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Datasheet for the decision of 5 April 2017

Case Number: T 2411/11 - 3.5.07

Application Number: 08392002.5

Publication Number: 1983524

IPC: G11C11/16

Language of the proceedings: EN

Title of invention:
MRAM with enhanced programming margin

Applicant:
Headway Technologies, Inc.

Headword:
MRAM programming margin/HEADWAY TECHNOLOGIES

Relevant legal provisions:
EPC Art. 56, 84, 113(2)
RPBA Art. 11

Keyword:
Claims - clarity (no)
Inventive step - (no)

Decisions cited:

Catchword:

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Case Number: T 2411/11 - 3.5.07

D E C I S I O N
of Technical Board of Appeal 3.5.07
of 5 April 2017

Appellant: (Applicant)
Headway Technologies, Inc.
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Milpitas, CA 95035 (US)

Representative:
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Decision under appeal:
Decision of the Examining Division of the European Patent Office posted on 29 June 2011 refusing European patent application No. 08392002.5 pursuant to Article 97(2) EPC.

Composition of the Board:

Chairman R. Moufang
Members: R. de Man
M. Jaedicke

Summary of Facts and Submissions

I. The applicant (appellant) appealed against the decision of the Examining Division refusing European patent application No. 08392002.5.

II. According to its "Facts and submissions" section, the decision was based on the set of claims 1 to 19 filed with the letter of 31 May 2011. It cited the following documents:

D1: WO 03/075634 A, 18 September 2003; and
D2: WO 03/050817 A, 19 June 2003.

According to the reasons for the decision, the subject-matter of claims 1 to 26 lacked inventive step in view of a combination of documents D1 and D2.

III. In the notice of appeal, the appellant requested that the decision under appeal be set aside and that a patent be granted "on the basis of the claims filed with letter of 31.05.2011 or on the basis of the set of claims which will possibly accompany the Grounds For Appeal".

The statement of grounds of appeal was accompanied by a "revised set of claims" that was said to be significantly similar to the set of claims filed on 31 May 2011, apart from one minor correction (relating to the substitution of "opposing regions" for "opposing [[tip]] regions" in both independent claims). The appellant requested that "the Decision of 29 June 2011 be set aside to the extent that it affects one of the revised claims".

IV. In a communication accompanying a summons to oral proceedings, the Board introduced the following document:

D3: US 6 490 217 B1, 3 December 2002.

The Board pointed out that it understood the revised set of claims filed with the statement of grounds of appeal to replace the previous set of claims. It questioned whether claim 1 complied with Articles 84 and 123(2) EPC and expressed the preliminary view that its subject-matter lacked inventive step in view of a combination of documents D1 and D3.

V. In a letter dated 4 March 2017, the appellant informed the Board that it would not attend the oral proceedings and requested that "the Communication be continued in writing". It did not comment on the Board's communication.

VI. In a communication dated 13 March 2017, the Board informed the appellant that the oral proceedings would take place as scheduled in order to come to a decision on the appeal.

VII. Oral proceedings were held on 5 April 2017. At the end of the oral proceedings, the chairman pronounced the Board's decision.

VIII. Claim 1 of the revised set of claims reads as follows:

"A method to increase an operating margin of a magnetic random access memory, in order to increase its programming range, comprising:

providing a magnetically pinned layer, a magnetically free layer, and a transition layer between said pinned and free layers;
patterning said MRAM cell free layer into a shaped memory element whose shape consists of only first and second areas, characterized in that said first area having a magnetization along only a first magnetization direction that paralleles [sic] said pinned layer's magnetization direction and a second area consisting of two, and only two, opposing regions; each of said two opposing regions being limited to having a single second magnetization direction that is at an angle relative to said first magnetization direction; each of said second magnetization directions having a component that is perpendicular to said first magnetization direction with said first and second directions of magnetization differing by between about 5 and 90 degrees, and with said first area being between 10 and 95 % of said second area;
providing a circuit architecture that organizes said [sic] write word and bit lines into a plurality of segmented write line groups, each segmented group including a plurality of memory cells operatively coupled to a corresponding segmented write word line conductor, memory cells on one segmented write word line being simultaneously programmed by a plurality of bit lines operatively coupled to said magnetic memory cells for selectively writing states into the memory cells; and
thereby, as a consequence of being in combination with said shaped memory elements, making said magnetic random access memory innately more tolerant of local variations in film thickness, line width, and pattern shape, whereby differences in optimum programming conditions between different cells are reduced."

IX. The appellant's arguments as relevant to this decision are discussed in detail below.

Reasons for the Decision

1. The appeal complies with the provisions referred to in Rule 101 EPC and is therefore admissible.

2. *The appellant's requests*

The appellant has not contested the Board's understanding that the "revised set of claims" accompanying the statement of grounds of appeal replaced the set of claims originally maintained in the notice of appeal. Hence, the appellant requests that the decision under appeal be set aside and that a patent be granted on the basis of the revised set of claims.

3. *The decision under appeal*

It is apparent from the decision under appeal that its reasons are based on claims 1 to 26 filed with the appellant's letter of 7 February 2011 and not on replacement claims 1 to 19 filed with the letter of 31 May 2011. The decision was thus taken in violation of Article 113(2) EPC. Nevertheless, given that the latter set of claims was obtained from the former by deletion of claims 11 to 13 and 23 to 26 and that the reasons for the decision therefore directly apply to the correct set of claims, the Board considers that there are special reasons within the meaning of Article 11 RPBA for proceeding with the examination of the case.

4. *The application*

4.1 The application relates to magnetic random-access memories (MRAM). The background section explains that MRAM memory elements consist either of a magnetic tunnelling junction (MTJ) or of a giant magnetoresistance spin valve (GMR/SV) (page 1, lines 13 to 18, of the description of the application as filed). Such elements are formed of two ferromagnetic layers separated by a non-magnetic layer (a tunnelling dielectric layer for MTJs and a transitional metal for GMR/SVs). Usually one of the ferromagnetic layers has a fixed magnetisation direction (the "pinned layer") while the other layer is free to switch its magnetisation direction (the "free layer"). Both magnetisation directions lie along the long axis ("easy axis") of the memory cell, the free-layer magnetisation direction being either parallel or anti-parallel to the pinned-layer magnetisation direction (page 1, lines 20 to 28). Digital information is stored in an MRAM element by switching the magnetisation direction of the free layer (page 2, lines 1 and 2).

4.2 The magnetisation direction of the free layer may be switched by applying a field in the easy-axis direction. The required field to switch between the two states is denoted by Hs and is determined by the shape-anisotropy energy of the element. By applying an additional external field along the "hard axis" perpendicular to the easy axis, the value of Hs is reduced, becoming zero when the hard-axis field reaches a particular value denoted by Hy_sat (page 2, lines 2 to 9). In MRAM applications the external fields for programming the MRAM cell are provided by current lines: a "bit line" providing the easy-axis field and a "word line" providing the hard-axis field. A selected cell is programmed by applying both bit- and word-line currents as illustrated in Figure 3a (page 2, lines 11 to 16).

4.3 Due to variations in MRAM cells, the bit- and word-line currents (I_{bit} and I_{word}) needed for programming a cell vary from cell to cell. To reliably program any selected memory cell, the currents have to be chosen high enough to be suitable for programming the cell with the highest shape anisotropy. But if the bit- and word-line currents become too high, there is a risk that "half-select cells", i.e. cells that lie under either the bit line or the word line (but not both) are accidentally programmed. The higher the bit/word-line current and the smaller the Hs or Hy_sat values, the easier it is for a half-select error to occur (page 2, line 16, to page 3, line 3).

Thus, as explained on page 3, lines 5 to 10, the window for reliably programming an MRAM without half-select errors is determined by three boundaries:

- the combined field from both bit and word lines needed to reliably program the selected cells;
- the distance between the bit-line field and the smallest Hs at which $I_{word} = 0$;
- the distance between the word-line field and the smallest Hy_sat.

4.4 The background section then describes three known approaches for improving the programming window.

A first approach is to increase the shape-anisotropy value. This approach has the disadvantage of requiring higher bit and word currents, which is not desirable for high-density applications (page 3, line 10 to 12).

A second approach is to increase Hs at $I_{word} = 0$ by confining the free-layer magnetisation to the "C-state". This is achieved by patterning the MTJ cell into certain curved shapes. As a result, the probability of half-select errors under the bit line is reduced (page 3, lines 14 to 28). An example of a shape that induces C-state magnetisation is the "C-shape" shown in Figure 5 (page 5, lines 9 to 14).

A third approach is to use a segmented write architecture. In this approach, the hard-axis field is directed to a subset of the memory cells along the word line, which are all programmed simultaneously. Since all memory cells experiencing a hard-axis field are written simultaneously, there is no danger of half-select errors along the word dimension (page 4, lines 6 to 26).

4.5 The invention essentially proposes providing an improved MRAM by shaping its memory elements into shapes that facilitate a C-state magnetisation configuration and organising the memory elements in a segmented write architecture, i.e. by combining the second approach with the third approach.

5. *The shape of the free layer - claim interpretation and clarity*

5.1 According to present claim 1, the free layer of the MRAM cell is patterned into a shape consisting of first and second "areas". The first area has "a magnetization along only a first magnetization direction that paralleles [sic] said pinned layer's magnetization direction". The second area consists of two "opposing regions", each region being "limited to having a single second magnetization direction that is at an angle relative to said first magnetization direction".

The application as filed does not mention explicitly that each of the first area and the two opposing regions has a *single* magnetisation direction, but the Board considers that these amendments do not add subject-matter, because the skilled person understands the magnetisation of an area to refer to the (single) *overall* magnetisation of the area, i.e. to the vector sum of the area's individual magnetic field vectors.

5.2 Claim 1 further specifies that the angle between the first and either of the second magnetisation directions is "between about 5 and 90 degrees" and that "said first area" is "between 10 and 95 % of said second area".

The Board understands the latter limitation to mean that the size of the first area is between 10 and 95% of the size of the second area.

5.3 The application does not contain any specific definition of the term "area". In fact, it is used only in the original claims and in the description of Figure 9e, which reads as follows:

"FIG. 9e symbolizes the general class of shapes that we will describe as 'more complex'. In the general case, any such shape would include a first area (central region) which magnetization lies in a first direction that is along the magnetization of pinned layer and second area (two tip regions) which magnetizations have an angle with respect to the magnetization directions of 1st area, the magnetizations of those 3 region [sic] forms [sic] a general 'C' configurations [sic], said first and second directions of magnetization differing by between about 5 and 90 degrees. Additionally, said first area should occupy between about 10 and 95 % of the area occupied by said second area. It should also be noted that either or both areas may be made up of more than one non-contiguous sub-areas."

Figure 9e shows the following shape:

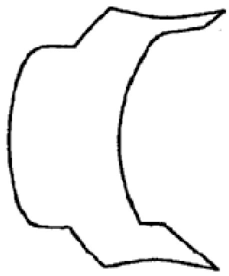

FIG. 9e

5.4 Figure 9e and its description do not offer much help in giving the term "area" a specific meaning. Indeed, at first sight it appears to be natural to equate the upper and lower "legs" of the shape with the two opposing (tip) regions, but then the area of the remaining first (central) region would appear to be significantly greater than 95% of the combined area of the two opposing regions. Although Figure 9e may not have been meant to accurately disclose size ratios, the point remains that no clear restrictions on the meaning of the term "area" can be derived from the example.

5.5 Other parts of the description use the term "region" instead of "area" but do not give any further definition (see page 6, lines 14 to 19, of the summary of the invention and page 8, lines 26 to 29, of the detailed description). The application further contains a number of example shapes and corresponding descriptions, without however giving information on how the boundaries of "areas" or "regions" are to be identified in those shapes.

5.6 The Board therefore considers that an "area" is not a region of the free layer that is somehow physically demarcated from other regions. Rather, any arbitrarily chosen area of the free layer qualifies as an "area" within the meaning of the claim.

Since there is freedom in conceptually choosing the demarcations of the first (central) area and the two opposing (tip) regions, the claim features relating to their magnetisation directions and their relative areas impose unclear limitations. Indeed, by varying the demarcations of the areas, both their (overall) magnetisation directions and their area sizes are changed. Thus, one and the same free layer may or may not satisfy the claimed limitations, depending on how the area boundaries are conceptually drawn.

5.7 Hence, the definition of the matter for which protection is sought is unclear (Article 84 EPC).

6. *Inventive step*

6.1 Document D1 discloses a method for improving the write selectivity of individual memory cells in an MRAM array (abstract). According to page 7, first paragraph, an MRAM cell includes a free magnetic layer, a pinned magnetic layer, and a transition layer between the two magnetic layers in the form of a tunnelling barrier layer.

6.2 Document D1 explains on page 9, line 5, to page 10, line 27, that the external magnetic field required for switching the magnetisation direction of the free layer depends on the cell's equilibrium magnetic vector state. If the cell is elliptically shaped, its equilibrium vector state may be either the S-state (where the vector field pattern resembles an S-shape as shown in Figure 1a) or the C-state (where the vector field pattern resembles a C-shape as shown in Figure 1b). The C-state requires a larger external magnetic field than the S-state. To have a well-functioning MRAM circuit, it is important that all cells are in the same state.

6.3 Due to variations in size, shape and the presence of local defects, symmetrical elliptically shaped memory cells are prone to switching randomly between the S-state and the C-state (page 10, lines 28 to 40). Document D1 therefore proposes asymmetrically shaped memory cells such as those shown in Figures 2A to 2F (page 11, lines 1 to 13). These asymmetrically shaped memory cells are said to be less sensitive to variations in shape and size than conventional elliptically shaped memory cells and to increase the selectivity of the write operation (page 11, lines 14 to 19).

6.4 Figure 2D shows the following geometrical C-shape:

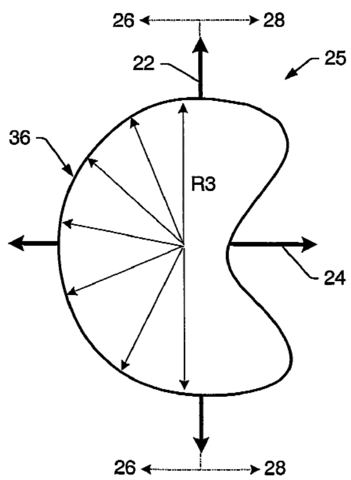

FIG. 2D

According to page 13, lines 27 to 32, the concave curvature of Figure 2D induces a relatively strong C-state.

6.5 Although claim 1 does not explicitly require a geometrical C-shape or a shape inducing C-state magnetisation, all the example shapes shown in Figures 6a to 6e, 7a to 7c, 8a to 8d and 9a to 9e are concave, and the description on page 6, lines 14 to 19, and on page 8, lines 16 to 18, makes clear that a shape inducing the C-state switching mode is intended. The Board therefore considers the method of document D1 applied to an MRAM cell with magnetic layers patterned as shown in Figure 2D to represent a suitable starting point for assessing inventive step.

6.6 In this prior-art method, the shape of the cell's free layer as shown in Figure 2D consists of a first central region (first area) and two opposing tip regions (second area). Since the shape induces C-state magnetisation, i.e. a C-shaped vector field pattern, the overall magnetisation direction of the central region of the free layer will be at an angle with the overall magnetisation directions of the two tip regions. It will also be essentially parallel to the overall magnetisation direction of the pinned layer.

In view of the discussion under point 5 and in particular point 5.6, the Board takes the view that the central region and the two tip regions may be identified in Figure 2D in such a way that they satisfy the broad (and unclear) limits on angles and areas imposed by claim 1. (In any event, since the application contains no indication that shapes that fit the wide ranges specified in claim 1 have a specific technical advantage other than that of inducing C-state magnetisation, which is an advantage shared by the shape of Figure 2D, those ranges could not contribute to an inventive step over the prior-art method.)

6.7 The subject-matter of claim 1 differs from the prior-art method in that it employs a segmented write architecture, which

- organises word and bit lines into a plurality of segmented write line groups,
- each segmented group including a plurality of memory cells operatively coupled to a corresponding segmented write word line conductor,
- memory cells on one segmented write word line being simultaneously programmed by a plurality of bit lines operatively coupled to said magnetic memory cells for selectively writing states into the memory cells.

Since in this architecture all memory cells experiencing a hard-axis field are simultaneously written, half-select errors on the word line are excluded.

The objective technical problem solved by the distinguishing features may therefore be regarded as how to further reduce the probability of half-select errors.

6.8 Claim 1 includes a further feature reading "thereby, as a consequence of being in combination with said shaped memory elements, making said magnetic random access memory innately more tolerant of local variations in film thickness, line width, and pattern shape, whereby differences in optimum programming conditions between different cells are reduced". This feature has no literal basis in the application as filed; it appears to have been taken from the appellant's arguments in the letter of 9 December 2009. However, the Board considers that, essentially as the appellant argued in that letter, both a suitable shape of the free layer like that of Figure 2D of document D1 and the claimed segmented write architecture render an MRAM memory device "innately more tolerant of local variations in film thickness, line width, and pattern shape" and reduce differences in optimum programming conditions between cells (see points 6.3 and 6.7 above and see also column 6, lines 34 to 43, of document D3 discussed below and relating to the same segmented write architecture). Thus, this feature is essentially implied by the preceding features and does not further distinguish the claimed subject-matter from the prior-art method.

6.9 Document D3 is one of two prior-art documents referred to in the background section of the application as disclosing a segmented write architecture (see page 4, lines 6 to 8, of the application). It relates to an architecture for improving a write margin within an MRAM device (see column 1, lines 13 to 59). It explains how memory cells are written by passing electrical currents simultaneously through a bit line and a word line and that half-select problems may arise due to variations in shape and size of memory cells (column 1, line 60, to column 2, line 20).

Document D3 proposes a segmented write line architecture as illustrated in Figure 3 (essentially identical to Figure 3b of the present application, which only lacks some of the reference signs). In this architecture, the memory cells on word and bit lines are organised into segmented write line groups 334, 336, 338 and 340 (column 5, lines 16 to 35). The memory cells in a group are operatively coupled to a corresponding segmented write word line conductor (column 5, lines 36 to 54; segmented write lines 326, 328, 330, 332). Memory cells in a group (i.e. memory cells "on one segmented write word line") are simultaneously written by means of a plurality of bit lines (column 6, lines 41 to 57; column 8, lines 43 to 49). According to column 6, lines 63 to 67, since all memory cells experiencing a hard-axis field by definition will be written simultaneously, there are no half-selected memory cells along the word dimension.

The skilled person reading document D3 understands that, since there are no half-selected memory cells along the word dimension, half-select errors on the word line are excluded and that, consequently, the probability of half-select errors is reduced (see also column 6, lines 34 to 43).

6.10 Thus, starting from the method of document D1 and faced with the above-mentioned objective technical problem, the skilled person would apply the teaching of document D3 to the method of document D1 and thereby arrive at the subject-matter of claim 1 without the exercise of inventive skill.

6.11 The Board's reasoning deviates from that in the contested decision (which is based on a combination of Figure 1B of document D1 and the segmented write architecture of document D2), and the appellant has neither commented on the Board's communication nor attended the oral proceedings.

In the statement of grounds of appeal, the appellant submitted that the shape defined by claim 1 cannot "be reduced to the conventional C-shape which is known to the art". But the Board considers that its reasoning takes full account of the wording of the claim.

The appellant further submitted that it had been the first to claim a system combining the two approaches of shaping the memory cell and providing a segmented write line architecture and that it believed that such a system had not been previously reported in the prior art because the *prima facie* improvements which could have been reasonably expected by the skilled person did not justify the added expense of building the combined system.

However, in the context of Article 56 EPC the relevant question to ask is whether the skilled person would have made the combination because the prior art incited him to do so in the hope of solving the objective technical problem (see Case Law of the Boards of Appeal, 8th edition 2016, I.D.5). In the present case, document D3 teaches the skilled person to solve the objective technical problem by means of a segmented write line architecture as claimed. The Board is not aware of - and the appellant has not pointed to - any technical reason why the skilled person would have believed that making the combination would have posed significant technical difficulties or would not have achieved the desired technical advantage.

6.12 Hence, the subject-matter of claim 1 lacks inventive step (Articles 52(1) and 56 EPC).

7. *Conclusion*

Since the sole substantive request is not allowable, the appeal is to be dismissed.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

I. Aperribay R. Moufang

Decision electronically authenticated