BESCHWERDEKAMMERN DES EUROPÄISCHEN PATENTAMTS | BOARDS OF APPEAL OF THE EUROPEAN PATENT OFFICE | CHAMBRES DE RECOURS DE L'OFFICE EUROPEEN DES BREVETS

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File Number: T 693/89 - 3.4.1

Application No.: 80 303 334.9

Publication No.: 0 026 629

Title of invention: Methods of manufacturing semiconductor devices, for example photodiodes, and devices so manufactured

Classification: H01L 31/10

D E C I S I O N
of 8 January 1991

Applicant:

Proprietor of the patent: Fujitsu Limited

Opponent: Siemens AG

Headword:

EPC Art. 46

Keyword: "Inventive step (no)" -
"effects of an analogous use to be expected on the basis of common general knowledge"

Headnote

Europäisches Patentamt | European Patent Office | Office européen des brevets

Beschwerdekammern | Boards of Appeal | Chambres de recours

Case Number : T 693/89 - 3.4.1

D E C I S I O N
of the Technical Board of Appeal 3.4.1
of 8 January 1991

Appellant : (Opponent)
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Decision under appeal :
Decision of the Opposition Division of the European Patent Office dated 31 August 1989 rejecting the opposition filed against European patent No. 0 026 629 pursuant to Article 102(2) EPC.

Composition of the Board :

Chairman : G.D. Paterson
Members : H.J. Reich
Y. van Henden

Summary of Facts and Submissions

I. European patent 0 026 629 was granted on the basis of European patent application 80 303 334.9.

Claim 1 reads as follows:

"1. A method of manufacturing a semiconductor device, characterised in that the method comprises steps of:
implanting ions of beryllium into a germanium substrate (11,21,31); and
heat treating the germanium substrate (11,21,31) at a temperature in the range 400°C to 700°C, to diffuse the beryllium introduced into the substrate by ion implantation, to form a p-type region (15,23,35) in the substrate;
the amount of beryllium introduced into the substrate by ion implantation being such that the concentration of beryllium at the surface of the substrate (11,21,31) in the p-type region (15,23,35) is $10^{17}cm^{-3}$ or more."

Claims 2 to 5 are dependent on Claim 1.

II. The grant of this patent was opposed by the Appellant on the ground of lack of inventive step, citing two documents. In the course of the proceedings before the Opposition Division the Opponent cited three further documents, among them:

D4: "Applied Physics Letters", Vol. 34, No. 12, 15. June 1979, pages 866-868.

After having examined all five cited documents on the basis of Article 114(1) EPC, the Opposition Division rejected the opposition. It took the view that the subject-matter of Claim 1 of the opposed patent involved

an inventive step, because the selection of beryllium as a dopant for germanium in combination with the features claimed in Claim 1 would result in unexpected properties in the product so obtained, in particular in a deep penetration depth of Be into Ge, which could not be derived from the known behaviour of Be atoms in InSb or InGa AsP due to the specific properties of each individual semiconductor material.

III. The Appellant lodged an appeal against the decision of the Opposition Division. In his statement of grounds the Appellant cited four new documents in order to further support his view of lack of inventive step, thus relating the absence of any surprising advantage in applying the measures claimed in Claim 1, inter alia, to facts known from documents:

D6: "Soviet Physics-Semiconductors", Vol. 3, No. 2, August 1969, pages 236-237; and

D8: "Applied Physics Letters", Vol. 28, No. 12, 15. June 1976, pages 706-708.

IV. Based on Article 114(1) of the EPC, the Board took documents D4 and D8 into consideration and in a communication accompanying a summons to oral proceedings notified to the parties its preliminary view that the subject-matter of Claim 1 might be regarded as the result of an analogous replacement of the production of a p-region in a Ge substrate via Zn diffusion, such as known from document D4, by the more advantageous Be implantation and diffusion technology known from document D8 for doping a GaAs substrate. Such a replacement might be regarded as obvious due to the fact that the implantation properties of a Ge and a GaAs substrate can be expected to be similar on the basis of the generally known penetration behaviour

of ions into solids generally known for instance from document:

D10: I. Ruge: "Halbleiter-Technologie" Springer-Verlag, 1975, in particular pages 141-145.

V. Oral proceedings were held on 8 January 1991, during which the Appellant (Opponent) requested that the decision under appeal be set aside and that the patent be revoked.

The Respondent (Patentee) requested that the appeal be dismissed and that the patent be maintained, and that an award of costs be made in his favour having regard to the late filed documents introduced by the Appellant.

VI. In support of his request, the Appellant essentially submitted that:

(a) He agreed to the Board's preliminary view stated in point IV above.

(b) Relying on the arguments presented in his grounds of appeal, it would in particular be relevant to the obviousness of Claim 1, that document D6, on page 236, left column, lines 6-10, explicitly mentions an analogy between Be and Zn as dopants in a Ge substrate.

(c) In a diffusion step subsequent to the production of a dopant predeposition in a substrate by ion implantation, high penetration depths would not be surprising but expected by a skilled person. During the indispensable annealing step for electrically activating implanted dopants, the automatically occurring dopant diffusion would always enlarge the penetration depth resulting from the implantation

alone. On the other hand, due to the generally known difficulties in measuring diffusion coefficients, the experimental values of the penetration depths shown in Figures 1, 4A, 4B and 4C of the patent under appeal, might include measuring errors.

(d) A filing of additional evidence in support of a raised ground of opposition would be lawful in any moment of a pending procedure, if the previously filed evidence turns out to be insufficient for convincing the deciding body of the validity of the objection raised initially.

VII. The above submissions were contested by the Respondent, who argued essentially as follows:

(a) In order to realise the technical aim underlying the patent under appeal, i.e. to produce a deep-lying p-region in a germanium substrate, a skilled person would never think of making use of ion implantation instead of diffusion for introducing dopants into the substrate. Document D10, on page 141, lines 1-3, explicitly states that in practice ion implantation is limited to doping regions near the substrate surface.

(b) Moreover, Zn and Be being known to have substantially the same diffusion coefficient in a Ge substrate (see the patent under appeal, column 2, lines 15-18), a skilled person would not expect that in the production of a deep lying p-region the effective diffusion temperature can be lowered from its known value of 830°C for Zn (see D4, page 867, left column, line 7) to the claimed region from 400°C to 700°C for Be.

(c) A comparison of values for the projected penetration depth Rp calculated on the basis of the LSS theory (document D10) and handed over during the oral proceedings results at 50KeV in an increase of only 0.06μm when replacing B by Be. Thus, a skilled person would expect the increase of the known experimental junction depth of 0.3μm of a p+ layer produced by implanting B-ions into a Ge substrate (see document D4, page 867, left column, lines 7-9) by implanting Be instead of B to be negligible. A p-region depth of 15μm produced by the method of Claim 1 (see the patent under appeal, page 10, line 57) would be surprising.

(d) An award of costs would appear to be justified. In the absence of the late filed documents, the Appellant would have had no reason to take part in the present oral proceedings.

VIII. At the conclusion of the oral proceedings, the decision was announced that the patent was revoked and the request for an award of costs was refused.

Reasons for the Decision

1. The appeal is admissible.

2. **Inventive step**

2.1 From document D8 there is known in accordance with the wording of Claim 1:

"A method for manufacturing a semiconductor device (see D8, the word "diode" in the subtitle of Figure 3), characterised in that the method comprises the steps of:

implanting ions of beryllium into a substrate (GaAs), and heat treating the substrate at a temperature to diffuse the beryllium introduced into the substrate by ion implantation, to form a p-type region (see D8, Figure 1 and the corresponding description), the amount of beryllium introduced into the substrate by ion implantation being such that the concentration of beryllium at the surface of the substrate in the p-type region is $10^{17}cm^{-3}$ or more (see $2x10^{18}cm^{-3}$ in the abstract of D8 on page 706 and Figure 1)."

The subject-matter of Claim 1 differs from the method of document D8 in that the substrate:

(a) consists of Ge and not of GaAs; and
(b) is heat treated at a temperature in the range 400°C to 700°C instead of at 900°C.

2.2 The remaining documents on file do not come closer to the process steps claimed in Claim 1. In particular, no prior art document dealing with Be-doped Ge mentions diffusion or implantation steps. The only document describing a diffusion and implantation into a Ge substrate is document D4, wherein Zn and B are used as dopants and not Be. The device in Figure 3 of the opposed patent corresponds to that described in document D4.

2.3 In correspondence with the technical aims disclosed in the description of the opposed patent, column 1, lines 6-47, the Board regards the prior art from which the teaching of the patent starts to be document D4, which is the only document on file describing explicitly a deep lying p-region in a Ge substrate; see D4, Figure 1 with the corresponding description. This known p-region, a guard ring of 4μm junction depth, was produced by diffusing Zn into Ge at 830°C for 3 hours.

2.4 Starting from document D4, the objective problem underlying the present invention is to provide in a Ge substrate a deep lying p-region in such a way that

(a) the thermal deformation of the Ge-wafer is reduced (see the description, column 1, lines 22-26), i.e. the temperature of an indispensable heat treatment can be lowered; and

(b) a surface concentration of the dopant above $10^{17}cm^{-3}$ can be realised, i.e. (relying on the corresponding value in the description of the patent under appeal, column 2, line 14) that a value of the surface concentration can be realised above the solid solubility of the chosen dopant in Ge.

A graded pn-junction production cannot be included into the objective problem. The subject-matter of Claim 1 does not comprise a diffusion time. The definition of this parameter would be essential in order to guarantee the transformation of the abrupt step junction after implantation into a dopant concentration which decreases gradually with the substrate depth. The same applies to the increase of the withstand voltage and to the decrease of the dark current mentioned in the patent, because no geometrical forms of the p-region are claimed in Claim 1.

2.5 The above objective problem is solved according to Claim 1 by substituting the thermal diffusion of a Zn dopant by an implantation and subsequent diffusion of a Be dopant, i.e. by the procedural measures and the dopant known from document D8, see point 2.1 above. In the Board's view such a replacement was obvious to a skilled person for the following reasons:

2.6 The Respondent's argument in point VII(a) above - a skilled person would not use ion implantation in producing a deep lying p-region - is not followed. It does not duly take into account the diffusion step claimed subsequent to implantation and the claimed dopant concentration. On the contrary, the claimed aim of realising a value of the dopant surface concentration above its solid solubility, forces the skilled person to start the overall doping process with an ion implantation step, which is the only known technical means to introduce dopants into a substrate practically independent from their chemical solubility in this substrate; see as expert opinion for instance document D10, page 140, last paragraph. Moreover, in order to combine the advantage of a selectable dopant dose with that of deeper lying doped region produced by diffusion, it is generally known to apply after an implantation step a diffusion step. This subsequent diffusion of an implanted predeposited dopant is known to make the dopant penetrate essentially more deeply into the substrate than implantation alone (drive-in diffusion); see as expert opinion for instance document D10, page 153, paragraph 1.

2.7 Also in view of the further aim in the objective problem in point 2.4 above, to lower the diffusion temperature, in the Board's view, a skilled person would be expected as a normal measure to carry out ion implantation prior to a diffusion step. In the Board's opinion, a person skilled in the field of doping knows that the ion bombardment during an implantation step creates vacancies in the crystal lattice of the substrate, so that the implanted impurities start to diffuse deeper into the substrate already at temperatures far below the normal diffusion temperature (radiation enhanced diffusion), see as expert opinion for instance document D10, page 152, paragraph 1. Hence, lower diffusion temperatures after an implantation

step are expected by a skilled person, see also point VII(b) above.

Moreover, due to the fact that a skilled person will always try to achieve the necessary electrical activation after an ion implantation step by annealing the substrate at the lowest possible temperature (see D10, page 154, last paragraph) in the Board's view no inventive merit can be seen in finding out by trial and error that for driving implanted Be-ions more deeply by diffusion into the substrate, the appropriate temperature lies in the claimed region of 400°C to 700°C for a Ge substrate and differs from the corresponding known value in GaAs (900°C; see D8, the subtitle of Figure 1).

2.8 The maximum diffusion depth is a function of the predeposited dopant dose and depends above all on the diffusion time applied. Claim 1 does not specify any times for the claimed diffusion step. For this reason the Appellant's argument in point VII(c) above is not relevant to the subject-matter of Claim 1. Moreover, the theoretical projected penetration depth Rp calculated by the Appellant on the basis of the LSS theory will not be regarded by an expert as an approximation which is consistent with the claimed method having regard to the diffusion after implantation. In the Board's opinion, the nearest comparable experimental values known are derivable - not from Figure 1 of document D4 due to the low implantation energy - but from Figure 1 of document D8, showing an experimental maximum p-region depth of 2μm, however as a result of a heat treatment of only 15 minutes. The values mentioned in the description of the opposed patent, column 6, lines 40 and 41 and put forward by the Appellant in point VII(c) above, have been obtained after a diffusion time of 60 minutes. Hence, in view of the 4 times longer diffusion time a resulting penetration

range from 5 to 15μm (depending on the implantation energy and predeposition dose applied; see Figure 4A of the patent under appeal) will not surprise a skilled person, in particular since a comparison of the slopes of the concentration curves in Figure 1 of document D8 with Figure 4A of the patent under appeal shows that in the prior art curve heat treatment was stopped more or less after the electrical activation and not much time was allowed for drive-in diffusion.

2.9 In the Board's view a skilled person, in solving the objective problem indicated in point 2.4 above, would not only substitute the sole diffusion step in document D4 by implantation and subsequent diffusion measures such as known from document D8, but would also replace the Zn dopant of document D4 by the Be dopant of document D8. Be is known to be a p-dopant as well in Ge as in GaAs. Due to the almost identical atomic weights of Ge (72.6), Ga (69.7) and As (74.9), comparable stopping properties of a Ge-lattice and a GaAs-lattice would be expected. Hence, the explicit statement in document D8, page 707, left column, lines 1-3: "Be is the lightest known p-dopant in GaAs, and therefore Be^+-ions will penetrate deeper than other p-type ions of the same energy" hints at the use of Be also to p-dope Ge, not only because of the deeper dopant predeposition at the start of the drive-in diffusion but also in view of being able to produce vacancies in deeper lying lattice regions and to promote thus the subsequent diffusion.

2.10 For the reasons stated above, the Board regards the subject-matter of Claim 1 as the result of an analogous use of measures known from document D8 in the technically close situation of the substrate known from document D4, which use was obvious in particular because all the stated effects of this use would have been expected by a skilled

person on the basis of his general knowledge and a corresponding adaptation of the temperature range to the claimed values could be found by normal trial and error routine. Therefore, Claim 1 is considered to lack an inventive step within the meaning of Article 56 EPC. Claims 2-5 fall because of their dependency on Claim 1.

3. Costs

3.1 The Board does not accept the Appellant's submission as summarised in point VI(d) above. As has been stated in a number of previous Board of Appeal decisions, (see in particular Decision T 326/87 dated 28 August 1990 (to be published)), the opposition procedure under Article 99 EPC and following is designed to ensure that an opponent should normally present all the main documents or other evidence in support of his grounds of opposition in the notice of opposition, and should not present such evidence separately by degrees.

3.2 However, the Respondent has not produced any evidence that the late filing in particular of documents D4 and D8 has given rise to extra costs incurred additionally to those which would have accrued in the normal course of defending the appeal. For this reason, the Respondent's request for an award of costs is refused.

Order

For these reasons, it is decided that:

1. The Decision of the Opposition Division is set aside.

2. European patent No. 0 026 629 is revoked.

3. The Respondent's request for an award of costs is refused.

The Registrar: The Chairman:

P. Martorana G.D. Paterson