Miniature sensor for two-dimensional magnetic field distributions

J H J Fluitman and H W Krabbe
Department of Electrical Engineering, Twente University of Technology, Enschede, The Netherlands

MS received 4 April 1972

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 magnetoresistive 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 (~0.001, C being ~10 nm), however, so that one can be sure of finding a region of the strip that has the desired width over a considerable length.

Golden contact strips are deposited next. The mask we used for this purpose has been constructed by simply winding tin 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 silvery paint 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
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).

Acknowledgments
We should like to thank our colleagues Ir P de Haan, Mr B Hurenkamp and Ing J H Veldkamp for their advice and technical assistance.

References
Middelhoek S 1961 Thesis University of Amsterdam
Printed in Great Britain © 1972