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NEW SEMICONDUCTOR BUBBLE DOMAIN DETECTOR EMPLOYING THE HALL EFFECT ASSOCIATED WITH AN INVERTED MAGNETIC FIELD

Shoei Kataoka, Hideo Yamada and Yoshinobu Sugiyama

Electrotechnical Laboratory

5-4-1, Mukodai, Tanashi, Tokyo, Japan.

So far, galvanomagnetic effects in semiconductors have mainly been discussed only under a uniform magnetic field, and very little is known what happens when a piece of semiconductor is subjected to an inverted magnetic field distribution. However, with the advant of magnetic bubble domain phenomena, understanding of galvanomagnetic effect under such an inverted magnetic field distribution becomes very important not only from a detector point of view but also from a fundamental physical point of view. All the Hall effect detectors so far reported are based on the conventional Hall effect, i.e. under a uniform magnetic field.[1][2] In such a conventional method, the active area of a Hall element must be small enough to be included completely in a bubble domain, as shown in Fig. 1(a)(b). Thus, for the detection of an extremely small bubble domain in garnet, difficulties arise not only in the fabrication of an element but also in the degree of output voltage, which is proportional to the size of an element.

This paper describes a principle and experimental results of a new Hall effect bubble domain detector, in which a magnetic bubble domain should completely be included in an active area of a semiconductor element like a Sun-Flag of Japan as shown in Fig. 2. In such a Sun-Flag arrangement, the directions of the Hall electric field due to the bias magnetic field and to the magnetic bubble domain are opposite to each other, and thus the Hall output voltage across the Hall output terminals of the element decreases to be zero, while a certain amount of Hall voltage due to the bias magnetic field appears when no bubble domain is present. In general, in an element either of non-uniform carrier concentration or under a non-uniform magnetic field, the Hall electric field always tends to be short-circuited, and the Hall output voltage decreases than the case of uniform carrier concentration or of uniform magnetic field. With an suitable geometry of the Hall element with respect to the size of a bubble domain, the current due to the internal Hall electric field would flow as indicated by dash-dotted lines in Fig. 3, and the net Hall voltage would be practically zero. Thus a magnetic bubble domain can be detected by the change of Hall voltage. If we use two three-terminal Hall elements of this principle in a similar way to the proviously reported method[3] as shown in Fig. 4, the voltage across the output terminals of both elements is a direct measure of a magnetic bubble domain. A two-dimensional arrayed structure can be made very easily with an arrangement as described before and functional action of Exclusive OR or AND will also be performed by this means.

Fundamental experiments were made with an InSb single crystal of electron mobility of 71,000 $cm^2/V\cdot sec$, and electron concentration of $1.6 \times 10^{16} cm^{-3}$. The width of the Hall elements ranges from 100 to 125 μm. When a Hall element of 125 μm width was subjected to a magnetic bubble domain of diameter about 110 μm in $YFeO_3$, the Hall output voltage became practically zero (0.01 mV at

5 mA), while about 0.4 mV appeared at 5 mA for no bubble domain. The maximum output voltage, about 1.5 mV was obtained with this element at 30 mA. When a Hall element of 100 μm width was subjected to the same kind of magnetic bubble domain of diameter less than 100 μm, an output voltage of 1.3 mV (difference in the Hall voltages without and with a bubble domain) was obtained at 25 mA. Since the Hall elements used for these measurements are of rather poor sensitivity (about 3mV/mA·KG), much improvement of the performance can be expected. Details of the relation between the element width and the bubble diameter will be discussed.

In conclusion, it is found that a magnetic bubble domain can be detected with an Hall element much larger than a bubble domain if a Sun-Flag arrangement is used. This will make the detector fabrication easier and increase the magnitude of an output voltage.

REFERENCES

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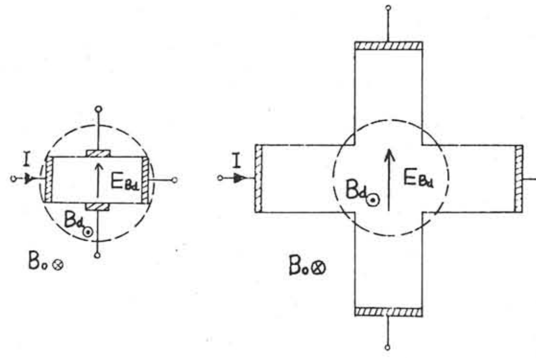

(a) Fig. 1 (b)

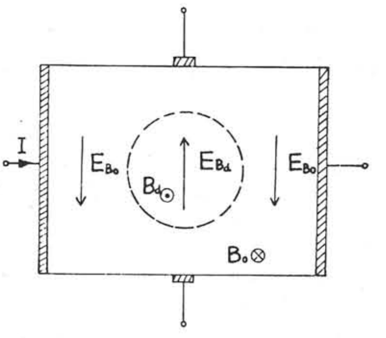

Fig. 2

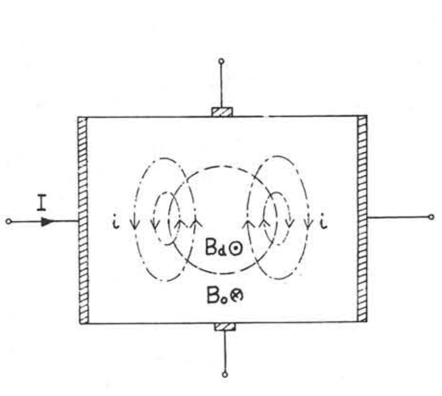

Fig. 3

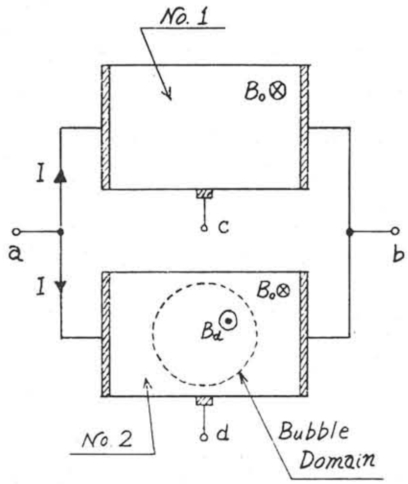

Fig. 4