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Bezeichnung der Erfindung:
Title of invention:
Titre de l'invention : Method of manufacturing a semiconductor device with an interconnection electrode layer.

Klassifikation / Classification / Classement : H01L 21/88 H01L 21/306

## ENTSCHEIDUNG / DECISION

vom / of / du 20 December 1988

Anmelder / Applicant / Demandeur :

Patentinhaber / Proprietor of the patent / Titulaire du brevet : Kabushiki Kaisha Toshiba

Einsprechender / Opponent / Opposant : Deutsche ITT Industries GmbH

Stichwort / Headword / Référence :

EPÜ / EPC / CBE Article 56 EPC

Schlagwort / Keyword / Mot clé : Inventive step (no)

**Leitsatz / Headnote / Sommaire**

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Case Number : T 349 /87 - 3.4.1

# D E C I S I O N
## of the Technical Board of Appeal 3.4.1
## of 20 December 1988

Appellant : (Opponent)
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Decision under appeal : Interlocutory decision of the Opposition Division of the European Patent Office dated 29 July 1987 concerning maintenance of European patent No. 0 050 972 in amended form.

Composition of the Board :

Chairman : K. Lederer
Members : C. Black
C. Payraudeau

## Summary of Facts and Submissions

I. European patent No. 0 050 972 was granted on the basis of European patent application No. 81 305 009.3.

II. Opposition to the granted patent was filed by the Appellant, Deutsche ITT Industries GmbH, mainly on the ground that its subject-matter did not involve an inventive step having regard to the disclosures in:

DE-A-2 340 442 (D1)
DE-A-2 422 922 (D2)
DE-B-2 536 718 (D3).

III. The Opposition Division, in an interlocutory decision, maintained the patent in amended form on the basis of the documents specified in the communication pursuant to Rule 58(4) dated 24 February 1987, the only independent claim of which reads as follows:

"1. A method for manufacturing a semiconductor device comprising a step of forming a first material layer (23) on a semiconductor substrate (21), a step of forming a second material layer (24) made of silicon nitride on the first material layer (23), a first etching step of selectively removing the second material layer (24) using a masking layer (25), and a second etching step of selectively removing the first material layer (23) with the second material layer (24) as a mask, characterized in that said second material layer (24) is selectively removed by a reactive ion etching method using a gas containing hydrogen and carbon-halogen bonds to form an opening (26a) with a sloped side wall, and, after removing the masking layer (25), said first material layer (23) is selectively removed by a reactive ion etching method to

form an opening (26b) with a sloped side wall, said reactive ion etching method permitting said first and second material layers (23, 24) to be etched away."

Claims 2 to 6 are dependent claims relating to particular embodiments of the method according to Claim 1.

The gist of the argumentation of the Opposition Division was that, since reactive-ion etching was known to be anisotropic i.e. produce vertical side walls, it was not obvious to use this etching process when the aim was to obtain sloped side-walls. Further, D2, although it disclosed an etchant gas composition including hydrogen and carbon-halogen bonds as required by Claim 1, did not fill the gap between the disclosure of D1, which used isotropic etching in the form of plasma etching for obtaining sloped side-walls by undercutting, and the subject-matter of the invention.

IV. An appeal was lodged against this decision. In the statement of grounds the Appellant (Opponent) cited DE-A-2 727 788 (D4), a reference to which had been introduced into the description by the Examining Division, and three further documents:

Solid State Technology, April 1980, pages 122 to 128 (D5);

J. Vac. Sci. Technology 17(5), Sept/Oct. 1980, pages 1177 to 1183 (D6); and

IBM Techn. Discl. Bull., Vol. 22, No. 11, April 1980, pages 4883 to 4885 (D7).

V. In a communication accompanying a summons to Oral Proceedings, the Board referred to three further documents as background material to clarify terminology:

Electronics Vol. 115, August 31, 1978, pages 117 to 121 (D8);

Solid State Technology, April 1979, pages 125 to 132 (D9); and

Applications of Plasma Processes to VLSI Technology, ed. Sugano, John Wiley and Sons, pages 222 to 245 (D10).

D10 was published after the priority date of the patent in suit but is a translation of an original Japanese language edition which was published 10 July 1980, and thus was admitted as prior art by the Respondent.

VI. Oral Proceedings were held during which the Board expressed that it was satisfied that document D6 is to be considered as prior art. This was not disputed by the Respondent although he pointed out that its exact publication date was not clear.

At the end of these proceedings the Appellant requested that the decision under appeal be set aside and that the patent be revoked.

The Respondent requested that the appeal be dismissed and that the patent be maintained on the basis of the documents specified in the communication pursuant to Rule 58(4) issued 24 February 1987, amended as follows:

Claims 5 and 6 in accordance with the proposal in Patentee's letter received 01 August 1987,

Description column 4, line 59 - "If, as" to be replaced by "As",

Figures 4D, 4E - reference numeral 36 to be replaced by 35.

VII. The arguments presented by the Appellant are essentially as follows:

The problem which is the basis of the patent in suit is known from D4. Even if the solution to the problem in D4 involves plasma etching rather than reactive-ion etching, as is required by Claim 1, the latter is an analogous process which it is obvious to investigate, the more so since the average skilled person knows that reactive-ion etching is particularly suitable in microfabrication. The choice of etchant falls within his competence. Moreover, it is known from D7 that reactive-ion etching can be employed to achieve sloped side walls. Here a patterned photoresist mask is post-baked to create sloping edges which are transmitted to an underlying layer when this is etched.

Accordingly, it is the resist which is decisive for achieving sloped side-walls and not the composition of the etchant gas. In any case, if it is accepted that reactive-ion etching is usually anisotropic, the definition of the invention should include those parameters which lead to side-walls which are not completely vertical, and Claim 1 is silent in this respect.

The Respondent's arguments may be summarised as follows:

The invention is based on the discovery that reactive-ion etching using a gas containing hydrogen and carbon-halogen bonds with a resist pattern as a mask produces an opening

with sloped side-walls in a silicon nitride layer although reactive-ion etching is normally anisotropic, that is, it should produce openings with vertical side-walls. None of the cited documents discloses this, although it is acknowledged that it is known from D10 to use a gas containing hydrogen and carbon-halogen bonds for reactive-ion etching of silicon nitride. D1 discloses some of the features of Claim 1 but differs in that it employs plasma etching, a different etchant gas composition and only a single etching step. D4 also shows some similarities to the method according to Claim 1 but again differs in not using reactive-ion etching. The references to reactive-ion etching in the acknowledgement of D4 in the description and in various communications were clearly in error because the pressures disclosed in D4 are above those required for reactive-ion etching. D4 achieves sloped side-walls in that during etching the resist is etched laterally resulting in openings larger than the openings in the resist. This does not occur in the method of the patent in suit. Moreover, D4 requires a different etchant gas composition, namely carbon-halogen compounds plus oxygen, and US-A-4 293 375, which is equivalent to D4 specifically states that the role of the oxygen is to etch the resist mask. Therefore, there is no indication that oxygen might be replaced by hydrogen. Finally, D4 does not disclose a two-step etching process. D7 again requires the resist to be laterally etched, and therefore has the same defects as D4. The method of the patent in suit does not require a resist pattern having openings with sloped side-walls, as is clear from the figures. The Respondent further contends that it is not a requirement for patentability that the mechanism whereby an observed effect occurs should be stated.

## Reasons for the Decision

1. The appeal is admissible.

2. The claims under consideration do not contravene Article 123(2) or (3). Claim 1 differs from the version as filed by the inclusion of the features indicated by underlining in paragraph III above, which features were clearly originally disclosed.

3. Before entering the discussion of novelty and inventive step some general remarks should be made for clarifying the terminology used in the art of semiconductor etching. In its communication, the Board drew the parties' attention to documents D5 to D9 as background material in the field of dry or plasma etching, and concluded that dry etching should be the generic term, encompassing ion-beam milling, sputter etching, reactive-ion etching (also known as reactive sputter etching) and plasma etching. Ion beam milling and sputter etching employ relatively low pressures, are directional, therefore anisotropic, but, to the extent that they are purely physical, are non-selective and slow. Plasma etching on the other hand is mainly chemical and therefore can be selective but is usually isotropic. Plasma etching is carried out at relatively high pressure in either a barrel reactor, in which case it is non-directional, or a parallel plate reactor, in which case it can be directional. Reactive ion etching is carried out in a parallel plate reactor at lower pressures than plasma etching, e.g. below 13.3 Pa (100 mtorr) when physical effects due to ion bombardment become important. As a result, reactive-ion etching can be anisotropic and selective. The foregoing is wholly consistent with the disclosures in the cited documents which moreover make clear that the demarcation between the various dry etching processes is not sharp.

4. Novelty.

4.1 D4 discloses a method for manufacturing a semi-conductor device comprising a step of forming a first material layer (of $SiO_2$) on a semiconductor substrate, a step of forming a second material layer of silicon nitride on the first material layer - see page 11, lines 1 to 3. The second material layer is selectively removed in a first etching step using a masking layer - see page 11, lines 4 to 6. On page 10, lines 14 to 16 it is stated that the silicon nitride is etched in order to obtain openings for contacting underlying layers. The person of average skill in the art understands by this electrical contact to the active portions of the silicon substrate and therefore that the silicon dioxide (first material) layer has also to be etched through. This must require a second etching step since by carrying on with the first etching step silicon nitride would continue to be removed much faster than silicon dioxide. D4 further discloses that sloped side-walls in the opening in the silicon nitride layer are obtained when the masking layer (photoresist) is etched faster than the silicon nitride layer and therefore is etched laterally also.

In contrast to the method as claimed in Claim 1, the etching process disclosed in D4 is a dry etching process using as etchant gas oxygen and a halogen-containing gas and involving pressures of 0.27-6.65 mbar (0.20-5 Torr) and therefore is a plasma etching process (in this respect the acknowledgement of this document in the patent in suit is incorrect). Thus, the subject-matter of Claim 1 differs from the disclosure in D4 in the following respects:

(a) it requires reactive-ion etching;

(b) it requires as etchant gas a composition comprising hydrogen and carbon-halogen bonds;

(c) removal of the mask prior to a second etching step is explicitly required;

(d) it is explicitly specified that a second etching step wherein the second material layer is used as a mask and both first and second layers are etched away takes place.

4.2 From D6 it is known that dry anisotropic etching is a prerequisite for high resolution pattern transfer and that the slope angle of the side wall in the etched pattern can be controlled by using a reactive mask or by balancing the isotropic and anisotropic components of the etch process so as to control undercutting.

From D7 it is known that if the patterned etch mask is provided with sloped side-walls and the underlying layer is etched using an etchant which also etches the etch mask ("reactive mask") the sloped side-wall of the mask will be transmitted to the material being etched.

From D10 it is known that a mixture of carbon tetrafluoride and hydrogen is a suitable gas for reactive-ion etching of silicon nitride. But, none of the documents 6, 7 and 10 discloses the combination of features claimed in Claim 1.

4.3 The other documents do not come closer to the subject-matter of Claim 1 and, therefore, need not be discussed.

4.4 For these reasons, the subject-matter of Claim 1 is considered as novel within the meaning of Art. 54 EPC.

5. Inventive step.

5.1 The nearest prior art is considered by the Board to be that disclosed in D4. D4 already solves the problem of discontinuities arising when a layer such as a metal connection layer is deposited over an underlying layer which has been patterned by etching to provide openings therein which have a right-angle profiled upper edge. Therefore, the problem underlying objectively the patent-in-suit is to find another, if possible, better solution to the problem of discontinuities.

5.2 This problem is solved by the features a) to d) as set out in point 4.1 above.

5.3 To (a) it is observed that anisotropic etching is known to be particularly appropriate for microminiaturisation where high resolution is required, because the area of substrate exposed by etching corresponds closely to the area of the aperture in the etch mask (see for example the introduction to D6, also D10, page 225, line 27). Accordingly the person of average skill in the art, faced with the problem of improving the process disclosed in D4 with a view to microminiaturisation as indicated in column 1 of the description, would be led to try replacing plasma etching as used in D4 by reactive-ion etching because of its known suitability therefor, despite the fact that the side-walls of anisotropically etched openings are vertical, and therefore, the problem of discontinuity arises again.

However, this problem, and an indication of its solution by providing sloped side-walls was already known at the priority date of the patent in suit. For example D6, page 1179 under III.A, which relates to profile control in

the case of microfabrication using reactive-ion etching, states that "control over the exact shape of the etch profile is certainly the central issue in any high resolution process," and that in microfabrication for applications other than diffraction optics "it should be possible to control the slope angle of the etch profile (e.g. contact holes on IC's to facilitate edge coverage during metallization)," for example by using a reactive mask (IIIA.2) which is laterally eroded during etching (cf. also D7 in this respect).

5.4 As regards (b) the average skilled person, having elected to use reactive-ion etching, will investigate gas compositions which are known for reactive-ion etching of silicon nitride, and one such composition, $CF_4 + H_2$, is known from D10 (Table 3.2.2). This falls within the scope of "gas containing hydrogen and carbon-halogen bonds" as is required by Claim 1. It is a matter of routine for him to determine what proportions of the etchant gas constituents are required to etch the silicon nitride layer selectively compared with an underlying layer. In this respect he knows, e.g. from D10, page 223, that the halogen constituent of the gas mixture is the reactive component whereas additives such as $O_2$, $H_2$, $N_2$ are employed to improve the selection ratio. When he then uses this gas mixture for reactive-ion etching of the silicon nitride layer using a patterned masked layer, he will automatically obtain openings with sloped side-walls, because it appears from the description and claims of the patent in suit that, apart from the conditions giving rise to the required selectivity, no particular etching conditions are necessary for achieving sloped side-walls when the etchant gas contains hydrogen and carbon-halogen bonds.

5.5 As regards (c), whether or not an etch mask is removed prior to a second etching step is an option available to the average skilled person, that is, he may remove it once it has fulfilled its purpose or retain it if it does not interfere with subsequent process steps. The question of inventivity does not hinge on this difference.

5.6 As regards (d) the skilled person knows already from D6 and D7 (Figure 1) that sloped side-walls of a patterned etch mask will be transmitted to openings formed in the material being etched by reactive-ion etching when the etch mask is also etched laterally. This is corroborated by the disclosure in D6, page 1180, section IIIA.2 "Slope angle control using a reactive mask". Here it is stated that "sloping side-walls in the substrate can be obtained reproducibly if a mask material is used which etches at roughly the same rate as the substrate (reactive mask). In addition, the mask profile should already be similar to the desired one." It is obvious to continue to use reactive-ion etching for the second etching step since, apart from the convenience of using the same apparatus, the requirement for high resolution still obtains. It is obvious too that if the etching conditions are such that the masking silicon nitride is etched also, the underlying layer will have openings with the desired sloped side-walls.

5.7 The Respondent's argument that a distinction can be seen in that the patent in suit does not require the use of a photoresist with sloped side-walls does not appear to be valid. It has been shown to be obvious to use a gas containing hydrogen and carbon-halogen bonds for reactive-ion etching of silicon nitride and that the openings so obtained will automatically have sloped side-walls.

5.8 For the foregoing reasons the subject-matter of Claim 1 does not involve an inventive step and the maintenance of the impugned patent is not allowable under Article 100(a) EPC.

6. Claims 2 to 6 can also not be maintained because of their dependency on Claim 1. In any case the characterising features of these claims cannot be seen as adding anything inventive to the subject-matter of Claim 1.

**Order**

**For these reasons, it is decided that:**

1. The decision under appeal is set aside.

2. The patent is revoked.

The Registrar: The Chairman:

F.Klein K.Lederer