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Datasheet for the decision of 24 May 2016

Case Number: T 2038/10 - 3.5.07

Application Number: 02761617.6

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Language of the proceedings: EN

Title of invention:
Programming a phase-change material memory

Applicant:
Ovonyx, Inc.

Headword:
Programming a phase-change memory/OVONYX

Relevant legal provisions:
EPC Art. 54(2), 54(3), 56, 84, 123(2)

Keyword:
Novelty - after amendment (yes)
Inventive step - after amendment (yes)

Decisions cited:
T 0243/91, T 1055/92, T 0813/03, T 2316/11

Catchword:

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Case Number: T 2038/10 - 3.5.07

D E C I S I O N
of Technical Board of Appeal 3.5.07
of 24 May 2016

Appellant: (Applicant)	Ovonyx, Inc. 1090 Boeing Street Boise, ID 83705 (US)
Representative:	Samson & Partner Patentanwälte mbB Widenmayerstraße 6 80538 München (DE)
Decision under appeal:	**Decision of the Examining Division of the European Patent Office posted on 21 April 2010 refusing European patent application No. 02761617.6 pursuant to Article 97(2) EPC.**

Composition of the Board:

Chairman	R. Moufang
Members:	P. San-Bento Furtado
	R. de Man

Summary of Facts and Submissions

I. The appeal lies from the decision of the Examining Division to refuse European patent application No. 02761617.6, filed on 11 September 2002 as international application PCT/US2002/028811 and published as WO2004/025659.

II. The Examining Division found that a main request was not allowable due to lack of inventive step of the subject-matter of independent claims 1 and 7 (Article 56 EPC), and lack of clarity of claims 1, 3, 4, and 7 to 9 (Article 84 EPC). The independent claims did not define an essential feature. The subject-matter of some dependent claims was defined in terms of the result to be achieved.

With respect to an auxiliary request, the Examining Division was of the opinion that the subject-matter of independent claims 1 and 6 was not new (Article 54(1) and (2) EPC), and was defined in terms of the result to be achieved. The latter was considered to result in an infringement of Article 84 EPC.

According to the decision, the dependent claims of both requests appeared to lack novelty or inventive step.

The Examining Division considered the closest prior art to be document:
D2: US 3 922 648, published on 25 November 1975.

III. In the statement of grounds of appeal, the appellant requested that the decision under appeal be set aside and that a patent be granted on the basis of the main request or of the auxiliary request considered in the contested decision. The appellant mentioned that the

reasoning of the Examining Division with respect to claim 1 of the auxiliary request appeared to relate to inventive step and not, as stated in the decision, to the question of novelty.

IV. The appellant was invited to oral proceedings. In a subsequent communication, the Board introduced the following prior-art documents:

D5: US-A-6 075 719, published on 13 June 2000;

D6: WO 03/058633, published on 17 July 2003, corresponding to the content of European patent application No. 02806193.5 filed as international application No. PCT/US02/40994 on 20 December 2002, claiming priority from US 10/034146 (D6') of 28 December 2001.

The Board gave its preliminary opinion on the requests.

With respect to the main request, the Board tended to disagree with some of the clarity objections raised in the decision, but expressed doubts that the requirements of Articles 84 and 123(2) EPC were met. The Board discussed novelty, under Articles 54(1) and (3) EPC and 54(4) EPC 1973, of the claimed subject-matter over document D6. It was of the preliminary opinion that the subject-matter of claim 1 did not involve an inventive step over the disclosure of either of documents D2 and D5 in combination with the common general knowledge of the skilled person.

Regarding the auxiliary request, it appeared that some of the issues discussed with respect to clarity and added subject-matter for the main request applied equally to the auxiliary request, and that the amendments might have resulted in the omission of essential features from the independent claims. The

reasoning of the Examining Division with regard to lack of novelty over document D2 did not seem convincing. Nevertheless, the subject-matter of independent claims 1 and 6 seemed to be neither new over the disclosure of document D6 (Article 54(1) and (3) EPC) nor inventive in the light of document D2 or document D5.

V. With letter dated 22 April 2016 the appellant filed a new main request and a new auxiliary request, to replace the previous requests on file. The appellant requested that the contested decision be set aside and that a patent be granted on the basis of the claims of the main request or, alternatively, of the auxiliary request, and on the basis of the following documents:
- description pages 1, 3 to 7 and 9 as published;
- description page 2, as filed with letter of 15 December 2005;
- description page 8, as filed with letter of 16 November 2007;
- respective description pages 2a and 2b for the main and auxiliary requests, as attached to the letter of 22 April 2016;
- Figures 1 to 9 as published.

VI. Oral proceedings were held on 24 May 2016. During the oral proceedings the appellant first submitted amended claims as a main request. It later replaced its pending substantive requests with a sole main request comprising amended claims 1 to 4 filed at 12.45 hours. This constituted the appellant's final request.

VII. At the end of the oral proceedings, the chairman pronounced the Board's decision.

VIII. Claim 1 of the sole main request reads as follows:

"A method for programming a memory device having an array of memory cells and waveshaping and driving circuitry formed in the same integrated circuit (IC) die and configured to generate a first current pulse (204) and a second current pulse (208; 308), said method comprising:

applying the first current pulse (204) to a constituent cell (604) of the memory device, the cell (604) having a structural phase-change material to store the cell's data, to leave the material in a first state,

applying the second current pulse (208; 308) to the cell (604) to change the material from the first state to a second, different state whose resistance is lower than the resistance of the first state, the second current pulse (208; 308) having a generally triangular shape with a leading portion that peaks at a maximum value and a trailing portion that decays to a minimum value, wherein the maximum value of the second current pulse (208; 308) is high enough to cause the phase-change material in at least some of the constituent cells (604) of the device to reach an amorphizing temperature if the second current pulse (208; 308) were applied to those cells (604), and a decay rate of the second current pulse (208; 308) is slow enough to cause those constituent cells (604) that have reached the amorphizing temperature to cool down at a sufficiently slow pace so that the phase-change material in those cells (604) changes from the first state to the second state."

Dependent claims 2 and 3 respectively read as follows:

"The method of claim 1 wherein the leading portion has a steeper slope than the trailing portion."

"The method of claim 2 wherein the second current pulse (208; 308) further includes a relatively short intermediate portion between the leading portion and the trailing portion and wherein the intermediate portion has essentially zero slope relative to the leading and trailing portions."

Independent claim 4 reads as follows:

"A memory device comprising:

an array having a plurality of constituent cells (6O4), each cell (604) having a structural phase-change material to store the cell's data; and

waveshaping and driving circuitry (608) coupled to provide the voltage and current levels needed to program the plurality of constituent cells (604), the circuitry to generate a first current pulse (204) to be applied to one of the plurality of constituent cel1s (604) of the memory device to leave the material of said constituent cell (604) in a first state, and then a second current pulse (208; 308) to be applied to said constituent cell (604) to change its material from the first state to a second, different state whose resistance is lower than the resistance of the first state, wherein the second current pulse is to have a generally triangular shape with a leading portion that peaks at a maximum value and a trailing portion that decays to a minimum value, wherein the circuitry shapes the second current pulse (208; 308) with the maximum value high enough to cause the phase-change material in at least some of the constituent cells (604) of the

device to reach an amorphizing temperature, if the second current pulse (208; 308) were applied to those cells (604), and with a decay rate low enough to cause those constituent cells (604) that have reached the amorphizing temperature to cool down at a sufficiently slow pace so that the phase-change material in those cells (604) changes from the first state to the second state, wherein the array and the waveshaping and driving circuitry (608) are formed in the same integrated circuit (IC) die."

Reasons for the Decision

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

The invention

2. The invention is related to programming a structural phase-change material solid-state memory device which can be programmed into different resistivity states to store data (see page 1, lines 3 to 5 of the published international publication).

A memory cell of a phase-change memory is conventionally programmed by applying a rectangular pulse of current, referred to as "reset pulse", to the cell at a voltage greater than a material-dependent "switching threshold", which leaves the material in the reset state (amorphous and with high resistivity). The reset pulse raises the temperature of the phase change material to the amorphising temperature T_m, before the material is rapidly cooled down. A subsequent rectangular pulse, also at a voltage greater than the switching threshold, then brings the material into a

"set state" (crystalline and with low resistivity). That is achieved by heating the material back up to an optimum temperature T_{opt}, which is lower than T_m (page 1, line 19 to page 2, line 2). At the temperature T_{opt} the material crystallises.

Due to the fabrication process and material variations, the actual temperature of the phase-change material in cells of a device varies significantly for a given current/voltage level of the set pulse. As explained in the application, this variation "can cause the material in one or more cells of a device to inadvertently reach T_m during application of the conventional rectangular set pulse, and thereby cause those cells to erroneously remain in the reset state rather than change to the set state" (page 2, lines 3 to 9, Figure 1).

According to the application, the conventional solution to this problem is to use a longer rectangular set pulse with a reduced magnitude. This solution slows down the programming of the memory device. Furthermore, it may reduce the dynamic range in resistivity between the set and reset states in the cells (page 2, lines 9 to 18).

To remedy that problem, the invention proposes using a generally triangular pulse, also known as a "set sweep". With this solution, "the magnitude of the set pulse current can be increased, so that the phase-change material in all cells of a device can reach temperatures of at least T_{opt} during the set pulse yet still change to the set state, due to the downward slope in the trailing portion of the pulse" (page 3, lines 16 to 21). Even if a cell reaches T_m, it cools down to T_{opt} due to the decaying or downward sloping trailing portion of the pulse. According to the

application, the advantages are better crystallisation and more pronounced resistivity differences between the set and reset states, despite the fabrication process and material variations (page 3, lines 16 to 32). The shape of the pulse can be selected in view of the fabrication process and material variations (page 4, lines 14 to 26).

Basis in the application as filed

3. The subject-matter of claim 1 is based on original claim 1, as well as the following originally filed claims:
   - claim 2, describing the generally triangular shape of the second current pulse with a leading and a trailing portion;
   - claim 4, reciting that the resistance in the second state is lower than that in the first state;
   - claim 6, defining the magnitude of the second pulse in terms of the amorphising temperature;
   - claim 7, defining the decay rate, and the state change by cooling down slowly;
   - claim 8, specifying the waveshaping and driving circuitry; and
   - claim 14, for the IC die.

   Although original claims 8 and 14 are not dependent on original claim 1, the skilled reader would understand from the disclosure on page 7, lines 1 to 8 and 21 to 30, and in Figures 8 and 9, that the waveshaping and driving circuitry and the IC die were to combine with the other features of claims 1 to 7.

   Additionally, the maximum and minimum values mentioned in claim 1 are described in detail on pages 4 and 5. In particular, the feature "a leading portion that peaks

at a maximum value and a trailing portion that decays to a minimum value" is based on page 4, lines 15 to 17.

4. The features of independent claim 4 are disclosed in original claim 8 and, as described above for claim 1, in original claims 2, 4, 6 to 8 and 14, and on page 4, lines 15 to 17 of the description.

5. Dependent claim 2 recites the remaining features of original claim 2, i.e. those which have not been included in claim 1, and claim 3 was drafted by adding "relatively short" to the text of original claim 3, in the feature "the second pulse includes a relatively short intermediate portion". This additional feature finds support in the passage on page 5, lines 12 to 16 of the description.

6. The added-subject-matter objection raised in the Board's preliminary opinion against the feature referring to "a minimum value which is above the zero level" no longer applies because the feature has been deleted.

7. The Board is therefore satisfied that the claims fulfil the requirements of Article 123(2) EPC.

Article 84 EPC

8. In the contested decision, the Examining Division found the term "generally triangular shape" to render the claim unclear because the shape of the second pulse of claim 1 was composed of a triangle and a rectangle and that of claim 2 of two rectangles and a triangle.

8.1 In the Board's view, this objection no longer entirely applies to the present claims because the "generally

triangular shape" is defined in detail in independent claims 1 and 4. Furthermore, the Board agrees with the appellant that the term "generally triangular shape" implies that the pulse does not have to be a geometrically exact triangle. The term is also defined in that way in the description, for example on page 3, lines 16 to 21, page 4, lines 14 to 26, and on page 5, lines 12 to 20, and depicted in Figures 2 and 4. Even the pulse shown on Figure 4, which includes an intermediate portion, is described on page 5, lines 12 to 20, as having a "generally triangular" shape.

9. The Examining Division also argued that claim 1 of the then main request was unclear because it failed to "define the continuation of the current set pulse after the trailing portion", therefore suggesting that the pulse did not return to a zero current amplitude. However, it was essential for the invention that the current's amplitude returned to zero, as supported by the description and Figure 2.

9.1 In response to this objection the appellant stated that the invention was concerned with the shape of the (set) current pulses and not with a no-signal current between two pulses. As was explained on page 5, lines 8 to 11, when the minimum value was reached, the current pulse ended. What happened after the set current pulse had ended depended on how the memory was used.

9.2 The present independent claims no longer exclude the return of the current to zero. The Board agrees with the appellant that it is not essential to define the return to zero, especially since present claim 1 further specifies other technical characteristics of the second pulse which guarantee the effect of the

invention (see point 16 below). The same applies for independent claim 4.

10. In the appealed decision the Examining Division raised an objection under Article 84 EPC because it considered that features corresponding to the following features of present claim 1 were defined in terms of the result to be achieved:

- "the maximum value of the second current pulse (208; 308) is high enough to cause the phase-change material in at least some of the constituent cells (604) of the device to reach an amorphizing temperature if the second current pulse (208; 308) were applied to those cells (604)", and
- "a decay rate of the second current pulse (208; 308) is slow enough to cause those constituent cells (604) that have reached the amorphizing temperature to cool down at a sufficiently slow pace so that the phase-change material in those cells (604) changes from the first state to the second state".

10.1 In the grounds of appeal, the appellant claimed that the wording and meaning of the two features were perfectly understandable for the skilled person. The Examining Division had not objected to the language. The appellant further argued that the claims included all the essential features necessary to distinguish the invention from the prior art. The claims therefore fulfilled the necessary requirements for defining a feature in terms of the result to be achieved, as established in the case law, in particular decisions T 813/03 of 7 January 2004, points 3.1 and 3.2, and T 1055/92, OJ EPO 1995, 214, point 5.

According to the appellant, the essential features were those which were necessary to solve the technical problem with which the application was concerned. The invention solved the problem of enabling a better crystallisation and saving time required for a set operation. This problem was solved by increasing the set current pulse magnitude. Furthermore, in order to allow even those cells that reached the amorphising temperature to spend the minimum required time interval at approximately the optimum temperature, the invention called for a decay rate of the set current pulse which was slow enough to cool down the material in such a way that the cells that reached the amorphising temperature still changed their state.

10.2 The Board agrees that the two features are formulated clearly and finds that they reflect well the gist of the invention which applies generally to different phase-change memories. In the present case, it would not be possible to further define the above-mentioned results to be achieved without unduly limiting the scope of claim 1 to a programming method adequate only for specific material or fabrication conditions. The same applies to corresponding claim 4. The Board is also satisfied that the skilled person would be able to reduce both features into practice without undue burden, as required for functional features by the established case law (see "Case law of the Boards of Appeal of the European Patent Office", 7th edition 2013, II.A.3.4, T 243/91 of 24 July 1991, reasons 5, T 2316/11 of 14 January 2014, reasons 2).

In order to assess whether the claim recites all the essential features, it has to be established whether the claim defines all the features necessary to solve the technical problem with which the application is

concerned (T 813/03, reasons 4). As the appellant mentioned, these are a shorter duration of the second pulse and an improved crystallisation.

The question of whether the duration of the second pulse created by the claimed method is shorter depends on parameters characterising the pulse, such as the maximum and minimum values, the decay rate, and pulse width (these parameters are mentioned on page 4, lines 21 to 26). Even though independent claims 1 and 4 do not specify these parameters in detail, the Board is of the opinion that the use of a second pulse as described in each of claims 1 and 4 allows pulses to be designed having an optimal duration for specific material and fabrication characteristics of the memory device, which is impossible with rectangular pulses. This is enough to consider that each of the independent claims defines the essential features of the invention.

11. It follows from the above that the claims fulfil the requirements of Article 84 EPC.

Novelty

12. *Document D6 - Novelty under Article 54(1) and (3) EPC*

12.1 In its communication, the Board expressed its preliminary opinion that the content of document D6 introduced by the Board into the proceedings constituted prior art under Article 54(3) EPC.

12.2 Document D6 discloses a method of programming a memory device having an array of memory cells of a structural phase-change material (see D6, page 6, last paragraph to page 7, first paragraph). On page 12 it mentions the problems of different fabrication processes and

material variations, and the need to adapt the shape of the programming pulses to the characteristics of the cells.

The cell programming method of D6 comprises applying a first current pulse to a cell, to leave the material in a first state, and a second current pulse to the cell to change the material from the first state to a second, different state whose resistance is lower than that of the first state (page 10, second full paragraph; page 11, full paragraph; paragraph bridging pages 12 and 13; Figures 3 to 6). The second current pulse has a (generally) triangular shape, the leading portion having a steeper slope than the trailing portion (page 8, second paragraph). Document D6 also discloses "waveshaping circuits" (page 14, first full paragraph).

Therefore, document D6 indeed discloses most of the features of each of the current independent claims.

12.3 However, in reaction to the Board's preliminary opinion, the appellant introduced into the independent claims the feature "an array of memory cells and waveshaping and driving circuitry formed in the same integrated circuit (IC) die", which is not disclosed in document D6.

12.4 Consequently, the claimed subject-matter is new over the prior art disclosed in document D6. Under those circumstances, it is irrelevant whether the further conditions laid down under Articles 153(5) EPC and 54(4) EPC 1973 are met.

13. *Document D2*

13.1 As argued in the contested decision, document D2 discloses in e.g. Figure 7B, column 10, line 67 to column 11, line 28, a method for programming a memory device having an array of memory cells, the method comprising applying a first current pulse (I_{reset}, Figure 7B) to leave the material in a first, amorphous state (see e.g. column 1, line 67 to column 2, line 3, and column 10, line 67 to column 11, line 1) and a second current pulse (I_{set}, Figure 7B) to change the material from the first to a second, lower-resistance crystalline state (see e.g. column 1, lines 47 to 56, and column 11, lines 3 to 28).

As can be seen from Figure 7B, the second current pulse of document D2 can have a generally triangular shape, with a leading portion that peaks at a maximum value and a trailing portion that decays to a minimum value, as in the invention claimed in the present case.

The Examining Division argued that the following passage of document D2, in column 1, lines 49 to 56, disclosed that the second current pulse was high enough to cause some cells to reach an amorphising temperature:

> "The set current pulse generally heats the semiconductor material above its glass transition and crystallization temperatures where sufficient heat accumulates under the relatively long duration involved to cause, upon termination or slow gradual reduction of the set current pulse, a slow cooling of the material which crystallizes the material in the filament".

However, while the second current pulse I_{set} depicted in Figure 7B achieves a maximum value of 3.5 milliamps and has a duration in the order of magnitude of milliseconds, the first current pulse I_{reset} has a magnitude of 27.5 milliamps and a duration of some microseconds (column 14, lines 17 to 32). The set current pulses are consistently described in document D2 as having a much lower magnitude and much longer duration than the reset current pulses (see e.g. column 1, line 56 to column 2, line 18, column 5, line 61 to column 6, line 12, column 10, lines 53 to 60). The Board therefore agrees with the appellant that document D2 should be interpreted as simply suggesting heating the cell material during a set pulse above its glass transition and crystallisation temperatures T_{opt}, which are lower than the amorphising temperature T_m. Document D2 does not teach that the set current pulses should be so high that some of the cells reach an amorphising temperature. On the contrary, the programming method of D2 relies on low set current pulses which are not expected to heat up any cells to an amorphising temperature.

Document D2 therefore does not disclose the feature:

- "the maximum value of the second current pulse (208; 308) is high enough to cause the phase-change material in at least some of the constituent cells (604) of the device to reach an amorphizing temperature if the second current pulse (208; 308) were applied to those cells (604)".

13.2 Additionally, as acknowledged in the appealed decision, document D2 does not suggest providing the array of memory cells and the waveshaping and driving circuitry in the same IC die.

13.3 From the above reasoning it follows that the subject-matter of claim 1, and consequently that of the corresponding device claim 4 and of dependent claims 2 and 3, is new over the prior art disclosed in document D2 (Article 54(1) and (2) EPC).

14. *Document D5*

14.1 In its preliminary opinion the Board introduced document D5 into the proceedings and argued that it disclosed a similar method for programming a memory device (see column 3, lines 8 to 28, and claims 1 to 3 of document D5), comprising first and second pulses like those recited in the claim (column 4, lines 20 to 50, claim 1). It was clear from column 5, line 65 to column 6, line 4, and claim 3, that document D5 described "current pulses", i.e. electrical pulses in which the current was controlled. The second pulse of document D5 was considered to be "generally triangular", since it was "characterized by an amplitude, duration, rise time and fall time" (column 4, lines 39 to 42).

14.2 In its letter, the appellant argued that document D5 neither suggested that the magnitude of the second current pulse was at least as high as that of the first current pulse, nor described that the second current pulse was such that some of the cells would reach an amorphising temperature. Document D5 did not address the problem of speeding up the set operation.

At the oral proceedings, the appellant further argued that document D5 did not describe the basic geometry of the pulse and that the skilled person reading document D5 would understand that the second current pulse was a conventional rectangular pulse. Therefore,

document D5 did not disclose a generally triangular pulse. In particular, the appellant noted that the wording "characterized by an amplitude, duration, rise time and fall time" was used in document D5 not only for the second current pulse, but also for the first current pulse, in column 4, lines 26 to 30.

The Board finds this argument convincing. Document D5 includes no drawings showing the general geometry of the pulses and does not describe their shape. Since the rise and fall times and the need to adapt the shape of the pulse to properties of the memory device are mentioned for both current pulses (see also column 4, lines 54 to 59), it cannot be concluded that the second current pulse has a different shape from the first current pulse, which the skilled person would assume to be generally rectangular. Even though document D5 discloses that the second current pulse is preferably longer than the first current pulse, it is silent about the fall times.

Consequently, the subject-matter of the claims is new over the disclosure of document D5 (Article 54(1) and (2) EPC).

Inventive step

15. Document D6 was published on 17 July 2003, i.e. after the date of filing of the present application, namely 11 September 2002, and is therefore not relevant for inventive step.

16. Taking into account the results of the novelty assessment (see points 13. and 14. above), the Board considers document D2 as the best starting point for assessing inventive step.

16.1 As a consequence of the distinguishing feature mentioned under point 13.1 above, reciting that the maximum value of the second current pulse is high enough to cause the phase-change material in at least some of the cells to reach an amorphising temperature if it were applied to those cells, the set current pulse does not have to be long to guarantee that the optimum temperature is achieved. Furthermore, as explained on page 2, lines 11 to 18, more cells will achieve the optimum crystallisation temperature than with the low set current pulses of long duration of the prior art. The distinguishing feature therefore solves the technical problem of making possible a better crystallisation of the memory cells in a shorter amount of time in a set operation.

16.2 None of the available prior-art documents discloses the distinguishing feature.

The available prior art rather suggests that at the filing date of the application it was an accepted general principle in the field of phase-change memories that the set current pulse should be low in order to avoid, as much as possible, that cells achieve the amorphising temperature during the application of the set current pulse. It would therefore not have been obvious to use a second pulse as claimed.

16.3 Since that difference is inventive, there is no need to discuss the other distinguishing features.

16.4 The Board therefore concludes that the subject-matter of claim 1, and that of equivalent device claim 4, involves an inventive step (Articles 52(1) and 56 EPC), taking into account the available prior art. The

subject-matter of claims 2 and 3 also comprises the inventive feature by virtue of those claims's dependency on claim 1. The subject-matter of claims 2 and 3 is hence also inventive.

Concluding remarks

17. Since the claims comply with the provisions of the EPC, the appeal is to be allowed. However, as the claims have undergone substantial amendments, the description and drawings may need to be adapted to the claimed subject-matter before a patent can be granted.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the department of first instance with the order to grant a patent on the basis of claims 1 to 4 of the sole main request filed at the oral proceedings and a description and drawings still to be adapted.

The Registrar: The Chairman:

I. Aperribay R. Moufang

Decision electronically authenticated