BESCHWERDEKAMMERN DES EUROPÄISCHEN PATENTAMTS

BOARDS OF APPEAL OF THE EUROPEAN PATENT OFFICE

CHAMBRES DE RECOURS DE L'OFFICE EUROPEEN DES BREVETS

Internal distribution code:
(A) [ ] Publication in OJ
(B) [ ] To Chairmen and Members
(C) [X] To Chairmen

D E C I S I O N
of 13 August 1997

Case Number: T 0597/94 - 3.4.1

Application Number: 85105255.5

Publication Number: 0160919

IPC: H01L 21/265

Language of the proceedings: EN

Title of invention:
Process for forming ic wafer with buried zener diode

Patentee:
Analog Devices, Inc.

Opponent:
Philips Electronics N.V.

Headword:
-

Relevant legal provisions:
EPC Art. 56

Keyword:
"Main and auxiliary requests I to III: inventive step (no)"

Decisions cited:
-

Catchword:
-

Case Number: T 0597/94 - 3.4.1

D E C I S I O N
of the Technical Board of Appeal 3.4.1
of 13 August 1997

Appellant: (Proprietor of the patent)	Analog Devices, Inc. Route 1, Industrial Park P.O. Box 280 Norwood Massachusetts 02062 (US)
Representative:	Heunemann, Dieter, Dr. Vossius & Partner Postfach 86 07 67 81634 München (DE)
Respondent: (Opponent)	Philips Electronics N.V. Groenewoudseweg 1 NL-5621 BA Eindhoven (NL)
Representative:	Tangena, Antonius Gerardus Internationaal Octrooibureau B.V. Prof. Holstlaan 6 5656 AA Eindhoven (NL)
Decision under appeal:	**Decision of the Opposition Division of the European Patent Office posted 11 May 1994 revoking European patent No. 0 160 919 pursuant to Article 102(1) EPC.**

Composition of the Board:

Chairman: H. J. Reich
Members: R. K. Shukla
M. Lewenton

Summary of Facts and Submissions

I. The appellant is owner of European patent No. 0 160 919.

II. This patent was revoked by a decision of the Opposition Division on opposition by the respondent on the basis of the main request and auxiliary requests I and II filed on 20 April 1994.

Claim 1 of the **main request** filed on 20 April 1994 reads as follows:

"1. A method of forming a buried reference diode in a large-sized IC wafer requiring relatively long process temperature ramps comprising the steps of:

- implanting p-type ions (20, 56) in said wafer;
- driving said implanted p-type ions into said wafer to a substantial depth; and
- introducing p-type dopant (22, 50) in said wafer in a region over said implanted p-type ions (20, 56) and extending out laterally beyond the sides of said implanted p-type ions to accommodate establishing electrical connection to the region of said implanted p-type ions; whereat
- said implanted p-type ions being driven into said wafer a distance substantially greater than the depth of said p-type dopant;
- implanting n-type ions (30, 54) having a concentration profile which is sharper than that of phosphorous over at least the whole region of said implanted p-type ions (20, 56) to form an all-implanted junction (32) to serve as a reference diode, and
- implanting said p-type ions (20, 56) in said sub-surface junction (32) in a higher

concentration than said p-type dopant (22, 50) has in any surface junction with said n-type ions."

Claim 1 of **auxiliary request I** (i.e present auxiliary request II) filed 20 April 1994 has the wording of Claim 1 of the main request wherein the words "implanting n-type ions (30, 54) having a concentration profile which is sharper than that of phosphorous" are replaced by the wording:

"implanting arsenic ions (30, 54)".

Claim 1 of **auxiliary request II** (i.e. present auxiliary request III) filed 20 April 1994 adds to the wording of Claim 1 of auxiliary request I after "driving said implanted p-type ions into said wafer to a substantial depth" the feature:

"by annealing"

Claims 2 to 15 of the main request and Claims 2 to 14 of auxiliary requests I and II are dependent on the respective Claim 1.

III. In respect of Claim 1 of the **main request** the Opposition Division took the view that the amendment specifying the n-type ions by the feature "having a concentration profile which is sharper than that of phosphorous" was not allowable under Article 123(2) EPC. In particular, the disclosure of arsenic as a suitable n-type dopant and the explanation of its effect in column 6, lines 53 to 57 of the patent as granted were not considered as an allowable basis for the more general amended wording of the claim.

The Opposition Division also took the view that Claims 1 of auxiliary requests I and II were lacking an inventive step in the sense of Article 56 EPC having regard to documents:

D1: JP-A-58 16574 (including a translation into English filed by the respondent with letter dated 5 August 1992) & Patent Abstracts of Japan, vol. 7, No. 94 (E-171) [1239], 20 April 1983;

D2: DE-A-3 151 437; and

D3: EP-A-0 082 331.

The first feature distinguishing the subject-matter of Claims 1 of auxiliary requests I and II over the closest prior art disclosed in document D1, concerning the specification of the wafer as "a large sized IC wafer requiring relatively long process temperature ramps" is vague and indefinite and as such not sufficient to distinguish the claimed method from the prior art. The selection of the n-type ions which are not specified in document D1, as "arsenic ions" according to the remaining second distinguishing feature would be obvious for the following reasons:

Document D1 indicates that the shallowness of the N^+ region is an important factor in controlling the fluctuation of the Zener breakdown voltage. It was well-known at the priority date of the opposed patent that with arsenic shallower highly doped regions with a sharper concentration profile can be obtained than that with the other most commonly used n-type dopant phosphorous, and that phosphorous diffuses faster in silicon than arsenic and develops a disadvantageous "kink" in the concentration profile as for example illustrated in Figure 1 of the opposed patent. Moreover, document D3 discloses the use of implanted arsenic to form the N^+ region of a Zener diode. The drive-in step of implanted p-type dopants "by annealing" as additionally claimed in Claim 1 of auxiliary request II to produce relatively deep doped areas and/or to recrystallise the semiconductor material damaged by ion-implantation is well-known in the art. Moreover, this annealing step is obvious in view of document D2, page 2, lines 1 to 26.

IV. The patentee lodged an appeal against this decision maintaining his requests as set out in paragraph II above. With a letter dated 25 January 1995 the opponent cited for the first time document

D4: S. M. Sze: "VLSI Technology", McGraw-Hill Book Company 1983, pages 199 and 200.

The patentee supplemented his grounds of appeal in a letter dated 1 December 1995.

V. Oral proceedings before the Board were held on 13 August 1997. During the oral proceedings the appellant (patentee) requested that the decision under appeal be set aside and that the patent be maintained on the basis of the main request or the auxiliary requests I and II (now renumbered II and III) filed on 20 April 1994 or on the basis of auxiliary request I submitted during the oral proceedings on 13 August 1997.

The wording of Claim 1 of auxiliary request I filed 13 August 1997 corresponds to that of Claim 1 of the main request (see paragraph II above) with the wording "having a concentration profile which is sharper than that of phosphorous" being replaced by the wording "having a concentration profile which is much more abrupt than that of phosphorous up to that of arsenic".

Claims 2 to 14 of auxiliary request I are dependent on Claim 1.

During the oral proceedings the appellant presented document D1', which is a translation of document D1 deviating from that filed by the respondent.

The respondent (opponent) requested that the appeal be dismissed.

VI. In support of inventive step in the subject-matter of Claims 1 of his requests, the appellant made essentially the following submissions:

(a) Document D1 deals with reducing the variation of the breakdown voltage caused by the fluctuation width X_d of the N^+ layer thickness Xj by making the concentration profile of the n-type dopant intersect with a concentration profile of the p-type dopant in the region of a plateau. In this method stability of the breakdown voltage is achieved by a P^+ plateau which is formed by a multiple p-ion implantation with stepwise variation in implantation energy. Along the P^+ plateau the N^+ diffusion thickness may fluctuate without varying the resulting breakdown voltage; see document D1, page 4. The curves of the N^+ concentration profile in Figures 2 and 3 of document D1 are idealised and - in the light of a skilled person's general knowledge - will be interpreted as resulting from the doping of a small wafer with the usual n-dopant phosphorous. The lack of a kink in these curves does not exclude the use of phosphorous in the method of document D1, since such a kink develops gradually with the length of a high temperature treatment and only under certain experimental conditions; see also the patent in suit, column 3, lines 54 to

58. Moreover, the detection verification of a kink needs a high precision measurement of the concentration profile. The kink in Figure 4 of document D4 is based on theoretical considerations which do not suggest the formation of a kink as an inherent property of phosphorus diffusion. Therefore, the teaching of document D4 cannot exclude the use of phosphorus in the method according to document D1. An annealing treatment of the implanted P^+ region would not be necessary in the method disclosed in document D1, since in this method the p-type dopant diffusion would primarily be caused by lattice defects.

(b) The problem underlying the present invention is to increase the yield of Zener diodes with reproducible breakdown voltage when produced on large-sized wafers. Large-sized wafers need long high-temperature treatments due to the necessary slow ramping of temperatures for avoiding crystal damage. The slowed ramp-down of high temperatures in large size waters increases the breakdown voltage and the uncertainty in achieving consistently uniform subsurface breakdown voltage. Document D1 does not suggest a solution to this problem. Only the present inventors recognised that this problem is caused by the use of phosphorous as explained in Figure 1 of the patent under appeal. The kink of the phosphorous profile transforms a slight shift of the N^+ profile into a strong shift of the point of intersection of the N^+ profile and the P^+ profile, causing thereby a significant shift of the breakdown voltage. Document D1 is totally silent about the use of a specific n-dopant and any differences resulting from the use of phosphorous, arsenic or antimony cannot be foreseen from the teaching of document D1. It is not obvious from document D1 to implant n-type ions having an implantation profile which is sharper than that of phosphorous, so that the N^+ concentration profile almost vertically intersects the P^+ profile.

(c) Document D4 discloses n-p-n transistors made with arsenic-diffused emitters, which are operated at a high frequency. Since in Zener diodes a DC voltage is applied, a person skilled in the art does not obtain any hint from document D4 to use arsenic as an n-type dopant in Zener diodes produced on large-sized wafers.

(d) Document D3 is not relevant, since it does not disclose a "buried" Zener diode and does not mention the necessity of a sharp n-type concentration profile and a corresponding intersection with the p-type profile.

(e) An annealing treatment for removing radiation damage after implantation and to electrically activate the dopants would not result in driving implanted p-type ions "to about 3 to 6 microns" as disclosed in the patent in suit, column 5, lines 25 to 32. Document D2 gives no hint to drive implanted p-type ions out of the range of radiation damage by annealing.

The appellant also made submissions with regard to the allowability of amendments to claim 1 of the main request, pursuant to Article 123(2) and (3) EPC.

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

(a) Document D1 discloses most of the subject-matter claimed in Claim 1. Though there is no explicit disclosure in document D1 concerning the kind of implanted n-type ions, there are three indications for the use of arsenic. The N^+ profiles in Figures 2 and 3 of document D1 show no kinks. Figure 1 attached to the appellant's letter dated 1 December 1995 recognises that fluctuations in the breakdown voltages arise from kinks in the concentration profile of phosphorous which enlarge the fluctuations of the P^+N^+ intersection point. Document D1, page 3, lines 12 to 15 (corresponding to D1', page 4, line 25 to page 5, line 1) states that the observed fluctuations of the breakdown voltage in the method of document D1 are almost negligible.

(b) In the semiconductor art it is generally known that a multitude of problems are caused by the uncontrollable outdiffusion of dopants from a doped region during a subsequent high temperature treatment step of a semiconductor wafer. Therefore, a skilled person would relate also any observed variation of the breakdown voltage of a Zener diode - when produced in a method requiring longer high temperature treatment steps - to an increased amount of uncontrollable outdiffusion from previously produced P^+ and N^+ regions. Document D1, page 2, lines 18 to 21 and page 3, lines 10 to 12 (corresponding to D1', page 3, lines 17 to 22 and page 4, lines 23, 24) teaches that the breakdown voltage fluctuates in relation to the fluctuation of the P^+ concentration and to the variation of the diffusion depth of the N^+ region.

(c) It is generally known that ion-implantation of relatively heavy arsenic ions results in implanted regions which are shallower than those produced with phosphorous. Document D4, page 199, paragraph "Phosphorus" to page 200, line 3 teaches that arsenic allows a better control of a narrow base width in n-channel MOSFETs. A skilled person will recognise that such better control results from the lower diffusion coefficient of arsenic. Therefore, the skilled person will routinely select arsenic and not phosphorous in order to produce a steep N^+ concentration profile with small variance. Antimony is rarely used, because of the necessary high implantation energies.

(d) Document D3 discloses implantation of arsenic ions for producing a "buried" P^+ N^+ Zener junction. This follows clearly from the stated Zener junction depth of 0.5 micron. The implantation energies of 20 to 200 KeV used in the embodiment of the patent in suit (see column 5, line 54), also produce a Zener junction depth below 1 micron.

(e) The flat P^+ plateau in Figure 3 of document D1 is formed from overlapping P^+ concentration maxima of different implantation energies in Figure 2. The comparison of the two curves shows that in the method disclosed in document D1 the P^+ region was annealed after its implantation. Annealing after implantation is moreover an indispensable step for electrically activating the implanted ions. Moreover, document D2, page 4, lines 12 to 24 discloses annealing as a drive-in step for implanted p-dopants in a Zener diode.

The respondent also contended that the subject-matter of claim 1 of the main request contravened the requirement of Article 123(2) EPC.

VIII. At the conclusion of the oral proceedings, the decision was announced that the appeal is dismissed.

Reasons for the Decision

1. As the patent in suit is revoked for lack of inventive step for the reasons which follow, the Board does not consider it necessary to deal with the objection under Article 123(2) raised by the respondent against claim 1 of the main request.

2. *Inventive step - Claims 1, main and auxiliary requests I and II*

2.1 Document D1 (interpreted with its translation D1' as filed by the appellant) discloses in the identical wording of Claims 1 of the main request and auxiliary requests I, II and III:

"A method of forming a buried reference diode in a ... wafer ... comprising the steps of:

- implanting p-type ions (3 in figure 1 of D1 and page 4, lines 9 to 15) in said wafer;
- driving said implanted p-type ions into said wafer to a substantial depth (page 3, line 5);
- introducing p-type dopant (2 in Figure 1) in said wafer in a region over said implanted p-type ions and extending out laterally beyond the sides of said implanted p-type ions to accommodate establishing electrical connection to the region of said implanted p-type ions; whereat
- said implanted p-type ions (3) being driven into said wafer a distance substantially greater than the depth of said p-type dopant (2);
- implanting n-type ions (4 in Figure 1) over at least the whole region of said implanted p-type ions (3) to form an all-implanted junction to serve as a reference diode (Claim 1 and page 3, lines 7 to 10)

- implanting said p-type ions (3) in said sub-surface junction (B in Figure 1) in a higher concentration (P^+, page 3, line 5) than said p-type dopant (2) has in any surface junction with said n-type ions (see region P in Figure 1 and profiles P and P^+ in Figure 2)".

2.2 Document D1 solves the problem of fluctuations of the breakdown voltage of a Zener diode due to the variation of the diffusion thickness of the N^+ region by a plurality of P^+ implantations at varying energies. The P^+ implantations resulting in a plateau-like concentration peak having a width that corresponds at least with the fluctuation width of the concentration profile for the N^+ region at the N^+ P^+ intersection point. The diffusion thickness of the N^+ region is set to extend to the centre of the P^+ plateau. Thereby variance in the breakdown voltage gets almost negligible; see document D1', page 4 in particular lines 6 to 9, 17, 18, 23, 24 and 27. Starting from the closest prior art disclosed in document D1, the objective problem underlying Claims 1 of the appellant's request, is to provide a method with an increased yield of Zener diodes having a reproducible breakdown voltage when formed in large-sized IC wafers requiring relatively long process temperature ramps, which method requires less boron and thus is technically more simple; see the patent in suit, column 2, lines 12 to 32 and column 6, line 57 to column 7, line 3. The disadvantage that the long process temperature ramps which are required in the formation of Zener diodes on large-sized wafers, lead to a lower yield of diodes having a breakdown voltage within a given range of tolerance, can be observed in practice. The fact that fluctuations in the extent of diffusion depend on the length of a high temperature treatment is generally known; see also paragraph VII-(b) above. Therefore, the Board regards a skilled person to be able to realise that the width of a P^+ plateau which is adequate to compensate for the enlarged N^+ fluctuation width at relatively long temperature ramps, must be sufficiently long, and would thus increase the number of necessary neighbouring boron (P^+) implantations with regard to document D1 and thereby unduly increase the production time. Hence, contrary to the appellant's submission in paragraph VI-(b) above, in the Board's view, the formulation of the objective problem cannot be regarded to contribute to an inventive step in Claims 1 of the appellant's requests.

2.3 The solution of this objective problem claimed in Claims 1 of all the appellant's requests is based on the same principle as disclosed in the patent in suit in column 6, line 53 to column 7, line 3: The degree of uncertainty in the dopant concentration at the p n-junction is reduced by establishing more controllably the position of the P^+ N^+ intersection point via a shallower N^+ implantation with a more abrupt concentration profile than that of phosphorous, such as realisable by arsenic. (As generally known in the art of Zener diodes at the priority date of the patent under appeal, a decreasing dopant concentration at the p n-junction results in an enlarged thickness of the depletion layer of the junction and thereby in an increased breakdown voltage, i.e. in an increased voltage necessary for electrons to start tunnelling through the depletion layer from the valence band of the P^+ region to the conduction band of the N^+ region and to thereby effect the onset of the avalanche breakdown.)

Claims 1 of the **main request** and of **auxiliary request I** define the above solution in the following wording which sets out the properties of the technical means employed:

implanting n-type ions "having a concentration profile which is sharper than that of phosphorous (main request)" or "having a concentration profile which is much more abrupt than that of phosphorous up to that of arsenic (auxiliary request I)".

Claims 1 of **auxiliary requests II and III** define that above solution by the technical means applied:

"implanting arsenic ions".

In the present case, in the assessment of inventive step the question which needs to be considered is whether the applied technical means (arsenic) and its exploited properties (shallower implantation with more abrupt concentration profile) are known in the art and whether it would be obvious for a skilled person to make use of these properties in order to solve the objective problem. Since the facts to be examined are the same,. the obviousness of the above-stated solutions as claimed in Claims 1 of all the appellant's requests can be discussed together.

2.4 In the Board's view, it is part of the skilled person's routine experimental knowledge that prolonged high temperature treatments of wafers increase the statistical uncertainty in the extent of dopant outdiffusion from a doped zone and thereby change the concentration profile of the doped region in an unpredictable manner; see also paragraph VII-(b) above. Thus, a skilled person is able to foresee that any prolongation of high temperature annealing step in the production of a semiconductor device would increase the shift of the position of a p n-junction. Since document D1', page 3, lines 17 to 22 teaches that any shift of the N^+ P^+ intersection point along the concentration profile changes the breakdown voltage, a skilled person has no difficulty to find out that the increased variation of the break voltage of Zener diodes produced on large-sized wafers, is caused by the increased uncertainty in the outdiffusion of the p and n dopants. In the Board's view, it is obvious to a skilled person to arrive at the logical conclusion that any reduction in the outdiffusion of the n and p dopants during the necessary high temperature treatment involved in the production process would reduce variation of the breakdown voltage of the diode. Therefore, the Board cannot see any inventive merrit in filling out the gap of information about the kind of n-type dopant in the teaching of document D1 by selecting among the conventionally used n-dopants for Zener diodes, i.e. phosphorous and arsenic, the one with the lower diffusion coefficient. Arsenic is generally known to have a lower diffusion coefficient than phosphorous; see also paragraphs III and VII-(c) above. Document D4 at page 199, last three lines, moreover suggests the use of arsenic having a low diffusion coefficient in that it teaches that arsenic allows a better control of the position of p n-junctions than phosphorus (in D4 a narrow base width of an n-p-n transistor). Document D4 at page 199, last three lines discloses the use of arsenic to produce emitter of an n-p-n transistor as it provides a better control of narrow base widths than that provided by phosphorus. Contrary to the submissions by the appellant (see paragraph VI(c) above), in the Board's view, a skilled person would learn from this disclosure that arsenic would also enable a better control of the location of a PN junction than phosphorus in the formation of a Zener diode, since the basic process of dopant diffusion is generally known to be independent of the subsequent operation of the device at frequencies higher than that for a Zener diode. Thereby a skilled person would automatically arrrive at a concentration profile which is "sharper" or "more abrupt than that of phosphorus"

2.5 A skilled person will routinely analyse the working principle of the P^+-plateau solution for stabilising the breakdown voltage disclosed in document D1 and notice that during thermal n-dopant shifts the breakdown voltage can be maintained, if the P^+ concentration gradient near to the N^+ P^+ intersection point is small. In the Board's view, it is not the lack of kinks in the N^+ concentration profile but the low P^+ concentration gradient of the P^+ plateau - as disclosed in document D1 - that gives the skilled person the decisive information about the kind of N^+ concentration profile that minimises the variation of the breakdown voltage caused by long high temperature annealing steps in the production of a Zener diode. It belongs to a skilled person's routine knowledge that arsenic due to its larger mass enables to realise such a profile with a higher precision than phosphorous; see also paragraph VII-(c) above.

2.6 Contrary to the appellant's opinion in paragraph VI-(d) above, document D3 at page 5, last two lines discloses that breakdown occurs at crossover point 58 in Figure 4 which corresponds to the buried junction between regions 18 and 20 in Figures 2 and 3; see also D3, page 6,line 18. The Zener diode disclosed in document D3 is moreover classified as being of the "sub-surface" type; see page 6, line 1. This fact, in the Board's view, represents an additional pointer to the use of arsenic for producing the obvious form of N^+ concentration profile set out in paragraph 2.5 above.

2.7 For the reasons indicated in detail in paragraphs 2.1 to 2.6, in the Board's judgment, Claims 1 of the main request and auxiliary requests I and II lack an inventive step within the meaning of Article 56 EPC:

3. *Inventive step - Claim 1 - auxiliary request III*

3.1 Claim 1 of auxiliary request III adds to the subject-matter of Claim 1 of auxiliary request II the feature specifying that the drive-in step of the implanted p-type ions is realised "by annealing"; see also paragraph II above. Document D2, page 4, lines 12 to 24 teaches annealing as a drive-in step for implanted p-type dopants in a Zener diode; see also paragraphs VII-(e) above. The analogous use of the annealing step according to document D2 in the method disclosed in document D1, is obvious, since no unexpected effect of such use was disclosed or submitted by the appellant. The alleged outdiffusion into regions with no radiation damage (see paragraph VI-(e)) finds no support in the wording of Claim 1 or in the description of the patent in suit; see in particular column 5, lines 25 to 32. Hence, the additional feature claimed in Claim 1 of auxiliary request III does not impart an inventive step to the claimed subject-matter.

3.2 For the reasons set out in paragraphs 2.1 to 2.6 and 3.1, Claim 1 of auxiliary request III lacks an inventive step within the meaning of Article 56 EPC.

4. The dependent claims of the appellant's requests fall because of their dependency on the respective Claim 1.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

M. Beer H. J. Reich