

Description

This invention relates to a method and apparatus for testing operation of a memory device.

In a disk drive in use, a read/write transducer typically flies tenths of microns from the disk surface. Because the read/write transducer flies so close to the disk surface, it is desirable to be able to measure the smoothness of the disk surface to determine the ability of the read/write transducer to fly without touching the surface of the disk.

Identification of transducer to disk contacts or near contacts is crucial to overall disk drive reliability. Disk surface terrain is a result of manufacturing defects or contamination. The read/write transducer flies on a cushion of air (air bearing) over the disk surface. As the read/write transducer encounters a defect or dust particle on the disk surface, it will attempt to follow the air cushion and fly over the defect, subject to the mechanical response time of the transducer. If the mechanical response of the transducer is not fast enough, the read/write transducer will make contact with the imperfection on the disk surface. This results either in an immediate head crash or in gradual damage to the disk surface. The gradual damage occurs from particles spreading caused by slight impacts between the transducer and the contaminate or defect.

Another failure mode occurs when the read/write transducer contacts the disk surface immediately after flying over an imperfection on the disk surface which causes a disruption in the air cushion supporting the read/write transducer. After repeated transducer-to-disk contacts, a depression in the disk begins to form and eventually a head crash may occur.

To ensure a reliable disk drive, it is necessary to identify disks which have topographical defects on their surfaces. Reliability problems are caused from defects in surface topography and not from defects in magnetic material. Testing methods for reading and writing patterns to the magnetic material on the disk are of limited value because this testing indicates defects in the magnetic material and provides no information regarding the smoothness of the disk surface.

In the prior art, disk surface integrity has been measured using a separate transducer to determine if the disk surface is flat and smooth enough for a read/write transducer to fly without touching the surface. This special transducer typically includes a piezo-electric sensor for converting mechanical motion to an electrical signal.

There are several disadvantages associated with the prior art method. First, although it measures the disk surface, it does not measure the inter-action of the read/write transducer with the disk surface. The actual read/write transducer is shaped differently from the special transducer, has different mechanical forces acting on it, and flies at a different height

above the disk surface. Because of these differences between the special transducer and the actual read/write transducer, there is a difference in how each transducer responds to varying disk surface topography.

Second, the prior art method requires the disk drive to be unsealed so that a special transducer can be used. Unsealing the disk drive introduces the possibility of contamination of the disk surface.

Third, because a clean room is required to prevent contamination of the disks, no on-site integrity testing is possible. On-site testing is desirable for detecting damage or contamination introduced during the assembly and shipping processes.

These prior art testing methods are disclosed in an article featured in IEEE Transactions on Magnetism, Volume MAG-23 (1987) January No.1, entitled "Use of Readback Signal Modulation to Measure Head/Disk Spacing Variations in Magnetic Disk Files". This article discloses a method for measuring the steady state spacing between the transducer and the disk. The method disclosed relies upon the fact that the amplitude of the play back signal is dependent upon this steady state spacing. Hence the method discloses monitoring the amplitude variations to indicate changes in the steady state spacing. A number of experiments are disclosed and the accuracy of this method compared against comparable measurements made with a laser doppler vibrometer and concludes that this technique is relatively accurate.

According to one aspect of the present invention, there is provided apparatus for testing a memory device having a rotatable memory medium for storing data and a read/write transducer, which during operation of the memory device is spaced by an air bearing from a surface of the memory medium and writes data onto the memory medium in response to a write signal and produces a play back signal as a function of data read from the memory medium, means for providing the write signal to enable the transducer to write data on to the memory medium, means for deriving, from the play back signal, a test signal which is representative of disturbances on the air bearing, characterised in that said deriving means includes means for identifying in said test signal the frequencies which correspond to the characteristic frequency of disturbances on the air bearing so as to indicate the presence of defects on the surface of the memory medium.

According to another aspect of the present invention, there is provided a method of testing a memory device having a rotatable memory medium and a read/write transducer comprising, writing a pattern of data on the memory medium with the transducer, deriving from a play back signal produced by the transducer a test signal which is representative of disturbances of an air bearing between the medium and the transducer, and characterised by identifying in said

test signal the frequencies which correspond to the characteristic frequency of disturbances on the air bearing so as to indicate the presence of defects in the memory medium.

In the present invention, therefore, disk drive integrity is measured from a flyability standpoint (i.e. the ability of the read/write transducer to fly over the disk surface without touching the disk surface). The present invention determines disk drive integrity from the read signal frequency response of the read/write transducer after the write signal of known frequency has been written to the magnetic surface of the disk.

In the present invention, a write signal of constant frequency is recorded on the disk surface by the read/write transducer. The read signal from the transducer is composed of the frequency of the write signal plus a modulation signature of the air bearing frequencies. This modulation signature is the result of read/write transducer disturbances causing abrupt changes in flying height.

If the write frequency and the air bearing frequencies are spaced far apart, signal processing (such as amplitude demodulation and low pass filtering) can be used to produce an output signal representative of air bearing disturbances. Typical recording frequencies are in the megahertz range while air bearing frequencies are in the kilohertz range, allowing a simplified detection scheme for the air bearing disturbance signal.

The invention may thus determine when contacts or near contacts between a read/write transducer and a rotating memory medium occur based on the amplitude modulation of the play back signal from the read/write transducer.

The invention is described further, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 is a block diagram of a disk drive system, and an integrity tester comprising test circuitry and a defect mapping system;

Figure 2 is a block diagram of a first embodiment of the test circuitry; and

Figure 3 is a block diagram of a second embodiment of the test circuitry.

Figure 1 shows a disk drive system 10 which comprises a disk 12 (magnetic medium), a drive motor 14, a read/write transducer 16, a servo 18, disk electronics 20, and read/write circuitry 22. Also shown is an integrity tester comprising test circuitry 24 and a disk defect mapping system 26. The disk drive system 10 provides data storage and retrieval on a rotating magnetic medium (disk 12). The test circuitry 24 provides a write signal, which is written to the magnetic medium 12 through the read/write transducer 16. During play back of this write signal, the test circuitry 24 detects defects in the disk surface 12A, which show up as air bearing disturbances. The test circuitry 24 detects these disturbances and provides them as a test

output (or disturbance) signal for the disk defect mapping system 26, which distinguishes real errors from noise and maps these errors to show where they occur physically on the disk 12.

In the disk drive system 10, the rotating magnetic medium or disk 12 is driven by the drive motor 14. The surface 12A of the disk 12 is slightly roughened so as to cause air molecules next to the disk 12 to be swept at the same velocity as the disk 12. The high velocity air at the surface 12A of the disk 12 creates an air bearing for the read/write transducer 16 to float on as it is moved radially back and forth across the disk surface 12A on a pair of rails (not shown). The movement of the transducer 16 on the rails is controlled by the servo 18, which positions the read/write transducer 16 to particular tracks on the magnetic disk 12. Each track is a concentric circle on the magnetic disk 12, which the servo 18 selects by moving the read/write transducer 16 back and forth along the radius of the disk 12. Both the servo 18 and the drive motor 14 are controlled by the disk electronics 20. The read/write circuitry 22 converts the digital input data signal to an analog write signal, which is supplied to the read/write transducer 16 for writing the information to the magnetic material on the disk 12. During the read cycle, the transducer 16 magnetically picks up an analog play back or read signal from the surface 12A of the disk 12, which the read/write circuitry 22 converts to a digital read signal which can be used by a digital computer or digital signal processor (not shown).

The electronic flying integrity tester of the present invention detects defects in the disk surface 12A which disrupt the read/write transducer 16 as it floats on the air bearing. Disruptions in the flying height of the read/write transducer 16 modulate the normal read (play back) signal from the transducer 16. The test circuitry 24 detects the modulation of the normal play back signal which is within the frequency response range of the air bearing. Mechanical responses to air bearing disturbances are at a precise frequency determined by the mechanical response time of the read/write transducer 16 to disturbances. Each time the characteristic frequency of the air bearing disturbance occurs, it indicates that the height of the read/write transducer 16 floating on the air bearing has been disturbed. The amplitude of the test output signal is proportional to the magnitude of the air bearing disturbance and the width of the disturbance signal is proportional to the time the disturbance lasts. This test output signal is then supplied to the disk defect mapping system 16.

The disk defect mapping system 26 performs signal processing on the test output signal (preferably in the form of software filtering) to differentiate between noise components and true disturbance signal components. Such signal processing includes the requirement that the disturbance signal occur at three out of the five adjacent tracks. A disturbance which

occurs at three of the five adjacent tracks is more likely to be a result of a surface defect causing the read/write transducer to be disturbed, rather than random noise. Another preferred form of processing is the requirement that a disturbance be picked up by both of the rails which support the read/write transducer 16. There are typically two rails, on which the read/write transducer is mounted, separated by a large number of tracks. Both of these are rigidly connected and fly very close to the disk surface physically and therefore a defect disturbing one of the rails should disturb the other rails sometime later when the second rail reaches the same track which disturbed the first rail. Therefore, a disturbance of either rail will disturb the transducer 16. The processing by the disk defect mapping system 26 requires a true surface defect to disturb the first rail to encounter the defect and, somewhat later in time, to disturb the second rail. These defects are then mapped to show their physical location on the disk surface 12A so that the defects may readily be visually inspected.

Figure 2 shows a portion of the disk drive system 10 together with a first embodiment of the test circuitry 24. The test circuitry 24 comprises of frequency source 30, a writer 32, a pre-amplifier 34, a peak following rectifier 36, a low pass filter 38, an amplifier 40 and a band pass filter 42. The test output signal from the test circuitry 24 is supplied to the disk defect mapping system 26 as shown.

The frequency source 30 is used in conjunction with the writer 32 to write a constant frequency pattern through the read/write transducer 16 to the magnetic disk 12. The play back (read) signal containing the frequency of the recorded signal plus the modulation signature of the air bearing frequencies is amplified by the pre-amplifier 34. The amplified play back signal is supplied to the peak following rectifier 36, which separates lower frequency air bearing disturbance signals, which are in the kilohertz range, from the recording carrier, which is in the megahertz range. The low pass filter 38 is used to remove the carrier signal (recorded pattern) components from the air bearing disturbance signal components. The output of the filter 38 is supplied to the amplifier 40, which increases the amplitude of the filter output. The output of the amplifier 40 is then presented to the band pass filter 42, which is tuned to the air bearing frequencies. The test output signal, which is representative of the air bearing disturbance signal components is then supplied to disk defect mapping system 26.

Figure 3 shows a block diagram of a second embodiment of the test circuitry 24 allowing the tester to be used where read/write transducers 16 have varying output voltages and where the air bearing disturbance frequencies vary. There are a number of common circuit elements in the two embodiments of the test circuitry and these are denoted by similar num-

bers in Figures 2 and 3.

In the embodiment shown in Figure 3, the test circuitry 24 includes the frequency source 30, the writer 32, the pre-amplifier 34, a programmable gain amplifier 50, the peak following rectifier 36, a multiplier/mixer 52, a programmable oscillator 56, and active bandpass filter 54, and an active rectifier/filter 58. The programmable gain amplifier 50 is used to maintain a constant amplitude play back signal for different read/write transducers 16 having different output voltages.

The multiplier/mixer 52 translates the frequency of the air bearing disturbance signal to a new carrier frequency matching that of the active bandpass filter 54. The programmable oscillator 56 provides the difference frequency required for the translation. A carrier modulated by the air bearing disturbance signal is thus provided to the active rectifier/filter 58, which separates the air bearing disturbance signal from the carrier while filtering out the carrier signal, thereby producing the test output signal representative of the air bearing disturbance.

The present invention provides a method of testing for defects or contamination on the disk surface 12A, which disturb the read/write transducer 16. Disturbances of the read/write transducer 16 modulate the normal play back (read) signal. Because disturbances of the read/write transducer 16 occur in a very narrow frequency range, these disturbance signals can be detected and used as an indicator of disk surface defects or contamination.

Because overall reliability of the disk drive system 10 is limited by the integrity of the disk surface 12A, the ability to determine the smoothness of the disk surface 12A is very important. From a reliability standpoint, it is important to identify defects in the disk surface 12A because surface defects cause failures to occur later in the life cycle and these failures do not shown up during the post-production check-out.

Because the present integrity tester measures disturbances of the actual read/write transducer 16, it is a better indicator of defects, which will cause reliability problems in the future, than known testing methods which use a separate special transducer for determining disk integrity. The tester of the present invention does not require the disk media to be unsealed and thereby avoids consequent introduction of contamination to the disk surface. Another advantage of not having to unseal the disk media is that a clean room environment is not necessary to test the disk surface integrity. Therefore, this type of testing can be performed on-site to check for damage that might have occurred to the disk media during shipping. With this type of tester, periodic on-site checking of the "health" of the disk drive is possible. Health check testing would indicate problems likely to cause future failures.



Claims

1. Apparatus for testing a memory device having a rotatable memory medium for storing data and a read/write transducer, which during operation of the memory device is spaced by an air bearing from a surface of the memory medium and writes data onto the memory medium in response to a write signal and produces a play back signal as a function of data read from the memory medium, means (30,32) for providing the write signal to enable the transducer to write data on to the memory medium, means (34 to 42: 34, 36, 50 to 58) for deriving, from the play back signal, a test signal which is representative of disturbances on the air bearing, characterised in that said deriving means includes means (42;58) for identifying in said test signal the modulation frequencies which correspond to the characteristic frequency of disturbances on the air bearing so as to indicate the presence of defects on the surface of the memory medium.
2. Apparatus as claimed in claim 1, in which the frequency of said write signal is several orders of magnitude greater than said characteristic frequency of the air bearing.
3. Apparatus according to claim 1 or 2, in which the deriving means comprises an amplifier (34) for increasing the amplitude of the play back signal and de-modulator means (36) for separating the test signal from the play back signal.
4. Apparatus according to claim 1, 2 or 3, in which the deriving means comprises a low pass filter (38) for separating out from the play back signal, signals and noise having frequencies above the characteristic frequency of the air bearing and an amplifier (40) for increasing the signal strength of the output from the low pass filter.
5. Apparatus according to claim 1, 2 or 3, in which the deriving means comprises a programmable oscillator (56) for generating a variable frequency output and a mixer (52) responsive to the variable frequency output for shifting the modulation frequencies to the frequency of the write signal.
6. A method of testing a memory device having a rotatable memory medium and a read/write transducer, said method comprising writing a pattern of data on the memory medium with the transducer, deriving from a play back signal produced by the transducer a test signal which is representative of disturbances of an air bearing between the medium and the transducer, and characterised by identifying in said test signal the frequencies which correspond to the characteristic frequency of disturbances on the air bearing so as to indicate the presence of defects in the memory medium.
7. A method according to claim 6, further comprising mapping the locations of the defects on a surface of the medium based upon said identified frequencies.
8. A method according to claim 6 or 7, in which the pattern is written in tracks on the medium, and in that a defect on a surface of the medium is identified only if said identified frequencies indicate the existence of a disturbance of the air bearing in relation to a plurality of adjacent tracks.
9. A method according to any of claims 6 to 8, in which deriving the test signal comprises removing, from the play back signal, a carrier frequency produced by the pattern of data, and processing the result to produce the test signal.
10. A method according to claim 9, in which processing the result comprises band pass filtering to separate out noise.
11. A method according to any one of claims 6 to 10, including repeating the identification of the modulation frequencies corresponding to the characteristic frequency to improve the accuracy of the identification of defects.

Patentansprüche

1. Vorrichtung zum Prüfen einer Speichervorrichtung mit einem in Drehung versetzbaren Speichermedium zum Speichern von Daten und mit einem Lese-Schreib-Wandler, der im Betrieb der Speichervorrichtung durch ein Luftlager im Abstand von der Oberfläche des Speichermediums gehalten wird und Daten in Abhängigkeit von einem Schreibsignal auf das Speichermedium schreibt und ein Wiedergabesignal als eine Funktion von von dem Speichermedium gelesenen Daten erzeugt, mit einer Einrichtung (30,32) zur Lieferung des Schreibsignals derart, daß der Wandler Daten auf das Speichermedium schreiben kann, und mit einer Einrichtung (34 bis 42; 34,36,50 bis 58) zur Ableitung eines Störungen des Luftlagers darstellenden Prüfsignals aus dem Wiedergabesignal, dadurch gekennzeichnet, daß die Einrichtung zur Ableitung des Prüfsignals Einrichtungen (42;58) zur Identifikation von Frequenzen in dem Prüfsignal einschließt, die der charakteristischen Frequenz von Störungen des Luftlagers entsprechen, um auf diese



Weise das Vorhandensein von Fehlern auf der Oberfläche des Speichermediums anzuzeigen.

2. Vorrichtung nach Anspruch 1, bei der die Frequenz des Schreibsignals um mehrere Größenordnungen größer als die charakteristische Frequenz des Luftlagers ist. 5
3. Vorrichtung nach Anspruch 1 oder 2, bei der die Ableitungseinrichtung einen Verstärker (34) zur Vergrößerung der Amplitude des Wiedergabesignals und Demodulatoreinrichtungen (36) zur Trennung des Prüfsignals von dem Wiedergabesignal umfaßt. 10
4. Vorrichtung nach Anspruch 1, 2 oder 3, bei der die Ableitungseinrichtung ein Tiefpaßfilter (38) zum Abtrennen von Signalen und Störungen mit Frequenzen oberhalb der charakteristischen Frequenz der Luftlagerung aus dem Wiedergabesignal und einen Verstärker (40) zur Vergrößerung der Signalstärke des Ausgangssignals von dem Tiefpaßfilter umfaßt. 20
5. Vorrichtung nach Anspruch 1, 2 oder 3, bei der die Ableitungseinrichtung einen programmierbaren Oszillator (56) zur Erzeugung eines Ausgangssignals mit veränderlicher Frequenz und einen Mischer (52) umfaßt, der auf das Ausgangssignal mit veränderlicher Frequenz anspricht, um die Modulationsfrequenzen auf die Frequenz des Schreibsignals zu verschieben. 25
6. Verfahren zum Prüfen einer Speichervorrichtung mit einem in Drehung versetzbaren Speichermedium und mit einem Lese-/Schreib-Wandler, das das Schreiben eines Datenmusters mit dem Wandler auf das Speichermedium und die Ableitung eines Störungen eines Luftlagers zwischen dem Medium und dem Wandler darstellenden Prüfsignals aus dem von dem Wandler erzeugten Wiedergabesignal umfaßt, 30
dadurch gekennzeichnet, daß in dem Prüfsignal die Frequenzen identifiziert werden, die der charakteristischen Frequenz von Störungen des Luftlagers entsprechen, um auf diese Weise das Vorhandensein von Fehlern in dem Speichermedium anzuzeigen. 35
7. Verfahren nach Anspruch 6, das weiterhin die Aufzeichnung der Positionen der Defekte auf einer Oberfläche des Mediums auf der Grundlage der identifizierten Frequenzen umfaßt. 40
8. Verfahren nach Anspruch 6 oder 7, bei dem das Muster auf Spuren auf dem Medium geschrieben wird, und daß ein Defekt auf einer Oberfläche des Mediums lediglich dann identifiziert wird, 45

wenn die identifizierten Frequenzen das Vorhandensein einer Störung der Luftlagerung hinsichtlich einer Mehrzahl von benachbarten Spuren anzeigen.

9. Verfahren nach einem der Ansprüche 6 bis 8, bei dem die Ableitung des Prüfsignals die Beseitigung einer durch das Datenmuster erzeugten Trägerfrequenz aus dem Wiedergabesignal und die Verarbeitung des Ergebnisses zur Erzeugung des Prüfsignals umfaßt. 50
10. Verfahren nach Anspruch 9, bei dem die Verarbeitung des Ergebnisses die Bandpaßfilterung umfaßt, um Rausch- und Störsignale abzutrennen. 55
11. Verfahren nach einem der Ansprüche 6 bis 10, das die Wiederholung der Identifikation der Modulationsfrequenzen entsprechend der charakteristischen Frequenz einschließt, um die Genauigkeit der Identifikation von Defekten zu verbessern.

Revendications

1. Appareil pour tester un dispositif de mémoire possédant un support de mémoire rotatif pour stocker des données et un transducteur de lecture/écriture qui, pendant le fonctionnement du dispositif de mémoire, est espacé d'une surface du support de mémoire par un palier d'air, et écrit des données sur le support de mémoire en réponse à un signal d'écriture et génère un signal de relecture en fonction des données lues à partir du support de mémoire, un moyen (30, 32) pour fournir le signal d'écriture afin de permettre au transducteur d'écrire des données sur le support de mémoire, un moyen (34 à 42; 34, 36, 50 à 58) pour dériver, à partir du signal de relecture, un signal de test représentatif des perturbations sur le palier d'air, caractérisé en ce que ledit moyen de dérivation comporte un moyen (42; 58) pour identifier dans ledit signal de test les fréquences de modulation qui correspondent à la fréquence caractéristique des perturbations sur le palier d'air de manière à indiquer la présence de défauts sur la surface du support de mémoire. 50
2. Appareil selon la revendication 1, dans lequel la fréquence dudit signal d'écriture est supérieure de plusieurs ordres de grandeur à ladite fréquence caractéristique du palier d'air.
3. Appareil selon la revendication 1 ou 2, caractérisé en ce que le moyen de dérivation comporte un amplificateur (34) pour augmenter l'amplitude du 55



signal de relecture et un moyen de démodulation (36) pour séparer le signal de test du signal de relecture.

4. Appareil selon la revendication 1, 2 ou 3, dans lequel le moyen de dérivation comporte un filtre passe-bas (38) pour éliminer du signal de relecture les signaux et bruits possédant des fréquences supérieures à la fréquence caractéristique du palier d'air et un amplificateur (40) pour augmenter l'intensité du signal issu du filtre passe-bas. 5
5. Appareil selon la revendication 1, 2 ou 3, dans lequel le moyen de dérivation comporte un oscillateur programmable (56) pour générer une fréquence de sortie variable et un mélangeur (52) sensible à la fréquence de sortie variable pour décaler les fréquences de modulation vers la fréquence du signal d'écriture. 10 15
6. Méthode pour tester un dispositif de mémoire possédant un support de mémoire rotatif et un transducteur de lecture/écriture, ladite méthode comportant l'écriture d'une combinaison de données sur le support de mémoire avec le transducteur, la dérivation, à partir d'un signal de relecture généré par le transducteur, d'un signal de test représentatif des perturbations sur un palier d'air entre le support et le transducteur, et caractérisée par l'identification, dans ledit signal de test, des fréquences qui correspondent à la fréquence caractéristique des perturbations sur le palier d'air de manière à indiquer la présence de défauts dans le support de mémoire. 20 25 30
7. Méthode selon la revendication 6, comportant en outre l'établissement d'une cartographie des emplacements des défauts sur une surface du support en fonction desdites fréquences identifiées. 35
8. Méthode selon la revendication 6 ou 7, dans laquelle la combinaison est écrite sur des pistes du support et selon laquelle un défaut est identifié sur une surface du support uniquement si ladite fréquence identifiée indique l'existence d'une perturbation du palier d'air par rapport à une multiplicité de pistes contiguës. 40 45
9. Méthode selon l'une quelconque des revendications 6 à 8, dans laquelle la dérivation du signal de test comporte la séparation, à partir du signal de relecture, d'une fréquence porteuse générée par la combinaison de données et le traitement du résultat afin de générer le signal de test. 50
10. Méthode selon la revendication 9, dans laquelle le traitement du résultat comporte un filtrage passe-bande afin d'éliminer le bruit. 55

11. Méthode selon l'une quelconque des revendications 6 à 10, comportant la répétition de l'identification des fréquences de modulation correspondant à la fréquence caractéristique afin d'améliorer la précision de l'identification de défauts. 7