Magnetic characteristics evaluation system for GMR heads

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Giant magnetoresistive (GMR) heads are magnetic sensors mounted on computer hard disks. The current high level of memory density on hard disks demands improvements in the internal precision of these sensors, while at the same time the sensors must be able to withstand the high temperatures created by the high-speed rotation of the media above which they are located. Retrieving data from high-density points requires high sensitivity, which GMR heads, unlike conventional MR heads, attain mainly through the use of spin-valve structure. However, ensuring heat resistance with spin-valve GMR heads can be problematic, and the head manufacturers are seeking for improvements by developing superior heat resistant heads. As hard disk memory density is now increasing in extremely short cycles, the problem facing manufacturers is to somehow evaluate new devices quickly.

1. Introduction

Conventional evaluation testing of electromigration in GMR heads is performed by placing the device in a high-temperature environment, applying a constant stress current, and measuring only low-resistance changes. Changes in resistance are slight, requiring high-precision resistance measuring equipment. Even then, it is difficult to accurately determine degradation in the magnetic characteristics of the GMR head from the measured resistance values alone. The magnetic characteristics evaluation system for GMR heads presented here not only examines resistance changes in the GMR head, but this system also impresses a magnetic field on the GMR head and directly measures and evaluates the magnetic characteristics of that field.

2. GMR heads

2-1 Hard disk structure

Fig. 1 shows the hard disk structure, while Fig. 2 presents details of the GMR head structure.

A slider is attached to the reading end of a device called the "arm," and a magnetic sensor (the GMR head) is mounted on this slider. The slider performs read/write operations without touching the disk.

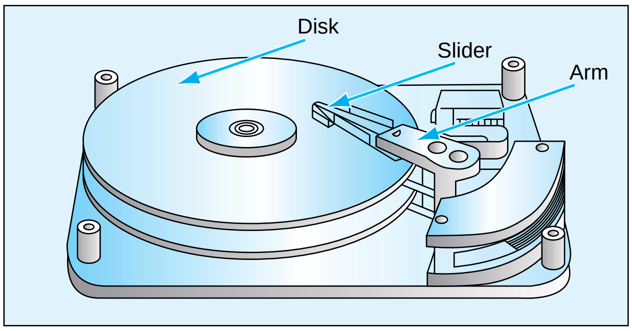

Fig. 1 Hard disk structure

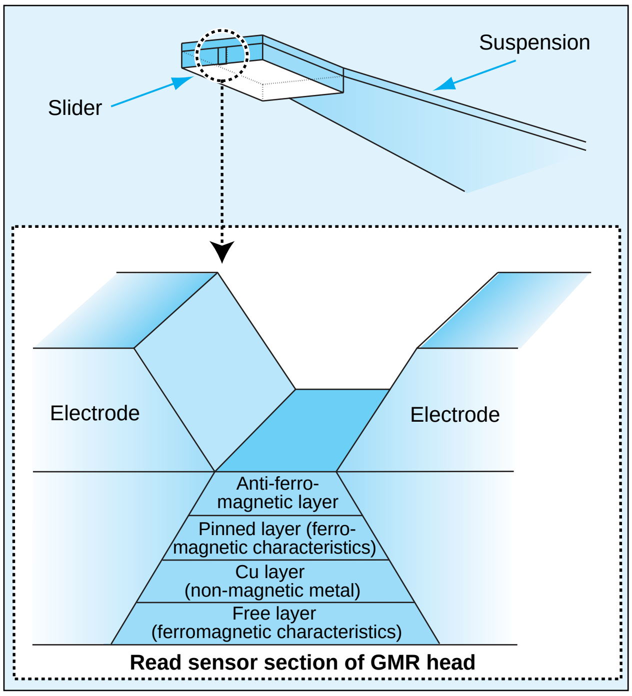

Fig. 2 GMR head structure

2-2 Operating principles of the GMR head

One of the newest types of read heads on current hard disks is the spin-valve GMR head, which utilizes a GMR spin-valve film containing anti-ferromagnetic material. The spin-valve film consists of an anti-ferromagnetic layer a few nanometers thick, a ferromagnetic layer (pinned layer), a Cu layer, and another ferromagnetic layer (free layer). (Fig. 2) The ferromagnetic layer usually referred to as the pinned layer has a fixed direction of flux because of its location beneath the anti-ferromagnetic layer, and so shows little reaction to external magnetic fields. The other ferromagnetic layer known as the free layer is beneath the Cu layer, a non-magnetic metallic layer, and the bottom free layer is more easily affected by external magnetic fields. This free layer is affected by flux from the surface of the disk. Changes in the direction of flux result in major changes in internal resistance, thus

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allowing the information to be read from the surface of the disk. Film with these properties is known as spin – valve film.

3. System structure

3-1 System appearance and main specifications

Photo 1 shows the external appearance of the system, and Table 1 presents the main specifications. Each 10-channel load box of the system shown in Photo 1 is capable of simultaneous testing using up to 6 load boxes (60 channels total) for different tests with each box involving temperature, current, magnetic field, and test time. Each load box can accommodate up to 10 sets of GMR heads on each test board, and the test boards can be attached to the load box with a one-touch operation.

Table 1 Main Specifications

Item		Specifications
Constant current output	Current output range	DC ±0.01 to DC ±20.0 mA
	Current output accuracy	Setting current ±5 µA (for min. 0.1 mA)
	Max. output voltage	±5 V guaranteed
Resistance measurement (at 50Ω)	0.1 mA	Measurement value ±2% (50Ω ±1Ω)
	1 mA	Measurement value ±0.2% (50Ω ±0.1Ω)
Output current monitor	Current monitor range	DC ±0.01 to DC ±20.0 mA
	Current monitor accuracy	Monitor current ±50 µA (for min. 0.1 mA)
Output current comparator	Current comparator range	DC ±0.1 to DC ±20.0 mA
	Current comparator speed	50 µs
	Current comparator accuracy	Monitor current ±100 µA (for min. 0.1 mA)
Magnetic field generation	Magnetic field generation range	±47400 A/m (±600 Oe)
	Magnetic field generation accuracy	F.S ±0.5% (±3 Oe)
Magnetic field measurement	Magnetic field measurement range	±47400 A/m (±600 Oe)
	Magnetic field measurement accuracy	± 79A/m (±1 Oe)
GMR head output voltage measurement (RH characteristics)	Voltage measurement range	±10 mV
	Voltage measurement accuracy	±8 µV
Temperature control	Temperature range used	30°C to 200°C (for environment of use: normal temperature)
	Temperature constancy	±0.5°C at 200°C (temperature control amplitude at control point)
	Temperature uniformity	±3.0°C at 200°C
	Temperature ramp up time	Max. 15 min. from 30°C to 150°C
	Temperature cool down time	Max. 35 min. from 150°C to 30°C * Measurement environment normal temperature (23°C)

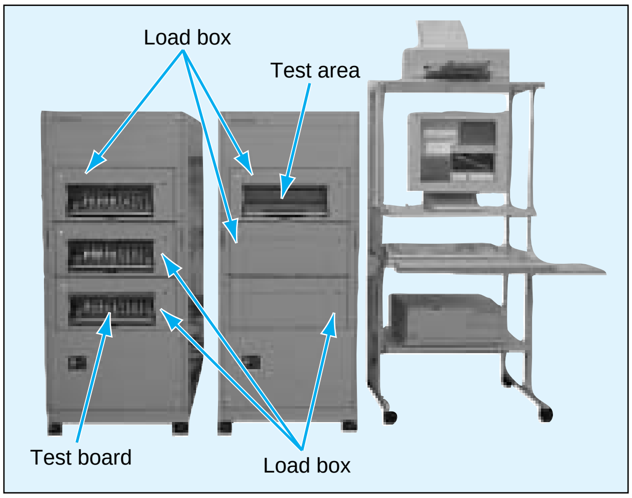


Photo 1 System appearance

3-2 System block diagram

Fig. 3 presents a system block diagram. This diagram represents a 10-channel system block. Only GP-IB and RS-485 connections were made to the centralized control microcomputer, providing a configuration enabling simple expansion.

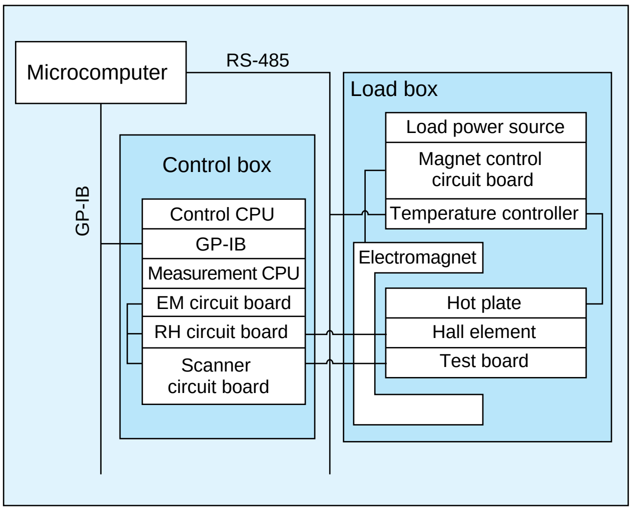


Fig. 3 System block diagram

4. Test method

Testing can be performed using sequential program settings, and settings can be stored as a file with optional settings of up to 100 steps. Temperature and measurement conditions can be set at each sequential step. (Fig. 4) Individual settings conditions are available for the following modes: current ramp mode, electromigration evaluation measurement mode, and magnetic field impression output characteristics (hereafter, RH characteristics) measurement mode.

During measurements, hot plates are used to control the temperature of the GMR heads at the set temperature, and resistance is measured while applying a constant current to the GMR head read terminal, and simultaneously impressing a periodic magnetic field and monitoring the read terminal voltage.

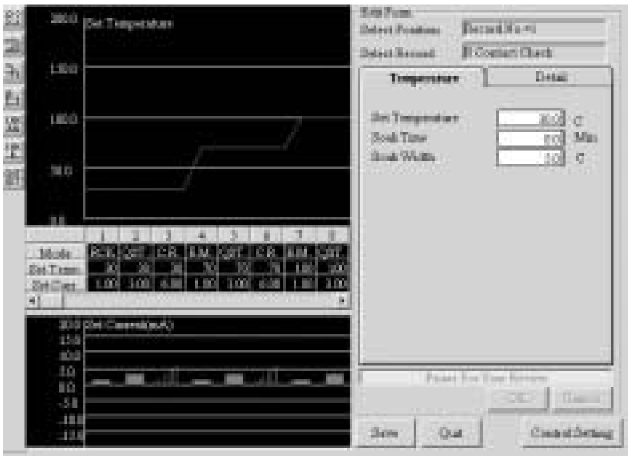


Fig. 4 Screen shot of sequence program settings

4-1 Test setting details

Any measurement mode settings mentioned above can be set at each step of the sequence program. Let's look at the details of each measurement mode.

(1) **RH characteristics measurement mode (QST)**

- This mode measures GMR head output characteristics. As a test to evaluate RH characteristics, constant current is applied to the GMR head read terminal while simultaneously impressing a magnetic field (Fig. 5) and measuring output characteristics to the GMR head. The measurement results can be shown as an RH characteristics graph (Fig. 9).
- Any mode can be set at each step.
- Optional settings can be made for measurement current and magnetic field impression. Repeated measurements can be made for a maximum of 25 cycles.
- All types of computational data can be displayed and stored. (Examples of computational data)
  Pk-Pk AMP (μV): output amplitude
  Pk-Pk ASYM (%): asymmetry
- The computational data obtained facilitates judgements about equipment life.

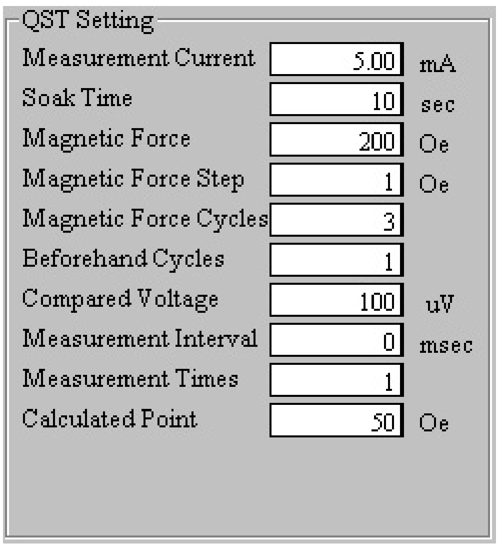
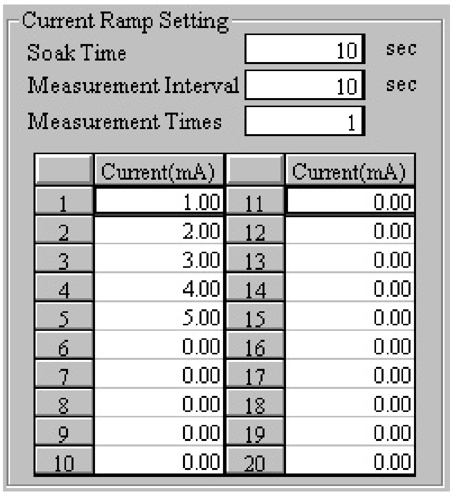


Fig. 5 Screen shot of measurement settings for RH characteristics

(2) **Current ramp mode (CR)**

- This mode measures the impression-current-dependent characteristics of the GMR head.
- Any mode can be set at each step.
- Current-dependent measurements can be made in a maximum of 20 steps.
- A maximum of 200 discrete points of data can be obtained with each channel, and so multiple resistance measurements can be made for each current setting.



	Current(mA)		Current(mA)
1	1.00	11	0.00
2	2.00	12	0.00
3	3.00	13	0.00
4	4.00	14	0.00
5	5.00	15	0.00
6	0.00	16	0.00
7	0.00	17	0.00
8	0.00	18	0.00
9	0.00	19	0.00
10	0.00	20	0.00

Fig. 6 Screen shot of current ramp mode settings

(3) **Electromigration evaluation measurement mode (EM)**

- This mode measures resistance as a means of evaluating electromigration on the GMR head. To evaluate electromigration, the test applies constant current as stress to the GMR head read terminal (Fig. 7), and measures resistance. Measurement results can be shown as trend graphs (Fig. 8).
- Settings can be made at each step.
- This measurement mode is used to evaluate electromigration occurring over a long time period.
- While applying current as stress, a magnetic field can simultaneously be impressed.

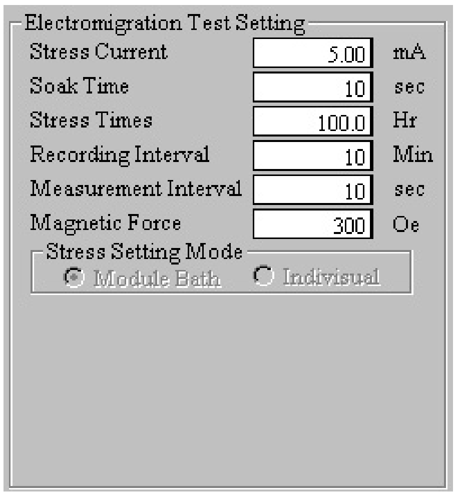


Fig. 7 Screen shot of electromigration evaluation measurement mode

5. Measurement results

5-1 Graph display

Measurement results for resistance and for RH characteristics can be output as graphs. Examples presented here include a trend graph for resistance measurements (Fig. 8), an RH characteristics graph (Fig. 9), and an RH characteristics time sequence rate-of-change graph (Fig. 10).

(1) **Trend graph for resistance measurements**

While stress is applied to the GMR head read terminal, terminal resistance measurements are recorded for each recording cycle set in the sequence program.

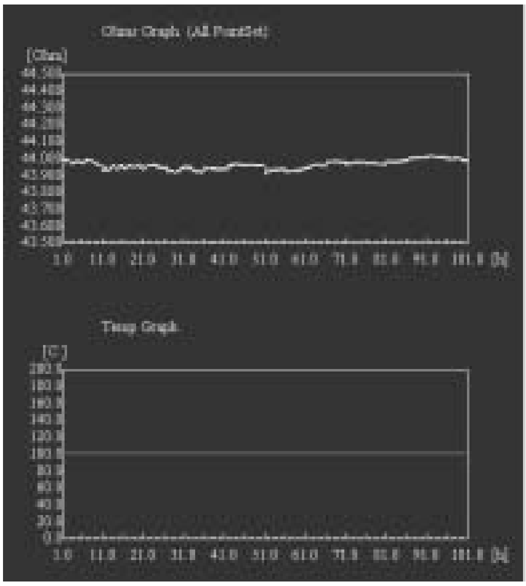
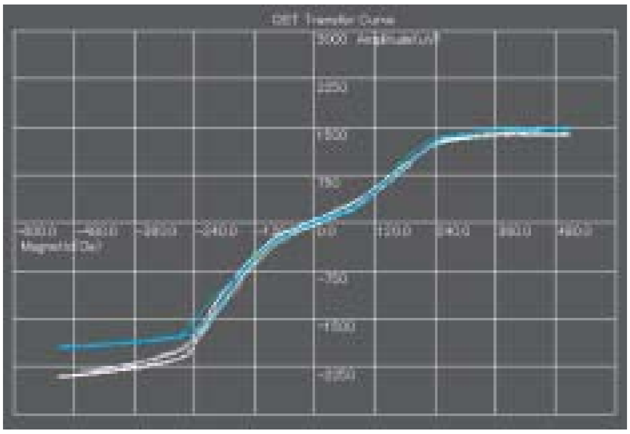


Fig. 8 Sample trend graph resistance measurements

(2) **RH characteristics graph**

With the timing set in the sequence program, this graph represents data monitoring the output voltage of the GMR head on an X axis (magnetic field), and a Y axis (output voltage). A single measurement timing can include multiple cycles of RH characteristics measurements, with data for multiple cycles represented as an average, and so the graph has the capacity to present all computational data. Multiple timing data can also be simultaneously plotted. Fig. 9 shows a graph that simultaneously plots data for the time of test initiation and data immediately prior to test conclusion.



White: Time of test initiation
Blue: Time immediately prior to test conclusion

Fig. 9 Sample RH characteristics graph

(3) **RH characteristics time sequence rate-of-change graph**

Fig. 10 presents an example of computational data for RH characteristics obtained from output voltage measured according to the timing set in the sequence program. The graph shows the time sequence rate of change for stress impression time and output amplitude (the amplitude for maximum output and longest output). The graph indicates that the output amplitude decreases over time.

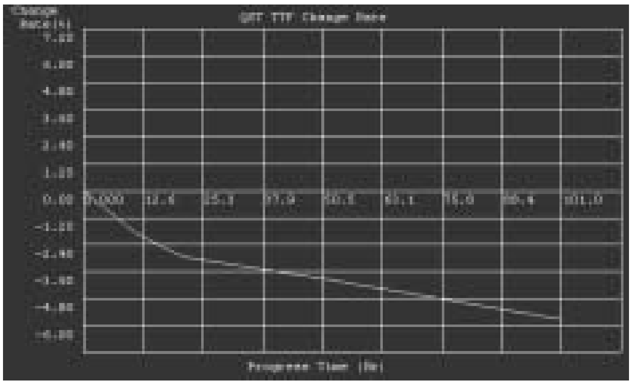


Fig. 10 Sample RH characteristics time sequence rate-of-change graph (Pk-PkAmp)

5-2 Comparison of measurement data

Table 2 shows a comparison between the rate of change of the output voltage amplitude (Pk-PkAmp) for device output in RH characteristics measurement and the rate of change in resistance measurements from the start-up of the electromigration test.

From table 2 we are able to grasp the rate of change (degradation characteristics) in the RH characteristics measurements much more clearly than in the resistance measurements.

Table 2 Comparison of the rate of change of resistance measurement data and RH characteristics data

	Resistance measurement data	RH characteristics data
At test start-up	43.993Ω	3683.509 μV
After 100 hours aging	Max. 44.017Ω (+0.05%) Min. 43.945Ω (–0.11%)	3373.339 μV (–5.86%)

6. Conclusion

As progress continues in developing ever higher density for hard disks, development time periods for magnetic heads will also be compacted. We at Espec will be very pleased if this equipment can provide some assistance in reducing magnetic head development times.