

PATENT SPECIFICATION

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(54) MAGNETIC BUBBLE MEMORY

(71) We, HEWLETT-PACKARD COMPANY, of 1501 Page Mill Road, Palo Alto, California 94304, United States of America, a corporation organised and existing under the laws of the state of California, United States of America, do hereby declare the invention, for which we pray that a Patent may be granted to us and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention is concerned with improvements in or relating to magnetic bubble memories.

15 Magnetic bubble memories are superior to most prior art memories such as magnetic discs and drums because they have greater information storage densities and operating speeds, and they require no moving parts. However, these memories require the application of a magnetic field to create the magnetic domains or bubbles as well as a field to maintain the domains at the proper locations within the memory. It is customary to have a static magnetic field perpendicular to the plane of the memory material for forming the domains, and the domains may be moved along a path by a rotating magnetic field generated by electromagnets around the memory material. When power to the memory is shut off, this rotating magnetic field is also turned off, and the domains are left relatively free to move in the magnetic material since they are restrained only by the coercive force in the material. Thus, when the power is again turned on the information stored in the memory may be lost and spurious information may be there in its place.

It is an object of the present invention to provide an improved magnetic bubble memory.

The present invention provides a magnetic bubble memory comprising:

[Price 25p]

a sheet of magnetic material having an easy axis substantially normal to the major surfaces of the sheet;

means for producing a first static magnetic field parallel to the easy axis for forming and maintaining magnetic bubbles in the sheet and a second static magnetic field normal to the easy axis for preventing movement of the magnetic bubbles in the absence of other coplanar magnetic fields;

a pattern of structures on a major surface of the sheet describing a path along that surface for guiding magnetic bubbles formed in the sheet along the path; and

means for producing a rotating magnetic field in the plane of the major surface for moving the bubbles along the path, including means for cancelling the second static magnetic field.

Preferably the means for producing the first and second magnetic fields comprises a permanent magnet producing a field canted with respect to a major surface of the sheet of magnetic material.

Preferably the means for producing a rotating magnetic field comprises:

- an A.C. signal generator;
- a first coil surrounding the sheet of magnetic material and connected to the A.C. signal generator;
- a phase shifter connected to the A.C. signal generator;
- a second coil, orthogonal to the first coil, surrounding the sheet of magnetic material and connected to the phase shifter; and
- a bucking bias supply connected to the coils to produce a field for cancelling the second static magnetic field.

The present invention further provides a magnetic bubble memory comprising a sheet of magnetic material having an easy axis substantially normal to the major surfaces of the sheet; means for producing a first static magnetic field parallel to the easy axis for forming and maintaining

magnetic bubbles in the sheet; a pattern of structures on a major surface of the sheet describing a path along that surface for guiding magnetic bubbles formed in the sheet along the path; means for producing a second static magnetic field normal to the easy axis for preventing movement of the magnetic bubbles in the absence of other coplanar magnetic fields; and means for producing a rotating magnetic field in the plane of the major surface for moving the bubbles along the path, including means for cancelling the second static magnetic field.

There now follows a detailed description which is to be read with reference to the accompanying drawings of a magnetic bubble memory according to the invention; it is to be clearly understood that this memory has been selected for description to illustrate the invention by way of example and not by way of limitation.

In the accompanying drawings:—

Figure 1 is a schematic illustration of a magnetic bubble memory according to the invention and the associated magnetic field vectors; and

Figure 2 is a schematic diagram of means of magnetic bubble memory according to the invention for generating the magnetic fields.

Magnetic bubble memories have been known for some time and are well documented in the literature. Therefore, the detailed operation of magnetic bubble memories will not be described herein; a complete description of the basic structure and operation may be found, for example, in "Magnetic Bubbles" by Andrew H. Bobeck and H. E. D. Scovil in Scientific American, June, 1971, pages 78-90.

In Figure 1 of the drawing, a sheet of magnetic material 10 such as a rare earth garnet has a pattern of structures 12, made of a soft magnetic material such as Permalloy, that describe a path along the surface of the sheet of material 10. The pattern shown is the so-called T-bar pattern but any pattern used with magnetic bubble memories may be used in connection with this invention. Several magnetic bubbles 14 are shown located around the pattern 12. These bubbles are formed by a magnetic field shown as a vector 16 which is parallel to the easy axis of the sheet of magnetic material 10. The sheet of magnetic material 10 has been formed to orient the crystal structure of the material such that its easy axis is normal to the major surfaces of the sheet of material. A vector 18 represents a rotating magnetic field. As this field rotates in a counter-clockwise direction, the magnetic bubbles 14 will move around the pattern 12 in a counterclockwise direction. For each rotation of the

vector 18 the bubbles will move to the next similar position on the pattern. Thus, a bubble 14b will move to the position occupied by a bubble 14a when the vector has completed one complete rotation.

Each rotation of the magnetic field may be considered to be a cycle, and an arbitrary phase of the rotation of the field may be selected as a starting point of a cycle. Thus the position of the vector 18 as shown in Figure 1 has been arbitrarily selected as the start of a cycle for the present purposes. Whenever the machine employing this memory is started or stopped, the vector 18 starts and stops in the position shown. To insure that the information in the memory will not be lost when the rotating field is turned off, an in-plane bias magnetic field component that is equal in magnitude to the vector 18, represented as a vector 20, is provided parallel to the starting point of the vector 18. Thus, whenever the rotating magnetic field is absent, the in-plane bias, represented by the vector 20, may be generated by putting the sheet of magnetic material 10 in a canted magnetic field, represented by a vector 22, which also produces the bubble-maintaining magnetic field, represented by a vector 16.

Figure 2 shows a schematic illustration of means for producing the magnetic fields shown in Figure 1. The sheet of magnetic material 10 is shown situated in the gap of means in the form of a permanent magnet 24 for producing a first static magnetic field parallel to the easy axis for forming and maintaining magnetic bubbles in the sheet and for producing a second static magnetic field normal to the easy axis for preventing movement of the magnetic bubbles in the absence of other coplanar magnetic fields. The sheet of material is canted with respect to the magnetic field lines in the gap of the permanent magnet. Alternatively separate means may be used for producing the field components which are normal and parallel to the easy axis. Figure 2 also shows means including coils 26 and 28 for generating the rotating magnetic field. The coil 26 is connected to an A.C. signal generator 30, and the coil 28 is connected to the A.C. generator 30 through a 90° phase shifter 32. If the generator 30 is sinusoidal, the magnetic field generated by the coils 26 and 28 will not only rotate but the vector representing the strength of that field will describe a circle. In order to cancel the field represented by the vector 20, a D.C. bucking bias is applied by a power supply 34 to create a D.C. field in the coil 28 equal in magnitude and opposite in direction to the vector 20. Thus, when the rotating magnetic field generating means is in operation, the in-plane bias

field is cancelled out by the field generated by the bucking bias. Whenever a power failure occurs in the machine using the magnetic memory, control circuits connected to the rotating magnetic field generating means will return the vector 18 to its starting position and shut down the generating circuitry. Once power is turned off, the bias field represented by the vector 20 will keep the bubbles from moving or wandering and thus protect the memory against information loss whether the power is shut off accidentally or purposefully.

WHAT WE CLAIM IS:—

1. A magnetic bubble memory comprising:

a sheet of magnetic material having an easy axis substantially normal to the major surfaces of the sheet;

means for producing a first static magnetic field parallel to the easy axis for forming and maintaining magnetic bubbles in the sheet and a second static magnetic field normal to the easy axis for preventing movement of the magnetic bubbles in the absence of other coplanar magnetic fields;

a pattern of structures on a major surface of the sheet describing a path along that surface for guiding magnetic bubbles formed in the sheet along the path; and

means for producing a rotating magnetic field in the plane of the major surface for moving the bubbles along the path, including means for cancelling the second static magnetic field.

2. A magnetic bubble memory according to claim 1 wherein the means for producing the first and second magnetic fields comprises a permanent magnet producing a field canted with respect to a major surface of the sheet of magnetic material.

3. A magnetic bubble memory according to either one of claims 1 and 2 wherein

the means for producing a rotating magnetic field comprises:

an A.C. signal generator;

a first coil surrounding the sheet of magnetic material and connected to the A.C. signal generator;

a phase shifter connected to the A.C. signal generator;

a second coil, orthogonal to the first coil, surrounding the sheet of magnetic material and connected to the phase shifter; and

a bucking bias supply connected to the coils to produce a field for cancelling the second static magnetic field.

4. A magnetic bubble memory comprising a sheet of magnetic material having an easy axis substantially normal to the major surfaces of the sheet; means for producing a first static magnetic field parallel to the easy axis for forming and maintaining magnetic bubbles in the sheet; a pattern of structures on a major surface of the sheet describing a path along that surface for guiding magnetic bubbles formed in the sheet along the path; means for producing a second static magnetic field normal to the easy axis for preventing movement of the magnetic bubbles in the absence of other coplanar magnetic fields; and means for producing a rotating magnetic field in the plane of the major surface for moving the bubbles along the path, including means for cancelling the second static magnetic field.

5. A magnetic bubble memory constructed, arranged and adapted to operate substantially as hereinbefore described with reference to the accompanying drawings.

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