a magnetic element **(16)** producing a magnetic field;

a mass **(12)** to move along a path and passing through said magnetic field;

a nanopositioner **(24)** operatively connected to said mass **(12)** for moving said mass **(12)**;

a giant magnetoresistor (GMR) **(14)** operatively connected to said mass **(12)** for changing in electrical resistance in response to changes in said magnetic field produced by said magnetic element **(16)**;

a voltage sensor **(20)** operatively connected to said GMR **(14)** for sensing a voltage across said GMR **(14)**;

said magnetic element **(16)** including a strip of magnetic bits **(18)** providing discrete magnetic field regions disposed linearly relative to one another along said path; and

said mass **(12)** and said magnetic bits **(18)** being supported for movement relative to one another along said path to produce digital signals from said voltage sensor **(20)**.

2. An encoder **(10)** as set forth in claim **1** further comprising a processor **(22)** operatively connected to said voltage sensor **(20)** for determining a position of said nanopositioner **(24)** based on said digital signals.

* * * * *