Abstract

It is shown that the presence or the absence of matter on a hard disk surface creates gravity-induction on the spinning hard disk that can be measured for as a mechanical force signal from piezoelectric Glide head and also as an induced electrical signal on a GMR head. This Provisional Patent Application is on the use of these mass spin valve type devices to produce an electric signal and/or associated mechanical force for general use for surface characterization work and power produced by the spinning disk. It is shown that the observed disk's gravity-induced mass spin-valve signal anti-Gforce (i.e., anti-gravity); here to uncharacterized, from pits is of opposite field direction to normal gravity and it is much weaker magnitude than the observed gravity-induced mass spin-valve signal Gforce from bumps.

Design	Defect	AFM	AFM Height	MR Modulation	MR Modulation	MR mass spin-valve Signal	MR mass spin-valve Signal	Expected normal Gravity Force
Width (μm)	Type	Width (μm)	or Depth (μin/ ηm)	Pulse Delay(μSec)	Delay x Velocity(μm)	Maximum Ampl(Vp) Anti-G_{Force} (ηNewtons)	Minimum Ampl(Vp) G_{Force} (−ηNewtons)	Bump Volume x 19.3g/cm^3 density of W (−ηNewtons)
40	Bump	40.9	1.27/32.3	3.23	41.021	NA	-2	-0.00010630
20	Bump	20.2	1.22/31	1.6	20.3	NA	-0.805	-0.00002489
10	Bump	10.9	1.27/32.3	0.858	10.8966	NA	-0.304	-0.00000755
6	Bump	6.56	1.22/31	0.518	6.5786	NA	-0.185	-0.00000262
4	Bump	4.76	1.24/31.5	0.38	4.826	NA	-0.14	-0.00000140
2	Bump	2.8	1.04/26.4	0.218	2.7686	NA	-0.065	-0.00000041
1	Bump	2.4	1.05/26.7	0.19	2.413	NA	-0.04	-0.00000030
40	Pit	42.2	1.7/43.2	3.31	42.037	0.378	NA	NA
20	Pit	20.4	1.99/50.5	1.59	20.193	0.287	NA	NA
10	Pit	10.3	2.02/51.3	0.814	10.3378	0.245	NA	NA
6	Pit	6.28	1.92/48.8	0.498	6.3246	0.163	NA	NA
4	Pit	4.25	1.59/40.4	0.34	4.318	0.141	NA	NA
2	Pit	2.4	1.65/41.9	0.208	2.6416	0.102	NA	NA
1	Pit	1.28	1.86/47.2	0.104	1.3208	0.055	NA	NA

Table 1

Field of Invention

On Earth's surface, a mass of 1 kg exerts a force of approximately 9.8 Newtons (N). 1 N is the force of Earth's gravity on a mass of about 102 g = (1⁄9.81 kg) of force [down] (or 1.0 kilogram-force; 1 kgf=9.80665 N by definition). It is shown that both bumps and pits on spinning disk produce a mechanical force that can be detected with a piezoelectric crystal mounted on a head slider. It is shown that an magneto-resistive (MR) element flying over a spinning disk coated with a magnetic media can be used to detect micro-fabricated pit and bump defects down to the 1μm x 1μm in area and to less than 1μ" height/depth or about 25.4 ηm. It is shown that part of the MR modulation read back signal corresponds to the switch in the magnetization polarity of the media produced by the edges of the bumps and pits. The product of the time change between the positive and negative magnetic transition modulation pulses times the linear velocity scales to within 200nm of the defects width along the circumference as measured with an atomic-force microscope (AFM). It is shown that MS signal is the central peak offset voltage whose offset voltage is dependent on the type of defect and its size. It is shown that the MR magnetic modulation signal induced by a micro-fabricated defect is dependent on the polarity of DC erase on the MR media but the MR mass spin-valve signal (MS signal) is independent of the polarity of DC erase. Independent of the magnetic media it is shown that an magneto-resistive (MR) element flying over a spinning disk that the MR element experiences increasing MR mass spin-valve signal (MS signal) with increasing defect width along a radius perpendicular to the direction of disk rotation. Pit defects exhibit a [up] going gravity-induced force which can be converted to an electric MS signal pulse due to increased MR element and disk spacing. It is shown that the bump defects exhibit a [down] going gravity-induced force which can be converted to an electric MS signal pulse representing a decrease in the MR element and disk spacing. For comparison purposes, the equivalent normal gravity force in units of –ηNewtons are provided based on the bumps volume as measured with the AFM times the density of Tungsten (W) 19.3 g/cm^3, as shown in Table 1.

Background of Related Art

High density recording requires that the hard disk surface be free of defects as small as 1μm x 1μm in areal size or less. Current methods for characterizing defects of this size are limited to a slow metrology technique such as Atomic Force Microscopy (AFM), and associated Magnetic Force Microscopy (MFM) and Magnetic Phase Microscope (MPM). An AFM micro-image from a 10μm x 10μm area pit (2 μ'' in depth) is shown in Figure 1. Faster defect detection techniques utilize a spin stand such as magnetic certification testers that detect missing pulses with high frequency write and read (i.e. Phase Metrics MG250). An atomic force microscope image from a 10μm x 10μm area pit is shown in Figure 1 a). A magnetic force microscope image of a written track from a typical hard disk is shown in Figure 1 b).[1] A MR read back signal from a magnetically erased disk and a certification missing pulse test reading for the same 10μm x 10μm area pit are also shown in Figure 1 c) and 1 d) respectively. In a previous study we explore the possibility of using the magnetically biased MR element in current recording heads to detect defects and characterize them by type and length along the track circumference direction without high frequency read/write. Previous work has focused on contact type thermal asperity detection and non-contact "thermal signals" from natural and man-made defects on the surface of a hard disk.

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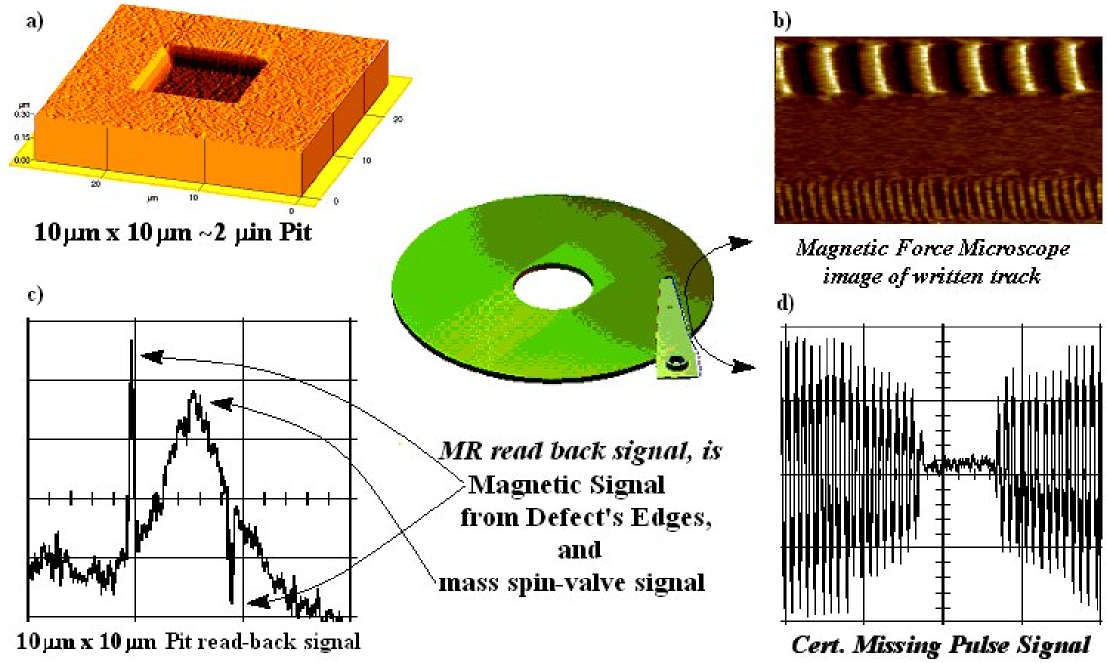
[1] http://www.calfree.com/MassSpinValveSummary/MassSpinValveSummaryFigure_1.pdf
Image in Figure 1 b) from http://www.esco.co.kr/pdf/ns/Magnetic_Force_Microscopy.pdf



10μm x 10μm ~2 μin Pit

Magnetic Force Microscope image of written track

MR read back signal, is
Magnetic Signal
from Defect's Edges,
and
mass spin-valve signal

10μm x 10μm Pit read-back signal

Cert. Missing Pulse Signal

Figure 1

For a typical SAL MR head, the change in modulation voltage is dependent on the bias field, the temperature field and the media magnetization.[2] [3]The dependence on media magnetization was examined by DC erasing the media in opposite directions. The dependence on bias field and the gravitomagnetic induction field was studied by applying various bias currents. The results reported were taken from micro-fabricated defects but these results have been validated using actual hard disk defects for comparison.

It should be noted that for some large defects we tested we saw the large mass spin valve signal dominates the MR modulation signal as in Figure 8. The flash temperature rise (or drop) nearby the MR sensor due to head disk contact leads to a thermally induced signal from the MR read element.[4] [5] This is called a "thermal asperity", and this effect is not applicable to this patent since it involves physical contact with the disk's surface. As the MR element flies near contact with the surface, the disk waviness induces a signal from the MR sensor.[6] When a bias current is applied to the MR element, its temperature will rise due to the Joule heating effect induced by the gravitomagnetic induction of gravitational fields produced by the presence or absence of matter within the distance between the MR read element and the disk's surface; which in this apparatus was within 40ηm of the disk's surface. The temperature rise ΔT can be calculated from a

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[2] H. N. Bertram, Theory of Magnetic Recording, 1994
[3] E. Sawatzky, *Data Storage.,* Vol. 5, No.3, p 49, 1998
[4] R.D. Hemstead, *IBM J. Res. & Dev.,* Vol. 18, p547, 1974
[5] E. Schreck, R.E. Fontana, and G.P. Singh, *IEEE Trans. Mag*., Vol. 28, p2548, 1992
[6] M.M. Dovek, *et al*., U.S. Patent 5,455,730 1995

measurement of resistance change of the MR element ΔR by the relationship; $\Delta T=\Delta R/(\alpha R_o)$, where the R_o and α are the initial resistance and the temperature coefficient of the MR element. In an SAL based MR head, as was used, there is a linear relationship between ΔT and ΔR (within a range of bias currents). The increase in the MR (non-contact pit MR mass spin-valve) signal corresponds to the increase in the spacing, while the big drop in the MR (non-contact bump MR mass spin-valve) signal corresponds to the decrease in spacing,[7] as was exhibited with the defects in this patent.

GMR is the acronym for giant magneto-resistive in hard disk drive storage technology. The term is usually referred to in reference to GMR heads. GMR heads are not named "giant" because of their size. The technology is named for the giant magneto-resistive effect, first discovered by two European researchers -- Peter Gruenberg and Albert Fert -- in the late 1980s. While working with large magnetic fields and thin layers of magnetic materials, Gruenberg and Fert noticed very large resistance changes when these materials were subjected to magnetic fields. Disk drives that are based on GMR head technology use these properties to help control a sensor that responds to very small rotations on the disk. The magnetic rotation yields a very large change in sensor resistance, which in turn provides a signal that can be picked up by the electric circuits in the drive.

When the head passes over a magnetic field of one polarity, the electrons on the free layer turn to align with those on the pinned layer, creating a lower resistance in the head structure. When the head passes over a field of opposite polarity, the free layer electrons rotate so that they are not aligned with the electrons on the pinned layer. This causes an increase in the structure's resistance. Because the resistance changes are caused by changes to the spin characteristics of electrons in the free layer, GMR heads are also known as spin valves, a term coined by IBM.

One of the most important fundamental circuit elements in spintronics is the spin valve. A spin valve is a device that allows the passage of one spin orientation, while blocking another. This allows one to create a spin-polarized “beam” of electrons from a typically unpolarized Fermi sea and allows for the readout of spin information through a measurement of electrical current. This device consists of a thin piece of material (which is metallic in the case of GMR), sandwiched between two conducting ferromagnetic materials. “Up” spins can enter a ferromagnet that is polarized “up” with high probability, whereas “down” spins have a significantly lower probability to enter an “up” polarized ferromagnet. When both of the ferromagnetic sandwich slices are polarized “up” there is significant electronic current through the device due to the flow of “up” spins. In contrast, if one of the ferromagnets flips its spin, current is inhibited for both spin orientations. The presence or absence of current through such a device determines the relative orientation of the two ferromagnets. Such a device is routinely used in hard-disk read heads, where the orientation of one of the ferromagnets is fixed and the other acts as a tiny magnetometer, sensing the 1’s and 0’s encoded in the magnetic domains of

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[7] H. Tian, *et al*, *IEEE Tans. Mag.,* Vol. 33, p3130, 1997

a hard drive. Figure 1b) is the image taken from a magnetic force microscope (MFM) from written track for a hard disk drive. The spin valve is a convincing demonstration of some of the advantages to using spin in electronic devices (without this device, hard drives would never have reached such small proportions).

In 1998, theoretical physicists Nima Arkani-Hamed, Savas Dimopoulos and Gia Dvali pointed out that gravity had never been measured below a distance of about a millimeter. Arkani-Hamed, Dimopoulos and Dvali whose model is known as ADD, short for their names — suggest that there could be extra dimensions as large as a millimeter in diameter. In particle physics, the ADD model, also known as the model with large extra dimensions, is an alternative scenario to explain the weakness of gravity relative to the other forces. This theory requires that the fields of the Standard Model are confined to a four-dimensional membrane, while gravity propagates in several additional spatial dimensions that are large compared to the Planck scale. [8] The model was proposed by Nima Arkani-Hamed, Savas Dimopoulos, and Gia Dvali in 1998. [9] [10]

In particle physics and physical cosmology, the Planck scale is an energy scale around 1.22×10^{19} GeV (which corresponds by the mass–energy equivalence to the Planck mass 2.17645×10^{-8} kg) at which quantum effects of gravity become strong. At this scale, the description of sub-atomic particle interactions in terms of quantum field theory breaks down (due to the non-renormalizability of gravity). At the Planck scale, the strength of gravity is expected to become comparable to the other forces, and it is theorized that all the fundamental forces are unified at that scale, but the exact mechanism of this unification remains unknown. Traditionally in theoretical physics the Planck scale is the highest energy scale and all dimensional parameters are measured in terms of the Planck scale. In models of large extra dimensions the fundamental scale is much lower than the Planck. This occurs because the power law of gravity changes. For example, when there are two extra dimensions of size d, the power law of gravity is $1/r^4$ for objects with $r \ll d$ and $1/r^2$ for objects with $r \gg d$. If we want the Planck scale to be equal to the next accelerator energy (1 TeV) we should take d approximately 1mm.

Gravity may spread into the extra dimensions while the other known forces and particles are confined to the three familiar spatial dimensions. So gravity could be just as strong as the other forces but only felt strongly at short distances. Scientists funded by the European Space Agency have measured the gravitational equivalent of a magnetic field

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[8] For a pedagogical introduction, see M. Shifman (2009). *"Large Extra Dimensions: Becoming acquainted with an alternative paradigm"*. Crossing the boundaries: Gauge dynamics at strong coupling. Singapore: World Scientific. http://arxiv.org/abs/0907.3074.

[9] N. Arkani-Hamed, S. Dimopoulos, G. Dvali (1998). *"The Hierarchy problem and new dimensions at a millimeter"*. *Physics Letters* B429: 263-272. doi:10.1016/S0370-2693(98)00466-3.

[10] N. Arkani-Hamed, S. Dimopoulos, G. Dvali (1999). *"Phenomenology, astrophysics and cosmology of theories with submillimeter dimensions and TeV scale quantum gravity"*. *Physical Review* D59: 086004. doi:10.1103/PhysRevD.59.086004.

for the first time in a laboratory.[11] Just as a moving electrical charge creates a magnetic field, so a moving mass generates a gravitomagnetic field. According to Einstein's Theory of General Relativity, the effect is virtually negligible. However, Martin Tajmar, ARC Seibersdorf Research GmbH, Austria; Clovis de Matos, ESA-HQ, Paris; and colleagues have measured the effect in a laboratory. Their experiment involves a ring of superconducting material rotating up to 6,500 times a minute.

What is needed is a device to harness an electric signal and/or associated mechanical force for general use for work, and power, produced by the spinning disk.

Summary

Fourteen defects were fabricated on a 2400 Oe 31.5mil 95mm MR disk[12] using a Focused Ion Beam (FIB).[13] Seven bumps of ~1.25µin height were deposited, and seven pits ~2µin deep were etched, on a disk 50 mils apart on a radius, as shown in Figure 2.[14] The specified areal dimensions were 40x40, 20x20, 10x10, 6x6, 4x4, 2x2 and 1x1μm^2 respectively. Following fabrication the disk was placed on the spindle of an MG250 and erased using a wide track MIG inductive head. The disk was then scanned using a 50% slider with a piezoelectric crystal mounted on the side of one of the sliders (i.e., a Piezo Glide or Glide head) and the disk was measured for mechanical force signal from the piezoelectric Glide head. The MG250 Read channel was then used with a 50% Slider MR head containing a magnetized MR element. The MR current was optimum at 16mA, and the linear velocity was maintained at 500 inches per second (ips) unless otherwise noted). Both the Glide head and the MR head was moved to the approximate location of the defect under analysis, and then stepped on a radius until a signal was detected on a Lecroy LC920 Oscilloscope. The signal was then optimized for maximum signal level. The maximum signal was then recorded and characterized for signal amplitude and timing characteristics.[15] [16] The maximum signal measured was recorded and characterized for both MR modulation and mass spin-valve signal amplitudes and timing

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[11] Martin Tajmar, Florin Plesescu1, Klaus Marhold1 & Clovis J. de Matos, *"Experimental Detection of the Gravitomagnetic London Moment Space Propulsion"*, ARC Seibersdorf research GmbH, A-2444 Seibersdorf, Austria, ESA-HQ, European Space Agency, 8-10 rue Mario Nikis, 75015 Paris, France. See http://esamultimedia.esa.int/docs/gsp/Experimental_Detection.pdf

[12] The surface of the hard disk contains a thin diamond like coating of 1ηm or less over the deposition of 10-20ηm thick layer of ferromagnetic perpendicular materials cobalt and platinum and Chromium (Cr) over a ~ 1µm thick nickel phosphorus (NiP) layer deposited on an aluminum substrate that has been polished to a roughness of less than 1Å.

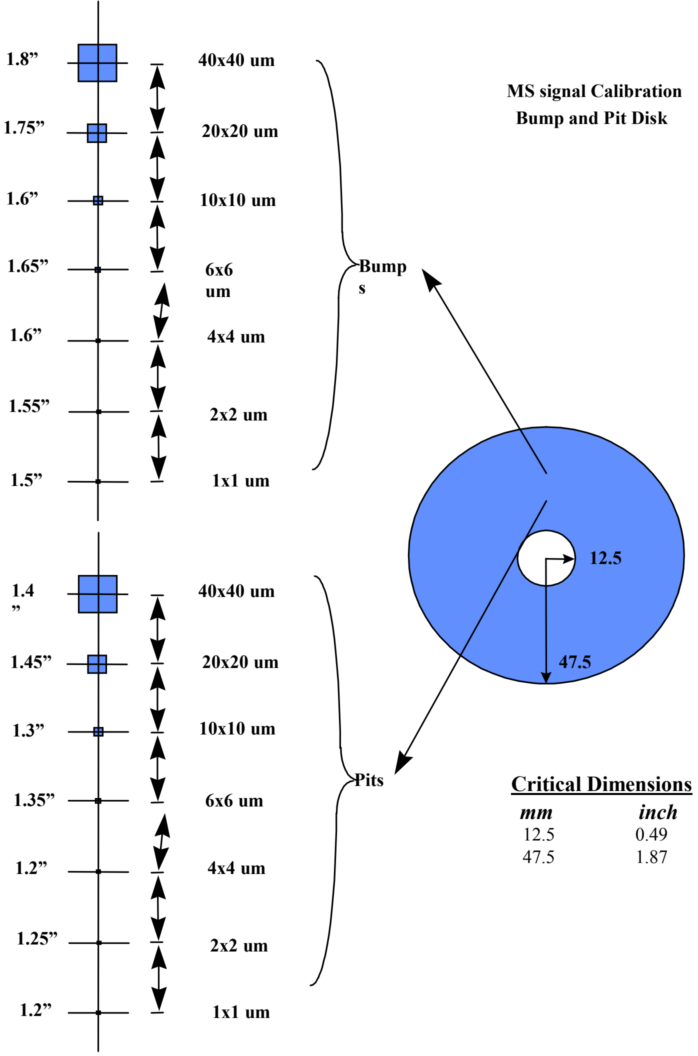
[13] A Focused ion beam, also known as FIB, is a technique used particularly in the semiconductor and materials science fields for site-specific analysis, deposition, and ablation of materials. A FIB setup is a scientific instrument that resembles a scanning electron microscope (SEM). However, while the SEM uses a focused beam of electrons to image the sample in the chamber, an FIB setup instead uses a focused beam of ions. FIB can also be incorporated in a system with both electron and ion beam columns, allowing the same feature to be investigated using either of the beams.

[14] http://www.calfree.com/MassSpinValveSummary/MassSpinValveSummaryFigure_2.pdf

[15] A magnetic field with density of 1 T generates one Newton of force per ampere of current per meter of conductor.

[16] R.D. Hemstead, *IBM J. Res. & Dev.,* Vol. 18, p547, 1974

characteristics. The disk was then removed and each individual defect was characterized utilizing a Park Scientific AFM for defect width along the direction of the circumference as reported in Table 1.



Critical Dimensions

mm	*inch*
12.5	0.49
47.5	1.87

Figure 2

Description of Drawings

Nine defects were fabricated on a 2400 Oe 31.5mil 95mm MR disk using a Focused Ion Beam (FIB). Figure 3 shows the AFM Micrograph and Figure 4[17] shows the MR magnetic modulation signal from a 6µm x 6µm Pit with ~ 7.2ηm Steps. Notice that the MS read back signal contains both the MR mass spin-valve signal (MS signal) base line modulation and the magnetic spikes produced as the MR head flies over the defect’s

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[17] http://www.calfree.com/MassSpinValveSummary/MassSpinValveSummaryFigure_3-4.pdf

edge, aka, the MR magnetic modulation signal. The small step around many of the defects was created as an artifact of the FIB fabrication process. This small step, on the order of 7ηm (or 1/4µin) induced an MR modulation signal but not the MS mass spin-valve signal. This demonstrates the MR modulation spikes' sensitivity to sub-micro-inch defects. The distance from the edge of the pit to the step was equivalent to the distance calculated utilizing the time delay between the corresponding signal spikes times the linear velocity. The results are listed in Table 1. The calculated width as a function of the measured AFM width for all pits and bumps shows a nearly perfect correlation between AFM measured width and the calculated one using the time delay between the MR modulation spikes times 500ips.

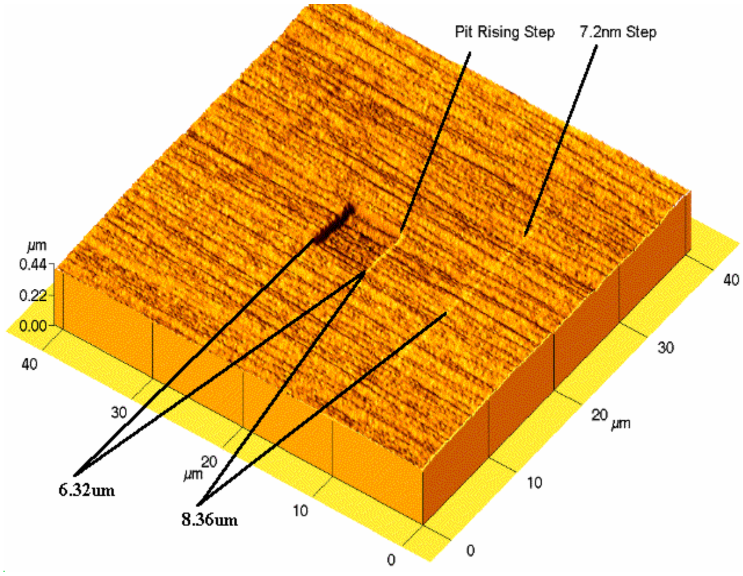
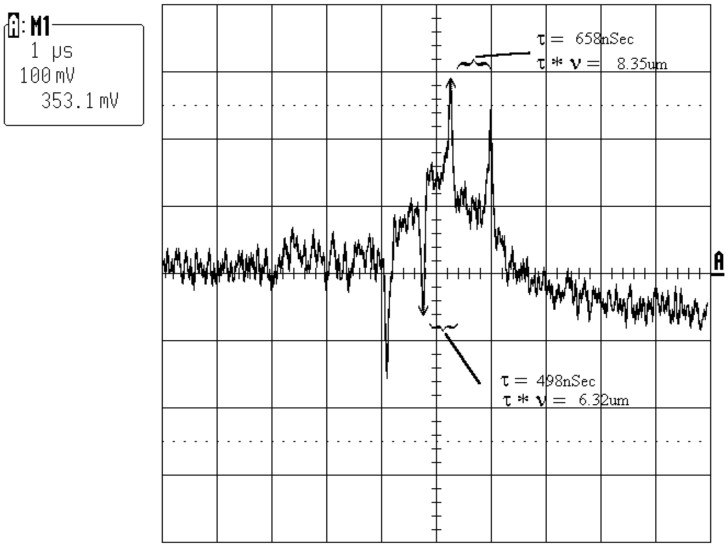


Figure 3



τ = 658nSec
τ * ν = 8.35um

τ = 498nSec
τ * ν = 6.32um

Figure 4

Figure 5, 6,[18] 7, and 8,[19] shows the AFM micro-graphs and the MR read signals respectively for a ~1µm x 1µm 1.8µin deep pit and a ~20µm x 20µm 1.22µin height bump respectively. This shows the signal amplitude, width and polarity depend on the size and the type of the defects. It was noted that the MS signal of bump defects exhibited a negative polarity pulse as shown in Figure 8, which decreased in amplitude with decreasing defect width along a radius. The MS signal of pit defects exhibited a positive polarity pulse as shown in Figure 1 c), which also decreased in amplitude with decreasing defect width along a radius.

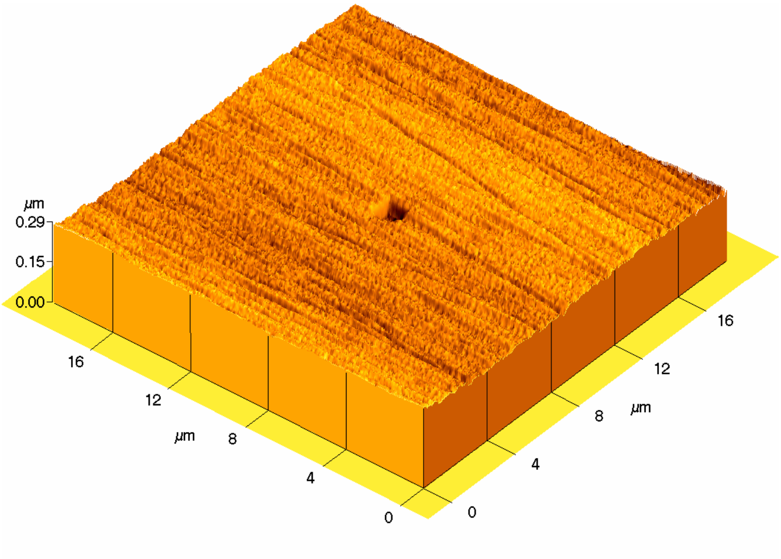


Figure 5

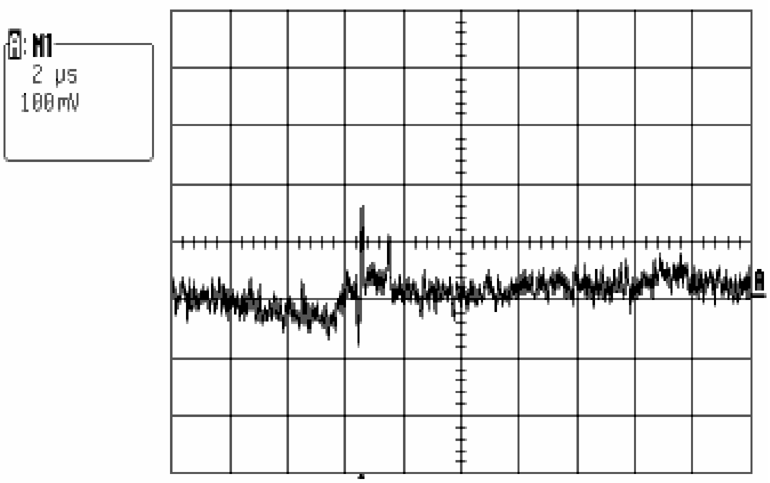


Figure 6

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[18] http://www.calfree.com/MassSpinValveSummary/MassSpinValveSummaryFigure_5-6.pdf
[19] http://www.calfree.com/MassSpinValveSummary/MassSpinValveSummaryFigure_7-8.pdf

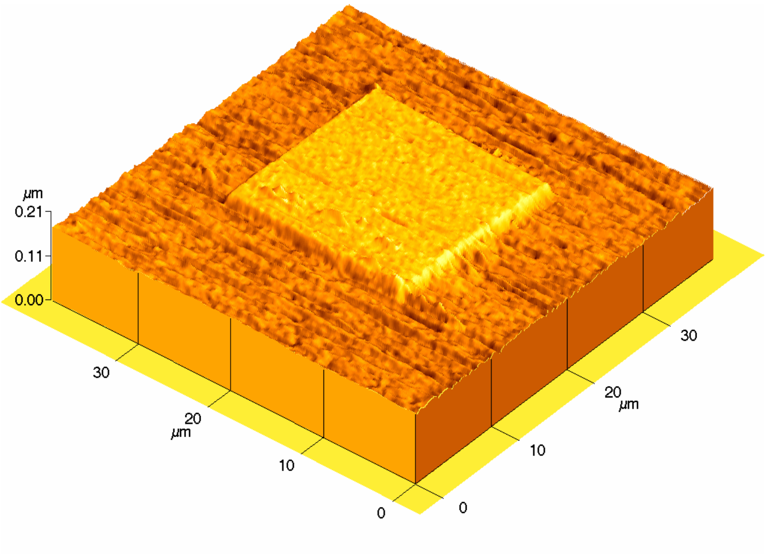

Figure 7

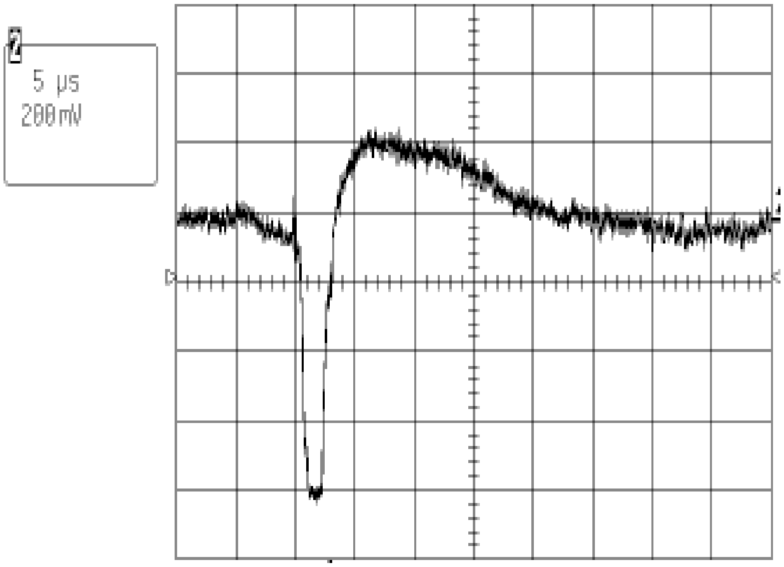

Figure 8

Figure 9[20] shows that for 1.25µin 10µm x 10µm bump measured with an AFM produces a characteristic PZT Glide signal and a characteristic MR magnetic modulation signal plus MS signal of a bump (labeled as non-contact MS-valve signal). Figure 10[21] shows that for ~2µin 10µm x 10µm pit measured with an AFM produce a PZT Glide signal and a characteristic MR magnetic modulation signal plus MS signal of a pit.

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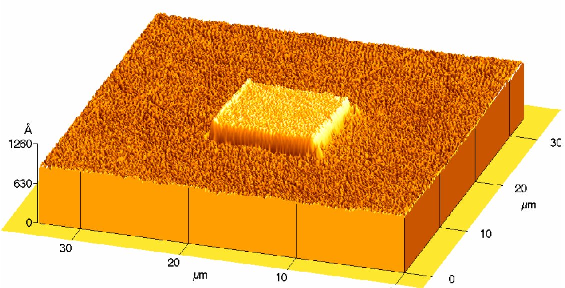
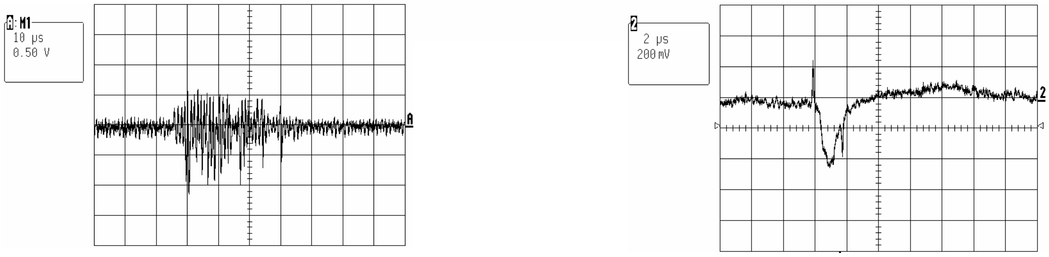
[20] http://www.calfree.com/MassSpinValveSummary/MassSpinValveSummaryFigure_9.pdf

[21] http://www.calfree.com/MassSpinValveSummary/MassSpinValveSummaryFigure_10.pdf

Signal Characteristics from Reference 10µm x 10µm ~1.25 µin Bump Defect



AFM Microgaph

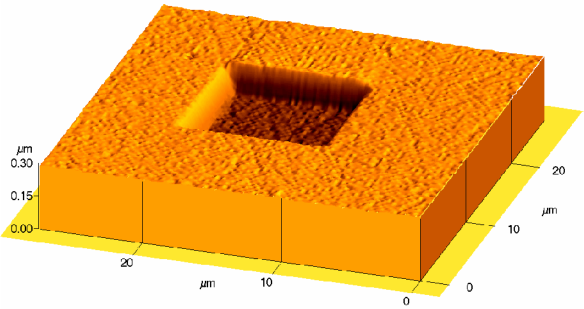


Non-contact PZT Glide

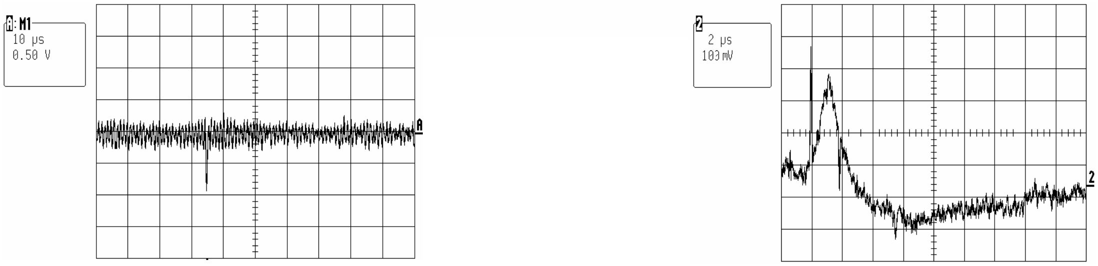
Non-contact MS-valve signal

Figure 9

Signal Characteristics from Reference 10µm x 10µm ~2 µin Pit Defect



AFM Micrograph



Non-contact PZT Glide

Non-contact MS-valve signal

Figure 10

Patent Pending
Provisional Patent Application 61/465,823
Filed March 25, 2011

While the invention has been described in connection with what are presently considered to be the most practical and preferred embodiments, it is to be understood that the invention is not limited to the disclosed embodiments, but rather as intended to cover various modifications and equivalent arrangements which are included within the spirit and scope of the following claims:

I claim:

1. An apparatus utilizing gravity-induction on the spinning disk that can be utilized to produce mechanical and electrical energy for work and power.

2. An apparatus utilizing the presence or the absence of matter on a spinning disk surface that can be utilized to characterize other similar disk surfaces for defects by type and size along the direction of rotation of the disk.

3. An apparatus utilizing the presence or the absence of matter on a spinning disk to produce anti-gravity.