of 50 kHz and a pulse length of 150 μs the shortest transition which we can record with 1% accuracy is 15 μs.

3 Conclusions

The use of a more realistic bandpass characteristic than a simple high frequency cut-off gives a very simple relation between the error involved in recording a transition and the frequency response of the recording instrument. It can be seen from the figure that the present model gives less stringent bandwidth requirements than the sharp cut off model.

Acknowledgments

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References

Jacobs I S and Lawrence J C 1958 *Rev. Sci. Instrum.* **29** 713–4

Ricodeau J A, Lee E W and Melville D 1972 *J. Phys. E: Sci. Instrum.* **5** 472–4

Starovoitov A T and Bokov V A 1967 *Instrums Exp. Tech., Pittsburgh* **3** 174–8

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Miniature sensor for two-dimensional magnetic field distributions

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Abstract We describe a simple method of production of a sensor for two-dimensional magnetic field distributions. The sensor consists of a strip of Ni–Fe (81–19), of which the magnetoresistance is utilized. Typical dimensions of the strip, placed at the edge of a glass substrate, are: length 100 μm, width 2 or 3 μm and thickness 40 nm.

1 Introduction

The sensor is, in fact, a further miniaturized version of the magnetic readout transducer described by Hunt (1971) and can be used for sensing two-dimensional field distributions such as produced by recording heads, recorded data in magnetic layers, etc. Its operation is based on the magneto-resistive effect in thin ferromagnetic film strips.

2 Description of technique

The production of such a sensor starts with the preparation of two glass slides with very carefully polished edges, the angle between the surfaces at the edge being slightly less than 90°. One of the slides serves as a substrate, the other one, upside down (figure 1(*a*)), as a mask for the subsequent vacuum deposition of the strip. The problem is to fix the mask in such a way that only a few micrometres of the substrate are left uncovered. (Such a manipulation can hardly be observed through a microscope. The thickness of the mask prevents the achievement of a sharp image of sufficient magnification.) Our solution has been to place the mask obliquely over the edge of the substrate in a sense depicted in figure 1(*b*). With a relative small magnification, say 100 ×, it is possible to observe the mask being positioned in such a way that A and B are 10 μm or less. A wedge-shaped magnetic film of 81–19 nickel–iron alloy is then produced on the substrate by vapour phase deposition. The angle of the wedge can be made very sharp ($\sim$0·001, C being $\sim$10 mm), however, so that one can be sure of finding a region of the strip that has the desired width over a considerable length.

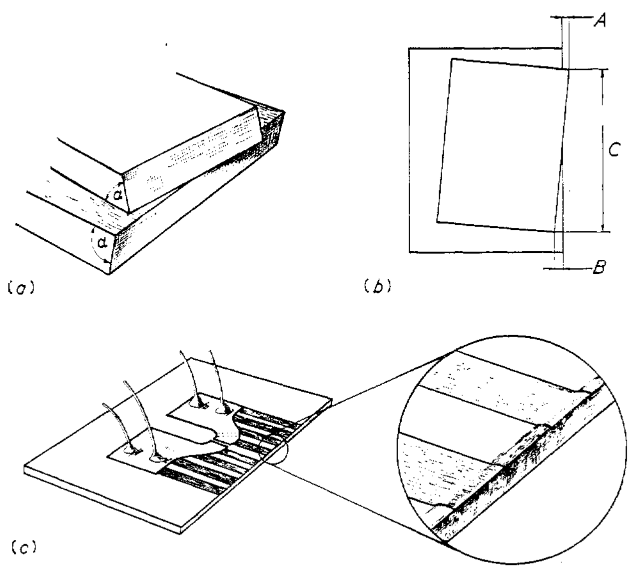

Figure 1 (*a*) Substrate and mask. The very carefully polished edges have been prepared with $\alpha \simeq 85°$.
(*b*) Position of the mask with respect to the substrate. A and B are 10 μm or less, C is about 10 or 20 mm.
(*c*) Completed sensor. The Ni–Fe strip is situated on the right edge. Of the contact strips (shaded), the nonrelevant ones are connected mutually with silver paint on to which contact leads are attached. If another part of the sensor has to be used, one has to remove the place of the breakthrough in the silver pattern (broken lines)

Golden contact strips are deposited next. The mask we used for this purpose has been constructed by simply winding thin copper wire (diameter 0·1 mm) around two small screws, fixed parallel to each other, about 20 mm apart. During deposition of the gold the substrate is situated within the space enclosed by the windings. From the resulting pattern the desired strip is selected (for our purpose 2–3 μm wide, 100 μm long and 40 nm thick) whereafter the nonrelevant goldstrips are mutually connected with silverpaint on to which the contact leads are attached (figure 1(*c*)).

3 Evaluation of the device

A clear advantage of this method of production is that the result contains many sensors, one of which can be chosen at will. As noticed by Hunt (1971) the range and sensitivity of sensors of this type depend on the width to thickness ratio as a consequence of demagnetizing fields within the film. So one is able to choose the film geometry according to the range and/or sensitivity requirements. An experimental (R, H) plot is shown in figure 2. R is the resistance of the Ni–Fe strip and H is the component of a transverse magnetic field (i.e. a field in a direction perpendicular to the axis of the strip), which is in the plane of the film. This curve is

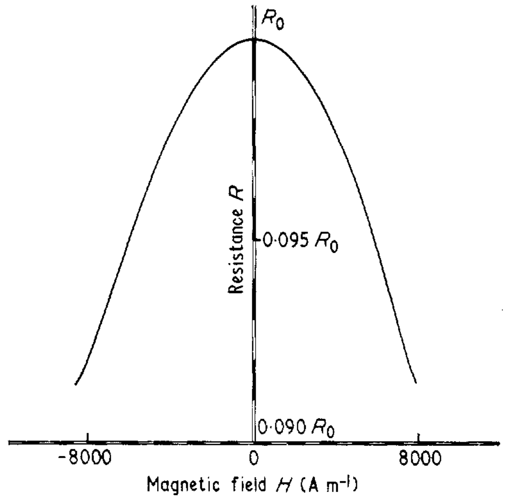

Figure 2 XY recorder plot of the resistance R of one sample as a function of the magnetic field H. R_0 is the zero field resistance. Since the vertical full scale is only 1% of the zero field resistance a stable DC potentiometric circuit is required. The resistance is measured by the four-terminal method

reproducible within a few percent of the full scale and applies to the situation in which the strip has been magnetized previously in a longitudinal direction. In this situation one has to be sure to avoid magnetic fields exceeding a certain critical value ($\sim$8000 A m^{-1} (100 Oe) for the example shown in figure 2) since from this point onwards nonreproducible processes occur in the film which make the sensor uncalibrated (in such a case proper operation can be restored by magnetizing the strip in a longitudinal direction once more). In a sensor of good quality this critical value is high. It depends on factors such as skew and dispersion of the direction of the easy axis of magnetization in the strip, which has been introduced in the longitudinal direction during deposition.

In general, the magnetoresistance of our samples showed good agreement with existing theories on this subject.

Descriptions of the magnetic properties of Ni–Fe films and the magnetoresistance behaviour of such films are given in several places in the literature (for example Middelhoek 1961, West 1961).

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References

Hunt R P 1971 *IEEE Trans. Magn.* **Mag-7** 150–4

Middelhoek S 1961 *Thesis* University of Amsterdam

West F G 1961 *J. Appl. Phys.* **32** 290 S–292 S

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An experimental study of the response of a venetian blind type photomultiplier

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Abstract The response of a windowless venetian blind type photomultiplier has been studied by scanning the first dynode which is used as a photocathode in a direction perpendicular to the slats. In our case the running of the photomultiplier (cathode grounded or at high negative potential; anode 3 kV positive with respect to the cathode) has a strong influence on the response. This effect is probably due to electrostatic field penetration through the mesh just before the first dynode (95% transmission), because the cathode faces the grounded exit slit of a vacuum monochromator. Remarkable differences in the response are measured across each slat. The influence of an additional mesh in front of the photocathode has been examined for both potential configurations. It makes the response more homogeneous and increases the overall sensitivity by about 80% (photocathode at high negative potential) or about 25% (photocathode grounded).

In order to study the response of a venetian blind type photomultiplier a microwave discharge was used as an intense and almost monochromatic light source (Saris *et al.* 1968) combined with a vacuum UV monochromator (used in near normal incidence). Grating, entrance slit and exit slit are placed on the Rowland circle. The concave grating (radius 1 m, 1200 lines/mm) is moved along the Rowland circle for wavelength selection. The entrance and exit slits are completely open so that the light from the source, directed through diaphragms, falls directly on the grating and the image on the photomultiplier. This special setting was used for a calibration of the quantum efficiency of grating and multiplier.

The photomultiplier is a windowless venetian blind type with 18 dynodes (EMI 9642/2A). The first dynode is used as a photocathode. Because of the distance (about 2 cm) between exit slit and multiplier, the image moves over the multiplier surface when the grating is moved along the Rowland circle; therefore the position of the slats with respect to the exit slit is very important for detection. In a direction perpendicular to the slats one can expect an inhomogeneity in the sensitivity as a result of the periodic structure of the detecting surface.

In order to study this inhomogeneity quantitatively we scanned the photocathode by means of a small light spot in a direction perpendicular to the slats (slats horizontal, multiplier moved vertically). The tracing light spot was formed by an additional slit just behind the vertical exit slit; this additional slit is parallel to the slats. The height of the thus obtained aperture was 0·5 mm; the width 3·0 mm was determined by the width of the light beam so that the dimensions of the light spot were small compared with the dimensions of the slats.

Measurements were performed in two configurations: (i) the photocathode at high negative potential (−3 kV), the anode being grounded, measurements by DC techniques; (ii) the photocathode grounded and the anode at high positive potential (+3 kV), measurements by pulse counting techniques.