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D E C I S I O N
of 8 July 1999

Case Number: T 0393/94 - 3.4.3

Application Number: 89200845.9

Publication Number: 0336515

IPC: H01L 21/76

Language of the proceedings: EN

Title of invention:
Method of manufacturing a semiconductor device having a silicon substrate with fully or partly sunken field oxide regions

Applicant:
Koninklijke Philips Electronics N.V.

Opponent:
-

Headword:
Sunken field oxide/PHILIPS

Relevant legal provisions:
EPC Art. 56

Keyword:
"Inventive step - auxiliary request (yes)"

Decisions cited:
-

Catchword:
-

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Case Number: T 0393/94 - 3.4.3

D E C I S I O N
of the Technical Board of Appeal 3.4.3
of 8 July 1999

Appellant: Koninklijke Philips Electronics N.V.
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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 16 February 1994 refusing European patent application No. 89 200 845.9 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: R. K. Shukla
Members: G. L. Eliasson
W. Moser

Summary of Facts and Submissions

I. European patent application No. 89 200 845.9 was refused by the decision of the examining division dated 16 February 1994. The ground for the refusal was that the subject matter of claims 1 to 7 as filed lacked an inventive step in view of the prior art documents

D1: IEEE Transactions on Electron Devices, vol. 35, no. 3, March 1988, pages 275 to 284;

D2: US-A-4 038 110;

D3: GB-A-2 083 947; and

D4: EP-A-0 071 203.

II. The appellant (applicant) lodged an appeal on 18 April 1994 paying the appeal fee the same day. A statement of grounds of appeal was filed the same day along with an amended claim 1.

Oral proceedings were requested in the event that the Board intended to dismiss the appeal.

III. In a communication annexed to a summons to the oral proceedings, the Board informed the appellant of its provisional opinion that the subject matter of claim 1 did not seem to involve an inventive step with respect to document D1.

IV. At the oral proceedings held on 8 July 1999, the appellant filed new sets of claims forming the main and the auxiliary requests. The appellant requested that

the decision under appeal be set aside and a patent be granted on the basis of the claims according to one of the following requests:

Main request:

Claim 1 filed during the oral proceedings as main request and claims 2 to 7 of the application as filed;

Auxiliary request:

Claims 1 and 2 filed during the oral proceedings as auxiliary request.

V. Claim 1 in accordance with the main request reads as follows:

"1. A method of manufacturing a semiconductor device comprising a silicon substrate with fully or partly sunken field oxide regions for mutual insulation of semiconductor elements to be formed in the substrate, in which method a mask is formed in a layer of silicon oxynitride SiO_xN_y deposited upon a surface of the substrate and an overlying layer of silicon nitride Si_3N_4, whereby in the layer of silicon oxynitride x/y is smaller than 0,5, after which, using said mask, recesses are first provided in the substrate in which recesses the field oxide regions are then formed by subjecting the recesses over their whole area to an oxidation treatment, characterized in that the recesses are provided in the substrate by performing a first oxidation and then etching away the silicon oxide thus formed."

VI. Claim 1 according to the first auxiliary request differs from that of the main request in that following feature is added at the end of the latter claim:

"and in that prior to performing the first oxidation step a further layer of silicon oxynitride (SiO_xN_y) is provided on the mask after which the said further layer of silicon oxynitride is etched anisotropically in such a manner that the edges of the apertures of the mask which bound the regions of the substrate where the recesses are provided remain covered with parts of the said further layer of silicon oxynitride."

VII. The appellant presented essentially the following arguments in support of his requests:

(a) Claim 1 of both requests is delimited with respect to document D4 which the appellant considers to be the closest prior art. The method of document D4 uses wet etching of the silicon substrate for forming the recess and thus has the disadvantage that a substantial underetching takes place of the substrate below the mask. The process of document D4 is thus unsuitable for isolating devices with small line widths.

(b) Regarding document D1, the method of claim 1 of the main request differs from that disclosed in this document in that (i) a deposited silicon oxynitride layer is used instead of a nitridized silicon oxide layer; (ii) the oxynitride layer has a higher proportion of nitrogen atoms than that of oxygen atoms; and (iii) no sidewall spacers are formed in the recess whereas in document D1

sidewall spacers are formed on the sidewall of the oxidation mask as well as in the recess. The nitridization process used in document D1 entails a long (seven hours) heating step at a very high temperature (1200° C) which makes the process of document D1 unsuitable for producing integrated circuits. Moreover, even after such prolonged heating, the nitrogen content of the oxynitrde film is apparently below the claimed range which is optimum for preventing the occurrence of oxide undergrowth. As to feature (iii), the rather complicated silicon oxide/silicon nitride sidewall spacer used in document D1 would be regarded as essential for obtaining field oxide regions with undergrowth of 150 nm or less.

(c) Regardless of whether document D1 or D4 is taken as the starting point, a skilled person considering the teaching of these two document would fail to arrive at the claimed method, since a skilled person taking the entire teaching of document D1 into account would regard the sidewall spacer in the recess as essential for attaining the desired small undergrowth, and therefore, the second oxidation step would not take place over the whole area of the recesses.

(d) As to the auxiliary request, the claimed process further differs from that of document D1 in that (iv) a sidewall spacer is formed before the first oxidation step whereas in D1 the sidewall is formed after the first oxidation step; and (v) the sidewall is formed of oxynitride instead of oxide/nitride. Since the method of document D1

teaches that the sidewall spacer is formed at a different stage than that specified in the claimed method, and document D4 does not mention sidewall spacers at all, a skilled person using the teaching of these prior art documents would not arrive at the claimed method without employing inventive skills.

Reasons for the Decision

1. The appeal is admissible.

2. *Amendments*

Claim 1 of the main request corresponds to a combination of the features of originally filed claim 1 together with the features disclosed on page 6, line 32 to page 7, line 1 (silicon oxynitride *deposited* and the ratio $x/y < 0.5$), and in Figures 4 and 5 together with page 8, lines 25 to 29 (subjecting the recesses *over their whole area* to an oxidation treatment) of the application as filed. Claim 1 of the auxiliary request corresponds to a combination of claim 1 of the main request and claim 6 as filed. Claim 2 of the auxiliary request corresponds to claim 7 as filed. The claims of both requests therefore meet the requirements of Article 123(2) EPC.

3. *Clarity*
The claims according to both requests are considered by the Board to be clear and therefore meet the requirements of Article 84 EPC.

4. *Prior art and novelty*

4.1 Document D4 discloses a method of manufacturing fully or partially sunken field oxide regions in a semiconductor substrate for mutual isolation of semiconductor elements. The method comprises the steps of forming a mask of a silicon oxynitride (SiO_xN_y) layer and an overlying silicon nitride layer; forming recesses by chemically etching the exposed silicon substrate using a CrO_3-HF etchant; and subjecting the recesses to an oxidation treatment (cf. page 9, lines 10 to 28; Figure 4). The purpose of the oxynitride layer is firstly to act as a buffer layer between the silicon substrate and the silicon nitride layer to avoid the creation of defects in the substrate, and secondly, to prevent the oxidation of the substrate below the edge of the mask, a phenomenon known in the art as "bird's beak" (cf. D4, page 6, line 34 to page 7, line 10). Special attention was paid in document D4 to the problem of finding the optimum ratio x/y of oxygen over nitrogen in the oxynitride layer for attaining these two objects, and the optimum ratio x/y is found to be less than 0.5 (cf. D4, page 9, lines 19 to 32; Figure 3). The silicon oxynitride layer is formed using a chemical vapor deposition method where the composition of the deposited layer is controlled by varying the composition of the reaction gases (D4, page 7, lines 12 to 18).

4.1.1 The method of claim 1 according to the main request thus differs from that of document D4 in that the recess is formed performing a first oxidation of the exposed silicon substrate and then etching away the silicon oxide thus formed, whereas in document D4 a wet

etching of the silicon substrate was used.

4.2 Document D1 also discloses a method of manufacturing fully or partially sunken field oxide regions in a semiconductor substrate for mutual isolation of semiconductor elements (cf. D1, Figure 1; page 276, left hand column). The method comprises the steps of forming a mask of a silicon oxynitride (SiO_xN_y) layer and an overlying silicon nitride layer (cf. Figure 1a); forming recesses by performing a first oxidation of the exposed silicon substrate (Figure 1b), and etching away the oxide (Figure 1c). The sidewalls of the mask and the recess are covered with a sidewall spacer made of an oxide layer and a nitride layer (Figures 1c and 1d). Finally, the recesses are subjected to an oxidation treatment (cf. Figure 1f). The silicon oxynitride layer used in the mask is formed by first depositing a silicon oxide layer and then thermally nitridizing the oxide film in an ammonia ambient at 1200° C for 7 hrs (cf. page 276, left-hand column, lines 6 to 10). There is no disclosure about the composition of the silicon oxynitride film obtained from the above nitridization process.

4.2.1 The method of claim 1 according to the main request differs from that of D1 in that (i) the mask contains a silicon oxynitride film which is deposited, whereas in D1 the oxynitride film is formed by nitridization of an oxide film; (ii) the ratio x/y of oxygen over nitrogen in the oxynitrde film is less than 0.5, whereas in D1 the composition is not disclosed; and (iii) the entire surface of the recess is subject to an oxidation treatment, whereas in D1 the sidewall of the recess is covered by an oxide/nitride sidewall spacer and the

oxidation is therefore not on the entire surface of the recess. The process of document D1 thus leads to a structure which is different from the claimed: The recesses are not filled with only pure silicon oxide as in the claimed process but the vertical sides of the recess are lined with a thin layer of silicon nitride.

4.3 The subject matter of claim 1 according to the main request is therefore new within the meaning of Article 54 EPC. Since the subject matter of claim 1 according to the auxiliary request contains all features of that of the main request, it is also new.

5. *Inventive step, main request*

5.1 In the decision under appeal, the examining division held document D1 to be the closest prior art. During the appeal proceedings, claim 1 has been amended to distinguish the claimed method further from that of document D1. As a result, the Board agrees with the appellant that document D4 represents the closest prior art. Claim 1 is also drafted in the two-part form according to Rule 29(1) EPC with respect to document D4.

5.2 In view of the difference between the method of claim 1 and that of document D4 discussed under point 4.1.1 above, the technical problem to be solved relates to finding an alternative method to that of document D4 whereby lateral etching of the substrate beyond the edges of the masks, a so-called under-etching, is minimized. This under-etching causes a substantial lateral growth of the field oxide below the oxidation mask. This problem is also addressed in the application

as filed (cf. column 1, line 54 to column 2, line 33).

5.3 The formulation of the above problem is, in the Board's view, immediately apparent to a person skilled in the art, since it is common general knowledge in the art that the use of an isotropic etchant, such as a liquid etchant, will result in under-etching of the substrate beyond the edges of the mask, and that the lateral extent of such under-etching is comparable to the depth of the recess to be etched.

5.4 In the method of document D1, a first oxidation of the silicon substrate is carried out, and, subsequently, the silicon oxide is etched away leaving a recess in the substrate (cf. D1, Figures 1b and 1c). A second oxidation follows whereby a sunken field oxide isolation region is formed, i.e., the same type of structure as produced by the method of document D4. The reported reduction in bird's beak length --and, hence, a reduced undergrowth of the final field oxide below the mask-- is mainly attributed to the use of a silicon oxynitride film in the oxidation mask (cf. D1, page 277, left hand column, first paragraph; Figures 2a and 2b), which is the same type of oxidation mask recommended in document D4. Thus, the skilled person faced with the above-mentioned problem with the process of document D4 would therefore find it advantageous to replace the isotropic etching step by the corresponding steps of the process of document D1 in order to reduce the undergrowth of the final field oxide.

5.5 In support of the inventive step of the claimed subject-matter, it was submitted by the appellant that the skilled person would only consider the teaching of

document D1 in its entirety. Consequently, he would find it necessary to include the steps of forming the sidewall spacers (cf. D1, Figures 1d and 1e) since the sidewall spacers are described therein as being essential for attaining a short bird's beak.

In accordance with the established case law of the boards of appeal, the disclosure of particular features in a prior art document must be considered in the technical context of the whole disclosure, so that the particular features cannot be selected in a manner which changes or contradicts the teaching of the document in question. In the present case, the Board finds that the manner of forming the recess (D1, Figures 1b and 1c) and the use of a sidewall mask (D1, Figures 1d and 1e) refer to different stages of a process of forming isolation regions which are not interrelated. This is *a priori* evident, since the sidewall spacer is formed after the recess is made, and the presence of a sidewall thus cannot have any effect on the resulting recess.

A skilled person moreover learns from document D1 that the presence of the sidewall spacer in Figures 1d and e has the effect of further reducing the bird's beak, but that the sidewall spacer is not indispensable for attaining this object: Comparing Figures 2a and 2b, it becomes apparent that the crucial feature of the process of D1 for reducing the bird's beak is the silicon oxynitride layer ("nitridized oxide") in the oxidation mask (cf. D1, page 275, right hand column). Thus, although the nitride sidewall spacer is mentioned as further improving the structure, it apparently plays a secondary role in this context (cf. D1, page 277,

left hand column). It is also evident from the disclosure in document D1 that the sidewall spacer mainly has the function of providing a mask for self-aligned field implantation (cf. D1, Figure 1d). Therefore, the skilled person concerned with providing an alternative method of forming a recess to that offered in document D4 would realize that the process steps in document D1 relating to the formation of the sidewall spacer are unrelated to those concerning the formation of the recess. It is also observed that, although the process of document D4 does not use sidewall spacers, its reported reduction in bird's beak is even larger than those stated in documents D1 and D6, a result which would signalize to the skilled person the importance of obtaining an optimum composition of the silicon oxynitride layer (cf. D4, Figure 3; D1, abstract; D6, Figure 1).

5.6 Thus, a skilled person seeking to improve the process of document D4 would in the light of the above considerations be able to replace the isotropic etching step used in document D4 by the steps 1a and 1b of the process of document D1 without employing inventive skills.

6. *Inventive step, auxiliary request*

6.1 From the discussion above, it is evident that the skilled person would regard sidewall spacers as optional. If however, the skilled person opts for the use of the sidewall spacers with a view to reducing the bird's beak further, he would first consult the process in document D1, as no sidewall masks are disclosed in document D4. In this case, a straight-forward approach would be to proceed in the same manner as prescribed in document D1, i.e., to form the sidewall between the first and the second oxidation steps (cf. D1, Figures 1d and e). In the method according to the invention as claimed, the formation of sidewall spacers before the first oxidation prevents the lateral undergrowth of oxide during the first oxidation itself. There is thus no hint in the available prior art documents to form the sidewall mask before the first oxidation to prevent the oxide undergrowth.

For the foregoing reasons, the subject matter of claim 1 is not obvious having regard to the cited prior art, and, accordingly, involves an inventive step within the meaning of Article 56 EPC as required by Article 52(1) EPC.

Claim 2 is dependent on claim 1, and, therefore, its subject matter involves an inventive step as well.

7. Since the subject matter of claim 1 according to the auxiliary request contains the feature of a sidewall mask, it appears that the embodiment depicted in Figures 1 to 5 no longer is part of the invention as claimed. Moreover, it also seems appropriate that

document D1 should be acknowledged in the description under Rule 27(1)(b) EPC. As the description needs extensive amendments, the Board finds it appropriate to remit the case to the department of the first instance under Article 111(1) EPC for further prosecution.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the Examining Division with the order to grant a patent on the basis of claims 1 and 2 submitted during oral proceedings as auxiliary request and the description and drawings to be adapted to the claims.

The Registrar: The Chairman:

D. Spigarelli R. K. Shukla