

MULTIPLEXED MAGNETIC BUBBLE DETECTORS

1. Field of the Invention.

The invention relates to the field of magnetic bubble detection.

2. Prior Art.

5 In the fabrication of magnetic bubble (single wall domain) devices, particularly magnetic bubble memories, it is important to limit the number of connections that must be made between the memory substrate and external circuits. Also, it is advantageous to use as few as possible external circuits and to have, for
10 example, the same driving circuit power two bubble generators. In copending U.S. application Serial No. 25,848, filed April 2, 1978, entitled "Multiplexed Single Wall Domain Generators", (assigned to the assignee of the present application), a system is described for multiplexing bubble generators. As will be seen,
15 the present invention teaches an apparatus for multiplexing the outputs of bubble detectors.

There have been attempts in the past to multiplex bubble detector outputs. In one scheme, four chevron detectors are formed at different angular orientations. For example, the
20 detectors are oriented each 90 degrees from the other, like spokes of a wheel. Then, the detectors are coupled to a common sensing circuit. One problem with this scheme is described in conjunction with Figure 3a of the specification.

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SUMMARY OF THE INVENTION

According to the present invention there is provided a magnetic bubble detection apparatus comprising a first magnetic bubble detector including a first propagation element which propagates bubbles from its leading edge to its trailing edge under the influence of a rotating magnetic field, and a first detection element disposed in the region of said leading edge of said first propagation element and insulated from said element so as to sense the presence of a bubble as it is propagated through the region of said leading edge of said first propagation element, and a second magnetic bubble detector including a second propagation element which propagates bubbles from its leading edge to its trailing edge under the influence of said rotating magnetic field, and a second detection element disposed in the region of said trailing edge of said second propagation element and insulated from said element so as to sense the presence of a bubble as it is propagated through the region of said trailing edge of said second propagation element, said first and second detectors being placed relative to one another such that the angles formed between said detectors and said rotating magnetic field are the same, whereby the outputs from said first detection element and second detector element may be multiplexed.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a plan view of a prior art magnetic bubble detector.

Figure 2 is a cross-sectional elevation view of a portion of the detector of Figure 1 generally taken through section line 2-2 of Figure 1.

Figures 3a - 3c illustrate various detector elements and the outputs from the elements.

Figure 3a illustrates a chevron detector and the output from this detector.

Figure 3b illustrates a bubble detector which includes a separate detector element, and the output from this element when the element is disposed in the region of the leading edge of the propagation element.

Figure 3c illustrates a bubble detector which includes a separate detector element, and the output from this element when the element is disposed in the region of the trailing edge of the propagation element

Figure 4 is a schematic of the detection apparatus of the present invention, in its presently preferred embodiment.

Figure 5 is a cross-sectional elevation view illustrating processing steps used to define the detector element used in the present invention and to optimize its output.

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DETAILED DESCRIPTION OF THE INVENTION

A magnetic bubble detection apparatus is described which provides multiplexed outputs from two separate detectors. With the invented apparatus two independent streams of bubbles are detected with separate detector elements and the resultant signal from these separate elements is sensed on a single pair of lines. This reduces the number of package pins required, and moreover, the number of sense amplifiers needed for detection.

In the following description numerous specific details are set forth such as specific thicknesses, etc. in order to provide a thorough understanding of the present invention. It will be obvious to one skilled in the art that the present invention may be practiced without these specific details. In other instances, well-known structures and processes are not set forth in detail, in order not to obscure the present invention in unnecessary detail.

Referring now to Figure 1, a prior art bubble detector is illustrated which includes an expander section 10, a propagation element 12 which comprises a column of chevrons, a bubble trap defined between chevron columns 13 and 14, and an additional column of chevrons 15. A magnetic bubble, as it is propagated past the element 12, is detected by an elongated detector element (strip of magnetoresistive material) disposed below element 12. As is generally the case, magnetic bubbles are moved

into the detector of Figure 1 in the direction 20 under the influence of an in-plane rotating magnetic field. As the bubbles are propagated past the column of chevrons 12, the resistance of the underlying detector element is changed, and this change is 5 sensed. Bubbles are then propagated onto element 13 and become trapped between the elements 13 and 14.

An additional column of chevrons 15 which is identical to the column of chevrons 12, and an additional "dummy detector" element 17 which is identical to the detector 16 is disposed 10 adjacent to the trap. Even though elements 15 and 17 do not receive and sense bubbles, they are affected by the rotating magnetic field. The signal from the element 17 is used as a reference signal to effectively cancel (reject) the effects of the rotating magnetic field on the element 16.

15 In Figure 2 only those layers of a memory or other device needed to view the detector of Figure 1 are shown. The structure is formed on a substrate 21 which is typically a garnet substrate. An ion implanted magnetic garnet (epitaxial layer 22) is employed on the substrate for the magnetic bubble storage 20 layer. The single wall domains are moved in this layer as is well-known. A silicon dioxide layer 23 which is approximately 1500A thick is formed over the epitaxial layer. Then the detector element 16 is fabricated on the layer 23 using ordinary photolithographic techniques from a magnetoresistive material 25 such as permalloy.

An additional oxide layer is formed

over layer 23 to insulate the detector 16 from the overlying permalloy members. This oxide layer 24 is approximately 1500A thick. Then, the permalloy propagation elements such as the 5 column of chevrons 12 are formed over the oxide layer 24 in a well-known manner.

The present invention may be best understood with reference to the diagrams of Figure 3. In Figure 3a, a prior art chevron detector 25 is illustrated which comprises a plurality of 10 interconnected chevrons. When a bubble is moved through this chevron detector under the influence of a rotating magnetic field, the waveform shown to the right of detector 25 results for each cycle of the rotating magnetic field. As can be appreciated, it is difficult to multiplex a number of outputs 15 from detectors such as detector 25 because of the resultant waveform.

In Figure 3b, a detector similar to the detector shown in Figure 1 is illustrated, however, the detector element 27 is disposed in the region of the leading edge of the propagation 20 element 26. Assuming bubbles are moving in the direction of arrow 29, they first reach a first edge of the element 26 (leading edge) and then are propagated to the opposite edge (trailing edge) of the element. For the relative location of the detector element 27 and propagation element 26 of Figure 3b, a 25 bubble is sensed by the detector during the first part of each cycle of the rotating magnetic field as shown to the right of

elements 26 and 27 (ignoring the effects of the rotating magnetic field on the detector element).

5 In Figure 3, another propagation element 30 is illustrated with an underlying detection element 28. This time, however, the detection element 28 is disposed in the region of the trailing edge of the element 30. In this position, a bubble is sensed towards the end of each cycle of the rotating magnetic field as indicated by the graph shown to the right of elements 28 and 30.

10 The appreciation that during a cycle of the rotating magnetic field a bubble can be sensed at different portions of this cycle (compare Figure 3b and Figure 3c) is put to use for multiplexing purposes as taught by the present invention.

15 Referring now to Figure 4, in the presently preferred embodiment, the detector elements of two detectors are coupled in a bridge circuit. Detector 1 of Figure 4 includes an expander section not illustrated which expands bubbles and propagate them into propagation element 32 (a column of chevrons). The bubbles are then propagated into a trap which is disposed between the column of chevrons 32 and the columns of chevrons 35. A
20 magnetoresistive detection element 33 is disposed beneath the propagation element 32 in the region of the leading edge of the element 32. An identical element, dummy element 34, is disposed in the region of the leading edge of the column of chevrons 35. Element 33 is electrically coupled between contacts 45 and 47,
25 and the dummy element 34 is coupled between the contacts 46 and

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49. Referring briefly to Figure 2, for the detector 1 of Figure 4, the detector element 33 and dummy element 34 would be centered about the line 36 and again insulated from the overlying chevrons.

Detector 2 of Figure 4 again includes an expander section not illustrated which propagates bubbles into the propagation element 40. Disposed beneath the propagation element 40 is a detector element 41 which again comprises a magnetoresistive material. The element 41 is coupled between the contacts 48 and 51. The element 41 is in the general region of the trailing edge of the propagation element 40. A trap is disposed between the propagation element 40 and the column of chevrons 42. A dummy element 43 is disposed beneath the column of chevrons 42 in the region of the trailing edge of chevrons 42. This dummy element is connected between contacts 50 and 52. Referring briefly to Figure 2, the detector element 41 and element 43 would be centered on line 37 for detector 2 of Figure 4. (Note that the precise location of the detector elements and dummy elements relative to the leading edge and trailing edge of the propagation element is not particularly critical.)

The layout (in terms of size and orientation relative to the rotating magnetic field) of elements 32 and 33 when compared to elements 35 and 34, respectively, is identical to provide proper electrical performance. The same is true for elements 40 and 41, and elements 42 and 43, respectively. (This, of course, is true for the prior art detector of Figure 1).



The detector 1 and detector 2 of Figure 4 are coupled in a bridge circuit. A potential is applied to the contacts 44 and 46. Contact 47 is coupled to contact 50, and contact 48 is coupled to contact 49. The contacts 51 and 52 are coupled to ground. In this bridge circuit, the dummy elements null out the effect of the rotating magnetic field on the detector elements and allow the bubbles passing through the propagation elements 32 and 40 to be sensed. The output signal from the detectors is taken from contacts 47 and 49 which contacts are typically coupled to package pins, and via lines on a printed circuit board to a sense amplifier.

By knowing the portion of a cycle of the magnetic field during which a bubble is detected (or not detected) the output from each of the detectors 1 and 2 is known.

Referring again to Figure 3, the output sensed from the bridge circuit of Figure 4 (and at the sense amplifier) consists of a graph of Figure 3b superimposed on the graph of Figure 3c. It is apparent that the signal caused by a bubble moving through element 32 of Figure 4 can readily be discerned from a bubble moving through element 40 even though the bubbles move through these column of chevrons at the same time. The "quiet period" (no signal) region of Figure 3c falls within the period when a signal is generated in Figure 3b, and vice versa.

It has been found that the output from the detector elements such as detector elements 33 and 41 of Figure 4 can be optimized by having the width to thickness ratio of these elements equal to

a predetermined number. By way of example, with a prior art chevron detector (Figure 3a), output signals of approximately 5mv are typical. By controlling the w/t ratio of the detector elements used in the present invention, output signals of approximately 20mv are obtained. (This assumes the length of chevron detector is approximately equal to the length of the element 33 or 41.

Through empirical determination it has been found that the ratio w/t for the detector element (see Figure 5) should be approximately equal to 100 for maximum output where a typical permalloy is used. (In the presently preferred embodiment, the permalloy comprises 81% nickel and 19% iron). Due to process variations the w/t ratio can vary as much as + 20%. These variations, particularly at the extremes, substantially deteriorate the output from the detector elements.

During fabrication in the presently preferred process, the layer from which the detector element 61 of Figure 5 is etched, is first formed over the oxide layer 60. (The detector element 61 corresponds to the elements 33, 34, 41 or 43 of Figure 4.)

After the fabrication of the layer, its thickness is checked, for example, by checking the sheet resistance of the layer. Once the thickness is known, the desired width is likewise known since the w/t ratio should be approximately 100. A photoresist layer is formed over the permalloy layer and with an ordinary masking step, a masking member 62 is formed which

is used to define the detector 61. Then the etching step used to etch the permalloy layer is controlled to provide an undercutting 64 under the photoresist member 62. This controlled undercutting is allowed to continue until the desired width w is achieved. As is well-known, this etching can be quite precisely controlled.

The thickness of the permalloy layer is generally quite uniform over the entire wafer. Thus, all the detector elements (and dummy elements) on a given wafer will require the same etching time and can be formed with one masking and etching step.

The same result can be achieved by first forming an extra thick permalloy layer from which the detectors are to be etched. Then, after the etching with a photoresist member such as member 62 of Figure 5, the width to thickness ratio is measured.

It, of course, would be expected that the ratio w/t is less than 100 since the permalloy layer was intentionally made thick. The detector elements are then etched to decrease their thickness until the desired thickness is achieved. This etching is preferably done with ion milling with the entire wafer being subjected to such milling.

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Thus, a magnetic bubble detection apparatus has been described which permits the multiplexing of the outputs from two detector elements.

In our copending U.K. patent application No. 84/19985

- 5 divided-out-of the present application there is described and claimed in the fabrication of a magnetic bubble detector which includes a magnetoresistive detection element and a propagation element insulated from said detection element, a method for optimizing the output from said detection element comprising:
- 10 controlling the ratio of the width and thickness of said detection element such that said ratio is approximately equal to a predetermined number; whereby the output of said detection element is optimized.



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CLAIMS

1. A magnetic bubble detection apparatus comprising:

a first magnetic bubble detector including a first propagation element which propagates bubbles from its leading edge to its trailing edge under the influence of a rotating magnetic field,

5 and a first detection element disposed in the region of said leading edge of said first propagation element and insulated from said element so as to sense the presence of a bubble as it is propagated through the region of said leading edge of said first propagation element; and,

10 a second magnetic bubble detector including a second propagation element which propagates bubbles from its leading edge to its trailing edge under the influence of said rotating magnetic field, and a second detection element disposed in the region of said trailing edge of said second propagation element and insulated
15 from said element so as to sense the presence of a bubble as it is propagated through the region of said trailing edge of said second propagation element;

said first and second detectors being placed relative to one another such that the angles formed between said detectors and
20 said rotating magnetic field are the same, whereby the outputs from said first detection element and second detector element may be multiplexed.

2. The apparatus defined by Claim 1 where said first and second propagation elements are each a column of chevrons.

25 3. The apparatus defined by Claim 2 wherein said first and second detection elements are disposed beneath said first and second propagation elements, respectively.



4. The apparatus defined by Claim 3 wherein said detection elements comprise a magnetoresistive material.

5. The apparatus defined by Claim 4 wherein the width to thickness ratio of said detection elements equals approximately 100.

5 6. A magnetic bubble detection apparatus comprising:

a first magnetic bubble detector including:

a first expander section for expanding a magnetic bubble;

a first propagation element for receiving an expanded magnetic bubble from said first expander section, said propagation element

10 for propagating said magnetic bubble from the leading edge to the trailing edge of said first propagation element under the influence of a rotating magnetic field;

a first detection element for detecting a magnetic bubble disposed below and insulated from said first propagation element,

15 said first detection element disposed in the region of said leading edge of said first propagation element; and,

a second magnetic bubble detector including:

a second expander section for expanding a magnetic bubble;

a second propagation element for receiving an expanded

20 magnetic bubble from said second expander section, said propagation element for propagating said magnetic bubble from the leading edge to the trailing edge of said second propagation element under the influence of said rotating magnetic field;

a second detection element for detecting a magnetic bubble

25 disposed below and insulated from said second propagation element, said second detection element disposed in the region of said trailing edge of said second propagation element;



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said first and second detectors being placed relative to one another such that the angles formed between said detectors and said rotating magnetic field are the same, whereby signals from said first and second detectors may be multiplexed.

- 5 7. The apparatus defined by Claim 6 wherein said first and second propagation elements are columns of chevrons.
8. The apparatus defined by Claim 6 wherein said first and second detection elements each have a thickness to width ratio of approximately 100.
- 10 9. A magnetic bubble detection apparatus comprising:
- a first magnetic bubble detector including:
 - a first expander section for expanding a magnetic bubble;
 - a first column of chevrons for receiving magnetic bubbles from said first expander section;
 - 15 a first detection element for detecting the presence of a magnetic bubble, said first detection element disposed below and insulated from said first column of chevrons adjacent to the first edge of said first column of chevrons;
 - a second column of chevrons;
 - 20 a first magnetoresistive element disposed below and insulated from said second column of chevrons adjacent to the first edge of said first magnetoresistive element;
 - a second magnetic bubble detector including:
 - a second expander section for expanding a magnetic bubble;
 - 25 a third column of chevrons for receiving magnetic bubbles from said second expander section;
 - a second detection element for detecting the presence of a

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magnetic bubble, said second detection element disposed below and insulated from said third column of chevrons adjacent to the second edge of said third column of chevrons, said second edge being opposite to said first edge of said first detection element;

5 a fourth column of chevrons;

a second magnetoresistive element disposed below and insulated from said fourth column of chevrons adjacent to the second edge of said fourth column of chevrons, said second edge being opposite to said first edge of said first magnetoresistive element;

10 said first and second detectors being placed relative to one another such that the angles formed between said detectors and said rotating magnetic field are the same, whereby said first and second magnetic detectors may be coupled in a bridge circuit with said circuit providing multiplexed outputs.

15 10. The apparatus defined by Claim 9 including a first magnetic bubble trap disposed between said first and second columns of chevrons and a second magnetic bubble trap disposed between said second and third columns of chevrons.

11. A magnetic bubble detection apparatus
20 substantially as hereinbefore described with reference to and as illustrated in Figs. 4 and 5 of the accompanying drawings.