INVESTIGATION OF THE STRUCTURE OF RECORDING HEAD FIELDS

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ABSTRACT

Head fields of two recording heads (gap lengths 2.1 and 2.8 micrometer) have been measured with the help of a series of magnetoresistive transducers. The widths of these transducers are 1.9, 4.1 and 7.0 micrometer and they have been positioned in the gap field region very accurately using optical methods.

The transducer outputs have been compared with computer simulated results. A systematic deviation between theoretical and experimental results may lead to the assumption that the surface of the recording head is magnetically inactive over a few tenths of a micrometer.

INTRODUCTION

It has been shown recently[1,2] that high-resolution measurements of magnetic field distributions on the micrometer scale (e.g. of recording head fields and flux reversals) are possible in spite of the experimental difficulties. These difficulties are mainly: production of a miniature field-sensitive transducer, accurate positioning of this transducer in the fields to be measured and the backwards analysis of the transducer response to the original field values. The latter difficulty arises from the fact that field gradients are important on the scale of the transducer dimensions. Two different approaches have been followed: Lustig et al.[2] from Sperry Research Center have developed and utilised a micro Hall-probe of thin film InSb, while we[1] use a magneto resistive transducer (MRT) of thin film $Ni_{81}Fe_{19}$.

Since the production and the positioning of the transducer and the analysis of the transducer responses make high demands on the equipment, the computer simulation and the skill of the investigators, it can only be an advantage that comparable measurements are and have been directed at two different places.

In this paper we describe the measurement of the transversal (y) component (see fig. 1) of recording head fields of two commercial disk slider-heads with optical gap lengths (2g) of 2.1 µm and 2.8 µm.

A series of MRT's with widths ranging from 1.9 µm to 7.0 µm, has been used and the results, which show a good interdependence, seem to corroborate the results of the Sperry group.

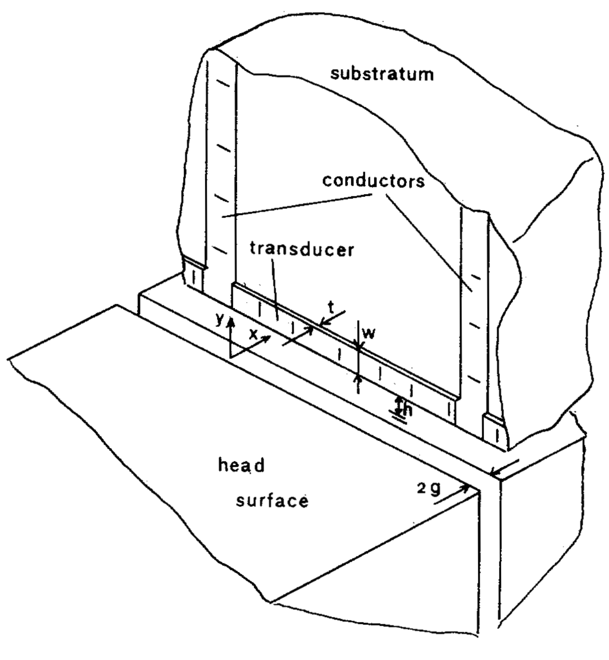

Fig.1: Magnetoresistive transducer, positioned in the vicinity of the gap of a recording head.

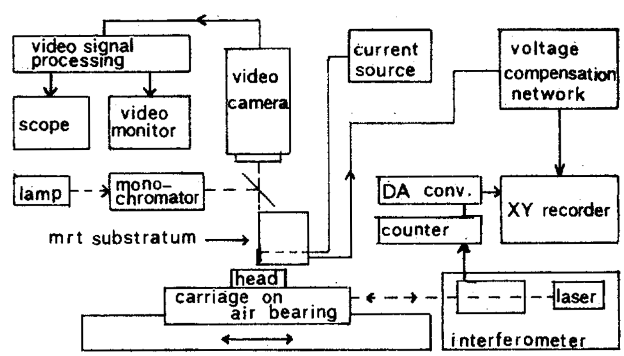

Fig.2: Schematic of the measurement system.

EQUIPMENT

An overview of the field measurement system is given in fig. 2 The slider head is mounted on the moving part of a Talytron S 90 air-bearing traversing table and can be moved underneath a fixed glass cube onto which the transducer has been deposited.

The separation h (see fig. 1) between the head and the transducer can be established by the pressure of the air bearing in a smooth and reversible way over a range of several microns.

A micrometer screw is needed to bring the separation within this range. The separation is measured using optical interference in the way described by Lin[3]. Interference fringes are gently produced because of the curvature of slider and head. The separation is determined using the fringes on the head surface itself. The accuracy with which h is determined is about ± 0.07 µm.

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The horizontal position of the moving part is determined with the help of a Michelson-interferometer with an accuracy better than 0.08 μm.[4]
The method of production of the MRT on the edge of a glass substratum is given in ref. 5.
The computer simulation program (described in ref. 1) is adjusted to the new configuration by altering the subroutines concerning the effect of the image charge. The influence of the image charge of the magnetized transducer with respect to the head surfaces cannot be ignored for small values of h.

ACCURACY

Since it is the intention to draw conclusions which extend to the sub-micron level, ample attention must be paid to all possible errors. The general form of the transducer output is shown in fig. 3. Such curves result as the gap field passes underneath the transducer in the horizontal (x) direction, while the separation h is kept constant. The accuracy to determine h is mentioned in the preceding section. The accuracy of x-values on the xy-recorder plot is mainly determined by the xy-recorder itself and is about 0.2 μm.

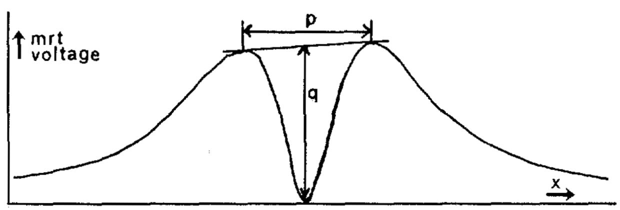

Fig.3: Typical transducer output (measured).

The transducer-axis must be oriented exactly parallel to the gap edges. Misalignment will result in a first order error in the depth q of the curves, but only in second order will affect the peak distance p. This can be derived from a simple model and has been checked experimentally. We have used only the parameter p in our analysis and consider a misalignment error as negligible.
The width of the transducer can be determined optically only with an accuracy of a few tenth of a micron. As is seen from fig.4 which is typical for all results, an error of, say, 0.2 μm in the transducer width w results in an error of about 0.1 μm in p.
The transducer output may show assymmetry (e.g. in the height of the two peaks). We have paid much attention to check, in such cases, whether the assymmetry had its origin in the structure of the head field or in some other effect.
One cause of assymmetry is the effect of stray DC magnetic fields, which will be enhanced by the ferrite body of the head. Since our transducers are inherently sensitive and our measurements are DC we have had to eliminate the stray field with a compensation coil surrounding the equipment. The check whether an assymmetry is "real" or "induced" is simple: in case of "real" assymmetry, the assymmetry will not reverse on reversing the polarity of the drive current through the head coil; in case of "induced" assymmetry by a stray field it will.
During measurement the fields to be measured were kept low to prevent saturation of(parts of) the transducer. This is necessary to hold full advantage of the accuracy of the computer simulation and to prevent irreversible switching in (parts of) the transducer. Switching sometimes occurs during measurement; curves which show suspect irregularities are rejected from analysis.

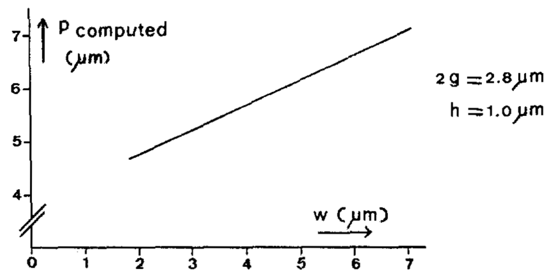

Fig.4: Computed values of P as a function of the MRT width w.

RESULTS

We have done a great number of measurements on two heads with gap lengths of 2.1 and 2.8 μm respectively. Three transducers were used; the relevant parameters of the transducers are mentioned in table I. As we have said in the preceding section we have concentrated the analysis on the parameter p and have studied the behaviour of this parameter as a function of the head/transducer separation h. An overview of all the results is given in fig. 5.
As can be seen there is a systematic difference between experimental and computed behaviour. The computed results are based on theoretical head fields (obtained by conformal mapping) assuming infinite permeability of the head material and gap lengths as they were determined optically.
The deviation between computed and experimental results is definitely outside the total error range of both the experiment and the computation and is systematically present in all the tests.

transducer number	width w(μm)	thickness t(nm)
1	1.9	9
2	4.1	16
3	7.0	18

Table I: Dimensions of the applied transducers.

DISCUSSION

One explanation of the observed deviation may be that there is a difference (of about 0.4 μm) between the head/transducer separation as determined optically (h) and as it is effectively. This might be ascribed to an inactive layer atop of the recording head. Of course it might be ascribed to an inactive part of the transducers as well, but we have no other indication that supports this idea. Optically the transducers are perfect and the edges of the substrata show no irregularities.
At this point it is important to remember the results of ref. 1 and 2. In these experiments the transducers are positioned with the plane of the substratum parallel to the head surface so that an inactive part of the transducer cannot play a role comparable to the configuration used in the experiment we describe here. Nevertheless an indication of a deviation between optical and effective separation is present in ref. 2 as well, while in ref. 1 an indication of an enlarged effective gap length is present.

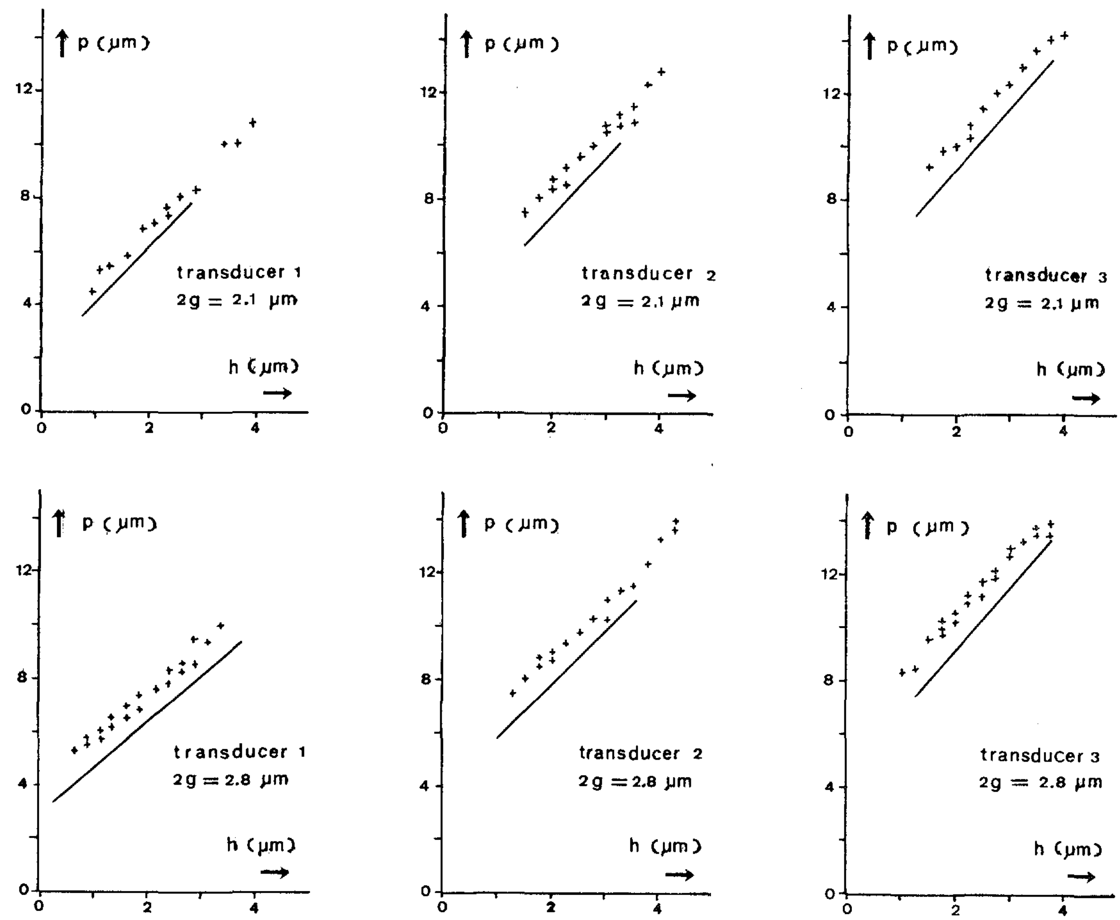

Fig.5: Curve parameter p as a function of the separation (h) between head surface and MRT edge. (See table I for the dimensions of the applied transducers).
measured +++
computed ——

With respect to the latter, a possible enlarged gap length as a consequence of inactive layers within the gap is to be expected if one thinks of inactive layers atop of the head; after all both surfaces are grinded and lapped.
Unfortunately the p-values are not sensitive enough to a variation in gap length as to conclude whether there are inactive layers inside the gap or not. We can only say at this moment that if a model is used with inactive layers on the top of the surface as well as on the inside gap surface, we must refit the experimental results to theory which results in a reduced value of the thickness of the inactive layer (from about 0.4 to about 0.3 μm).
A model with a more gradually decreasing magnetic permeability instead of a sharply defined dead layer can also not be excluded and we hope that further measurements (on sub-micron and "close to zero" gap length heads) may discriminate between possible models.

ACKNOWLEDGMENTS

We like to thank B.Hurenkamp and H.W.Krabbe for the production of the transducers and P.D. Ekkelkamp and A.J.F.Hollink for technical assistance.

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