

PATENT SPECIFICATION

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 (72) Inventor ANDREW HENRY BOBECK



(54) IMPROVEMENTS IN OR RELATING TO MAGNETIC DEVICES

(71) We, WESTERN ELECTRIC COMPANY, INCORPORATED, of 195, Broadway, New York City, New York State, United States of America, a Corporation organised and existing under the laws of the State of New York, 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 relates to magnetic devices.

G. B. Patent No. 1,241,235 describes an arrangement for moving single wall domains in a layer of material along multistage propagation channels defined by a pattern of magnetically soft elements in response to a magnetic field reorienting in the plane of the layer. Propagation of domains in the manner described in that pattern has become known as a "field-access" mode of propagation because the rotating field provides the driving force for domain movement.

U.S. Patent No. 3,723,716 describes a fine-grained pattern of magnetically soft elements which not only defines multistage propagation channels for domains but permits lateral displacement of domains from one channel to another as well as certain logic functions. The term "fine-grained" herein means that adjacent elements of a stage of a channel are spaced part distances about equal to or less than the diameter of a domain moved by the pattern.

The fabrication of any single wall domain arrangement necessitates certain mechanical operations which result in the introduction of spurious domains into the vicinity of operative domain channels. For example, domains are moved in a layer of epitaxially grown material which is diced into areas sufficiently large to accommodate the channel-defining patterns. The dicing pro-

cedure results in abraded edges which give rise to spurious domains during later operation. Moreover, the pattern of magnetically soft material which defines the domain propagation channels in the field-access arrangement is formed by photolithographic techniques which typically employ alignment patterns which give rise to spurious domains. Both circuit and crystal defects also give rise to spurious domains as is well known. Particularly during the testing of finished domain circuits to establish margin limits are such spurious domains introduced. But even in this situation, the domains have only negligible effect on circuit operation at quasistatic (low frequency) speeds.

At high speeds (in excess of 100 Hz) on the other hand, the situation is quite different. Even infrequent introduction of spurious domains, particularly when added to others introduced during testing, results in the presence of a considerable number of domains. If it is recalled that single wall domains repel one another, it may be appreciated that increasingly larger numbers of domains distribute themselves within the available space in an array which eventually encroaches on the operative circuit. When the "domain pressure" becomes sufficiently high, interaction between data representing domains and spurious domains results in random nonrecurring failures.

The problem then is how to prevent the movement of domains from the edge of the domain layer into the vicinity of the operative circuit and, further, how to eliminate spurious domains which are generated in the vicinity of the operative circuit. The problem is compounded by the realization that any implementation which functions in the sense of a familiar "guard rail" may be operative itself to generate spurious domains and is ineffective in eliminating domains within its confines.

[Price 33p]

According to the present invention there is provided a magnetic device comprising a layer of material in which single wall domains can be moved, and a first propagation arrangement defining a first channel therein, the propagation arrangement serving to move a said domain associated therewith across said channel from a first side thereof to the other side in response to a varying magnetic field, the net movement of said domain being substantially only lateral with respect to said channel.

The magnetic device may have a second propagation arrangement nearer to said first side than to said other side of said first channel, and in operation, when said magnetic field varies a domain associated with said second arrangement may be propagated in part of said layer associated therewith.

The first channel may be disposed to encompass the second propagation arrangement.

The varying magnetic field may be a field reorienting in the plane of the layer.

The first propagation arrangement may comprise a fine grained pattern of V-shaped elements. The fine grain pattern of elements may comprise a plurality of lines of said elements. The fine grained pattern of elements may comprise a plurality of said V-shaped elements disposed along a helical path.

The spacing between said second arrangement and said first channel may be substantially equivalent to three times the diameter of a said domain.

The device may include a third propagation arrangement defining a second channel encompassing said first channel, the third propagation arrangement may be disposed such that, in operation, in response to said varying magnetic field a domain associated with the third propagation arrangement moves towards the area between said first and third propagation arrangements.

In one embodiment of the invention a single wall domain circuit operative in the field-access mode may be encompassed by a propagation arrangement comprising illustratively a fine-grained pattern of magnetically soft elements operative, in response to the already present in-plane field, to move spurious domains along radial paths outwardly from the vicinity of the operative circuit. Such an arrangement is effective not only in excluding spurious domains generated, for example, at the edges of the domain layer but also in removing from within its confines any spurious domains which might be created due to alignment patterns or crystal or circuit defects in, for example, the event of a temporary loss of power.

It is to be remembered that it is most likely that an occasional spurious domain

will have only a negligible disrupting influence on an operative circuit as has been indicated above and that a considerable number of domains would be necessary to build up a "domain pressure" resulting in disruptive interactions. A propagation arrangement embodying the invention relieves this pressure allowing domain movement only outwardly "through" it into a nonoperative portion of a domain layer.

More specifically, a propagation arrangement is defined by three rows of elements arranged in a closed loop chevron pattern with the apices of the elements directed along the loop axis. In response to a counterclockwise rotating in-plane field, spurious domains are moved outwardly from an operative circuit encompassed within the closed loop.

The invention will now be described with reference to the accompanying drawing in which:

FIG. 1 is a schematic representation of a single wall domain magnetic device embodying the invention; and

FIGS. 2 and 3 are schematic representations of portions of the arrangement of FIG. 1.

FIG. 1 shows a domain propagation arrangement 10 embodying the invention. The arrangement comprises a layer 11 of a magnetic material in which single wall domains can be moved. A pattern of magnetically soft elements is formed by familiar photolithographic techniques for defining domain propagation channels. The illustrative pattern is shown in line diagram form as a major-minor memory organization disclosed in U.S. Patent No. 3,618,054. The major-minor memory organization as well as its implementation and operation is now well known in the art. What is important here is that an operative organization, illustratively implemented in the field-access mode is encompassed by a propagation ring 12 for the removal of spurious domains.

FIG. 2 shows a portion 13 of ring 12 to include a fine-grained pattern of chevron elements. These elements are formed by the same process which forms the channel-defining elements of the major-minor organization when the photographic mask which defines the pattern is suitably adapted. For an in-plane field rotating counterclockwise, magnetic poles are generated at the inside end of each chevron element; next at the apex of each chevron element; and thereafter at the outside end of each element of the propagation ring. Spurious domains, represented by circles D in FIG. 3, are either excluded by the outward progression of poles so generated in the elements of the ring 12 or moved outwardly from the area encompassed by the ring as the number of spurious domains increases.

It is helpful to appreciate that high speed operation is contemplated. Only domains moving in channels defined by the pattern of magnetically soft elements experience field gradients resulting from the rotating in-plane field (see source 20 of FIG. 1). Spurious domains do not experience such field gradients and are positioned mainly by the pressure of other domains. Spurious domains generated close to channels also experience a net repulsion force from domains moving about the channels at high speeds. Only when a sufficient number of spurious domains press upon one another, causing all the available space to be closely occupied, are spurious domains closely pressed into the propagation channel in a manner to cause an occasional failure by interaction or by the occupation of one space in the data stream by a spurious domain. Formation of a propagation annulus about three domain diameters away from the operative circuit takes advantage of repulsion forces between spurious and data domains to move the former to the annulus for removal.

Sources 20 and 22 are under the control of a control circuit represented by block 23 of FIG. 1 for activation and synchronization.

So far the description has been mainly directed to the function of a propagation ring to move spurious domains outwardly during high-speed operation. The ring may be used also to clear layer 11 of domains which arise spuriously during testing and characterization operations prior to high-speed operation. In practice, single wall domains are maintained at a normal operating size by a bias field supplied by a source represented by block 22 of FIG. 1 as is well known. A decrease in the magnitude of the bias field causes domains to increase in size and finally to strip out. If, after testing, the bias field is lowered, all domains in layer 11 strip out and latch onto poles simultaneously generated in the ring 12 by a counterclockwise rotating in-plane field. An increase in the in-plane field returns domains to an operating size to be removed, by the ring, from the operative part of layer 11. Some domains may remain within propagation channels during such a clearing operation. But these can be moved to an annihilator (not shown but typically present in operative circuits) for elimination.

Two multiple element rings of the type described here may be arranged concentrically, a first to move domains from within, a second to move domains to the area encompassed within it. If the second surrounds the first, all spurious domains are moved to a well-defined area between the two rings for annihilation. A double annu-

lus arrangement of this type is particularly suited also in conjunction with operative devices in which the in-plane field is reversed in orientation sequentially (viz: from counterclockwise to clockwise) normally during operation. FIG. 1 represents a second annulus of this type as a line designated 30.

Also, in practice, a propagation annulus with multiple elements as shown in FIG. 2 may be defined by line elements having apices aligned along a closely coiled path rather than along closely spaced concentric closed paths. The coiled path geometry results in a total clearing of the propagation annulus. The closed path geometry permits domains under some conditions to strip out and almost close on themselves into a coiled geometry leaving domain tips which may give rise to spurious domains. Particularly at the high speeds contemplated, however, the domains generated by such tips are negligible and the coiled path is employed to avoid a coiled strip domain primarily to approach an ideal condition where the propagation annulus cleans itself of domains constantly.

It is assumed that the pattern of elements which form the various channels of FIG. 1 are designed for a counterclockwise rotating in-plane field for consistency.

WHAT WE CLAIM IS:—

1. A magnetic device comprising a layer of material in which single wall domains can be moved, and a first propagation arrangement defining a first channel therein, the propagation arrangement serving to move a said domain associated therewith across said channel from a first side thereof to the other side in response to a varying magnetic field, the net movement of said domain being substantially only lateral with respect to said channel.

2. A magnetic device according to claim 1, wherein there is provided a second propagation arrangement nearer to said first side than to said other side of said first channel, and wherein, in operation, when said magnetic field varies a domain associated with said second arrangement is propagated in part of said layer associated therewith.

3. A device according to claim 2, wherein said first channel is disposed to encompass said second propagation arrangement.

4. A device according to claim 1, 2 or 3, wherein said varying magnetic field is a field reorienting in the plane of said layer.

5. A device according to any one of claims 1 to 4, wherein said first propagation arrangement comprises a fine grained pattern of V-shaped elements.

6. A device according to claim 5,



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So far the description has been mainly directed to the function of a propagation ring to move spurious domains outwardly during high-speed operation. The ring may be used also to clear layer 11 of domains which arise spuriously during testing and characterization operations prior to high-speed operation. In practice, single wall domains are maintained at a normal operating size by a bias field supplied by a source represented by block 22 of FIG. 1 as is well known. A decrease in the magnitude of the bias field causes domains to increase in size and finally to strip out. If, after testing, the bias field is lowered, all domains in layer 11 strip out and latch onto poles simultaneously generated in the ring 12 by a counterclockwise rotating in-plane field. An increase in the in-plane field returns domains to an operating size to be removed, by the ring, from the operative part of layer 11. Some domains may remain within propagation channels during such a clearing operation. But these can be moved to an annihilator (not shown but typically present in operative circuits) for elimination.

Two multiple element rings of the type described here may be arranged concentrically, a first to move domains from within, a second to move domains to the area encompassed within it. If the second surrounds the first, all spurious domains are moved to a well-defined area between the two rings for annihilation. A double annu-

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Also, in practice, a propagation annulus with multiple elements as shown in FIG. 2 may be defined by line elements having apices aligned along a closely coiled path rather than along closely spaced concentric closed paths. The coiled path geometry results in a total clearing of the propagation annulus. The closed path geometry permits domains under some conditions to strip out and almost close on themselves into a coiled geometry leaving domain tips which may give rise to spurious domains. Particularly at the high speeds contemplated, however, the domains generated by such tips are negligible and the coiled path is employed to avoid a coiled strip domain primarily to approach an ideal condition where the propagation annulus cleans itself of domains constantly.

It is assumed that the pattern of elements which form the various channels of FIG. 1 are designed for a counterclockwise rotating in-plane field for consistency.

WHAT WE CLAIM IS:—

1. A magnetic device comprising a layer of material in which single wall domains can be moved, and a first propagation arrangement defining a first channel therein, the propagation arrangement serving to move a said domain associated therewith across said channel from a first side thereof to the other side in response to a varying magnetic field, the net movement of said domain being substantially only lateral with respect to said channel.

2. A magnetic device according to claim 1, wherein there is provided a second propagation arrangement nearer to said first side than to said other side of said first channel, and wherein, in operation, when said magnetic field varies a domain associated with said second arrangement is propagated in part of said layer associated therewith.

3. A device according to claim 2, wherein said first channel is disposed to encompass said second propagation arrangement.

4. A device according to claim 1, 2 or 3, wherein said varying magnetic field is a field reorienting in the plane of said layer.

5. A device according to any one of claims 1 to 4, wherein said first propagation arrangement comprises a fine grained pattern of V-shaped elements.

6. A device according to claim 5, 130



wherein said fine grained pattern of elements comprises a plurality of lines of said V-shaped elements.

7. A device according to claim 5, wherein said fine grained pattern of elements comprises a plurality of said V-shaped elements disposed along a coiled path.

8. A device according to claim 2 or any preceding claim when appendant thereto, wherein the spacing between said second arrangement and said first channel is substantially equivalent to three times the diameter of a said domain.

9. A device according to claim 3, or any preceding claim when appendant thereto, further including a third propagation arrangement defining a second channel encompassing said first channel, the third propagation arrangement being disposed such that, in operation, in response to said

varying magnetic field a domain associated with the third propagation arrangement moves towards the area between said first and third propagation arrangements.

10. A device according to any one preceding claim, further including means for providing said varying magnetic field.

11. A device according to any one preceding claim, further including means for providing a magnetic field for maintaining stable the size of said domains.

12. A device substantially as herein described with reference to the accompanying drawing.

C. S. T. BUCKLEY,
Chartered Patent Agent,
5, Mornington Road,
Woodford Green,
Essex.
Agent for the Applicants.