AN ACTIVE HEAD USING THE MAGNETORESISTIVE EFFECT IN THE HIGH FREQUENCY REGION

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ABSTRACT --- A highly sensitive magnetic read-out head (HFMRH : High Frequency Magnetoresistive Head) is introduced, which is based on a new magnetoresistive (MR) effect. The author has experimentally discovered that a conventional MR head shows the new MR effect at a frequency (fr) so high as to cause ferromagnetic resonance (FMR). Head performance was evaluated with a new parameter, modified MR ratio ($\Delta R_{max}/\sqrt{R}$; ΔR_{max} : maximum resistance change, R:resistance) which is proportional to the signal-to-noise ratio (SNR). The experimental results showed that the modified MR ratio at fr can be much larger than that at a frequency lower than fr. It has been confirmed that the new effect can be applied to a magnetic read-out head with a higher output level and a higher SNR than the normal MR effect observed with direct current (dc). The new head design is promising for realizing future ultra high-density magnetic recording systems.

INTRODUCTION

Perpendicular magnetic recording systems have made it possible to write signals with a linear density of 680 kFRPI [1], and it has also been reported that recording is possible with a very narrow track width of 0.5 μm [2]. Nevertheless, it is almost impossible to read-out such high density signals using an inductive head, because it has inadequate output and SNR. From this point of view, the author has already developed a highly sensitive magnetic read-out head called the Active Head [3],[4],[5],[6]. The reproduction principle is to read-out signals by detecting the voltage change in an rf resonant circuit coupled to a soft magnetic film due to the sharp rf permeability change in the film. It has been reported that the Active Head is in principle more sensitive than inductive and/or MR heads [7],[8].

In this paper, another type of Active Head is introduced, the HFMRH (High Frequency Magnetoresistive Head), which is based on a new magnetoresistive (MR) effect. The author has experimentally discovered the new MR effect at a frequency (fr) so high as to cause ferromagnetic resonance (FMR). Head performance was evaluated with a new parameter, the modified MR ratio ($\Delta R_{max}/\sqrt{R}$; ΔR_{max} :maximum resistance change, R:resistance) which is proportional to the SNR. It has been confirmed that the new effect can be applied to a magnetic read-out head with a

higher output level and a higher SNR than the normal MR effect observed with dc.

PRINCIPLE

The feature of the HFMRH is that the MR effect is used in the high-frequency region in order to read-out signals. Figure 1 shows a schematic diagram of the new head. It has the same magnetic pole as that of a conventional MR head, and has the same electric circuit as the Active Head. The soft magnetic film which detects the signal field generated by the recording medium is an MR element and is directly used as an inductor composing a resonant circuit. A high-frequency current flows through the film in its easy axis direction. Read-out

Fig.1 Schematic diagram of the HFMRH

signals are obtained by detecting the voltage change in the resonant circuit due to a high-frequency resistance change in the film caused by the signal field.

EXPERIMENTAL METHODS

By using a conventional MR head, the frequency characteristics of a head impedance ($Z = R + jL$; R :resistance, L :inductance) at zero field and the frequency characteristics of both maximum head resistance change ($\Delta R_{\max}$) and maximum head inductance change ($\Delta L_{\max}$) were measured using an rf impedance analyzer (YHP:4191A). The measuring frequency range was 1 MHz to 500 MHz. $\Delta R_{\max}$ and $\Delta L_{\max}$ were measured by changing the external field applied in the hard axis direction of the MR element using a permanent magnet. Figure 2 shows the head configuration. The dimensions were as follows; W :80 μm , D :5 μm , Length:3 mm, MR film (NiFe) thickness:0.08 μm .

Fig.2 MR head for measurement

RESULTS AND DISCUSSION

Figures 3 and 4 show the measured frequency characteristics of R and L at zero field, respectively. Figures 5 and 6 show the frequency characteristics of the ratio of $\Delta R_{\max}/R$ and the ratio of $\Delta L_{\max}/L$, respectively. R and $\Delta R_{\max}/R$ remained almost constant (about 40 Ω and about 1 %) up to

about 100 MHz, as measured with dc. The results show that the normal MR effect was preserved at least up to about 100 MHz. R and $\Delta R_{\max}/R$ abruptly increased by about 2 times and 5 times, respectively, as the frequency increased from about 100 MHz to 500 MHz. On the other hand, L decreased up to about 10 MHz and then slowly increased with frequency from about 10 MHz to 500 MHz. $\Delta L_{\max}/L$ monotonically decreased up to about 300 MHz and thereafter increased slightly as the frequency increased from about 300 MHz to 500 MHz.

Fig.3 Frequency characteristics of R at zero field

Fig.4 Frequency characteristics of L at zero field

Fig.5 Frequency characteristics of $\Delta R_{\max}/R$

Fig.6 Frequency characteristics of $\Delta L_{\max}/L$

The sharp increase in R and the slight increase in L over the frequency range from about 100 MHz to 500 MHz can be considered to be caused mainly by ferromagnetic resonance (FMR) [3],[4], since in general the eddy current effect can not induce increases in both R and L . Therefore, the sharp increase in $\Delta R_{\max}/R$ over the frequency range from 100 MHz to 500 MHz must also be due to FMR. FMR would have begun at about 100 MHz and the degree of FMR would have continued to increase as the frequency increased from about 100 MHz to 500 MHz. This interesting phenomenon observed over the frequency range can be considered to be a new MR effect.

Let us define a new parameter, modified MR ratio ($\Delta R_{\max}/\sqrt{R}$). In general, the read-out signal level will be proportional to $\Delta R_{\max}$ (a product of $\Delta R_{\max}/R$ and R) and the thermal noise to $\sqrt{R}$. Therefore, an increase in the modified MR ratio implies an increase in SNR. Head performance can be evaluated with the new parameter. The experimental results showed that the $\Delta R_{\max}/\sqrt{R}$ value at a frequency (f_r ; $f_r >$ about 100 MHz for the MR head used) so high as to cause FMR was much larger than the value at a frequency lower than f_r . For example, the modified MR ratio at 500 MHz was about 7 times (17 dB) larger than that at a frequency lower than about 100 MHz. This means that the use of the new MR effect based on FMR can be very useful in obtaining a higher output level and SNR than that of only the normal MR effect.

CONCLUSION

A highly sensitive magnetic read-out head, HFMRH, has been introduced based on a new MR effect. The author has experimentally discovered that a conventional MR head shows the new MR effect at a frequency (f_r) so high as to cause FMR, and preserves the normal MR effect up to f_r . The head performance was evaluated with a new parameter, modified MR ratio ($\Delta R_{\max}/\sqrt{R}$) which is proportional to the SNR. The experimental results have shown that the modified MR ratio at f_r can be much larger than that at a frequency lower than f_r . It has been confirmed that the new effect can be applied to a magnetic read-out head with a higher output level and a higher SNR than the normal MR effect observed with dc. The new head design is promising for realizing ultra high density perpendicular magnetic recording systems.

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