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D E C I S I O N
of 24 June 1997

Case Number: T 0624/94 - 3.4.1

Application Number: 87107743.4

Publication Number: 0247603

IPC: H01L 21/31

Language of the proceedings: EN

Title of invention:
A method of stripping a photo resist on an aluminium alloy

Applicant:
FUJITSU LIMITED

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 56

Keyword:
"Inventive step (yes)"
"Unforeseeable effect of new parameter variation"

Decisions cited:
-

Catchword:
-

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Case Number: T 0624/94 - 3.4.1

D E C I S I O N
of the Technical Board of Appeal 3.4.1
of 24 June 1997

Appellant: FUJITSU LIMITED
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Decision under appeal: Decision of the Examining Division of the European Patent Office dated 21 March 1994 refusing European patent application No. 87 107 743.4 pursuant to Article 97(1) EPC.

Composition of the Board:

Chairman: H. J. Reich
Members: J. H. Van Moer
U. G. O. Himmler

Summary of Facts and Submissions

I. European patent application No. 87 107 743.4 (publication No. 0 247 603) was refused by a decision of the Examining Division in respect of claim 1 filed on 18 January 1994.

Claim 1 filed 18 January 1994 reads as follows:

"1. A method for forming an aluminum alloy pattern on a semiconductor substrate, comprising the steps of:

forming a layer of aluminum alloy (2) that reacts with chlorine to form a residual chlorine component having a sublimation temperature higher than that of aluminum chloride on a semiconductor substrate (1) having an insulation layer thereon;

forming a resist pattern (3) on said aluminum alloy layer (2);

dry etching an exposed portion of said aluminum alloy layer (2) with a gas containing chlorine, chosen from the group of chlorine gas, silicon tetrachloride gas, boron trichloride gas and carbon tetrachloride gas, using said resist pattern (3) as a mask, whereby said aluminum alloy layer (2) is patterned and said residual chlorine component remains on the substrate;

generating a gas plasma of a reaction gas containing an oxygen gas by applying electromagnetic power to a plasma generating chamber (29);

introducing reactive species, generated in said gas plasma, from said plasma generating chamber (29) via holes in a wall (28) forming a part of said plasma generating chamber, towards the semiconductor substrate (1), whereby said wall (28) essentially shields the semiconductor substrate (1) from said electromagnetic power, to provide an atmosphere containing said reactive species;

stripping said resist pattern (3) in said atmosphere containing reactive species; and

heating the substrate (1) in a vacuum at a temperature higher than 100°C but low enough to avoid damage to the aluminum alloy, whereby said residual chlorine component is removed from the substrate, said heating step being carried out concurrently with said stripping step or after said stripping step."

Claims 2 to 6 are dependent on Claim 1.

II. The reason given for the refusal was that the subject-matter of Claim 1 did not satisfy the requirements of Articles 52 and 56 EPC having regard to documents:

D1: Patent Abstracts of Japan, vol. 9, No. 47, (E-299) [1770], 1985, concerning JP-A-59-186328;

D2: EP-A-0 140 755; and

D4: IBM Technical Disclosure Bulletin, vol. 21, No. 6, 1978, page 2315.

The Examining Division took the following view: The steps of forming a patterned layer using resist are implicitly contained in the teaching of document D1 which discusses the etching of aluminium and in the disclosure of document D2 describing the etching of aluminium alloys. Both methods comprise reactive ion etching with chlorine containing gases, resist ashing and the removal of chlorine residues in an oxygen containing plasma (D4) or in an oxygen plasma plus heating (D1). Hence, no inventive merit can be seen in the analogous steps claimed in Claim 1. The remaining features of Claim 1 concern the use of the downstream ashing technique for the stripping of the resist and removal of the chlorine residue, rather than the direct plasma method employed in documents D1 and D4.

Document D2 discloses the claimed downstream ashing process and its two advantages: There is no ion bombardment of the substrate and no formation of Al_2O_3, both of which occur during plasma ashing in conventional apparatuses. However, the use of the downstream ashing does not give any advantages to the actual processes of removing the resist and the chlorine residues themselves. The subject-matter of claim 1 is thus simply the reactive ion etch and the subsequent removal of chlorine residues as taught in documents D1 and D4 along with the replacement of the direct plasma ashing of the resist by the downstream ashing disclosed in document D2.

III. The appellant lodged an appeal against this decision. With the statement of grounds of appeal on 29 July 1994 he filed a set of claims as a basis for grant. Claims 1 to 6 filed 29 July 1994 are identically worded as claims 1 to 6 filed 18 January 1994; see paragraph I above. The appellant submitted inter alia the following arguments: **Document D1** discloses direct oxygen ashing and the removal of chlorine compounds as used to pattern aluminium metallurgy. The present application discloses that, beyond the general problem of chlorine-containing residues, there is a specific problem arising in the case of aluminium **alloy** metallurgy. This specific problem is caused by particularly tenacious residues having sublimation temperatures higher than $AlCl_3$, which are not removed and which result in a "continued corrosion" of the alloy metallurgy. This problem is not recognised in the prior art. Starting from the method disclosed in **document D4**, a skilled person would not consider replacing the direct etching process with a downstream etching process, since he

regards material removal by direct physical ion bombardment as a significant mechanism involved in the removal of residue, and downstream etching to be insufficiently aggressive for satisfactorily removing residues.

IV. Considering the above arguments, in a communication accompanying a summons to oral proceedings, the Board drew the appellant's attention to document

D5: EP-A-0 010 138,

cited in the European Search Report. The Board informed the appellant of its provisional view that document D5 teaches to stabilise Al/Cu-alloy microcircuit formed by reactive ion etching in a carbon tetrachloride atmosphere, against open circuits by heating the circuits above 100°C in an oxygen atmosphere. Such backed circuits resist deterioration much longer. It may be regarded as obvious to fill out the gap of information about resist removal in document D5 by the downstream ashing disclosed in document D2. Heating the substrate "in a vacuum" instead of in O_2 as disclosed in document D5 would appear to be a measure within the routine discretion of the skilled person, since chlorine is generally known not to directly react with oxygen.

V. Oral proceedings were duly held on 24 June 1997, at the end of which the appellant requested that the decision under appeal be set aside and a patent be granted on the basis of claims 1 to 6 filed 29 July 1994.

VI. In support of this request the appellant argued essentially as follows:

(a) A skilled person would interpret the heating step disclosed in document D5 to be a passivation step rather than a stabilization step. It is not derivable from document D5 that the heating described therein removes chlorine residues and prevents the continued corrosion, but only that some improvement may be achieved.

(b) US-A-4 370 195 (document D3) teaches to remove residues produced by etching with a nitrogen glow discharge. Documents D1 and D4 disclose to remove residues with an oxygen containing plasma. The method disclosed in document D5 teaches to stabilize the circuit by baking it for ½ hour at 350°C under one atmospheric pressure of oxygen. The combination of documents D2 and D5 does not teach the omission of oxygen in the baking step. Since there is no hint in the prior art to remove chlorine residues in a vacuum, obviousness of this measure is based on a hindsight analysis. It has to be regarded as a surprising effect that baking in a vacuum, i.e. omitting the presence of oxygen in the heating steps of document D5, allows to shorten the time needed for baking out the residual chlorine component from ½ hour to 2 minutes, see the original description page 6, lines 15 to 19.

VII. At the conclusion of the oral proceedings, the decision was announced that the decision under appeal is set aside and that the case is remitted to the Examining Division with the order to grant a patent on the basis of claims 1 to 6 filed 29 July 1994 with a description to be adapted to the prior art.

Reasons for the Decision

1. The subject-matter of claim 1 comprises that of original claims 1 to 4 and features disclosed in the original description, page 3, lines 5 to 13 and page 9, lines 3 to 10 in combination with Figure 2. Claims 2 to 6 correspond to original claims 5 to 9. There is, therefore, no objection to such amended claims under Article 123(2) EPC.

2. Document D5 discloses in the wording of claim 1:

"A method for forming an aluminum alloy (see D5, page 2, lines 11 and 12, disclosing aluminum with 4% copper as the embodiment of the present invention disclosed on page 5, line 2) pattern on a semiconductor substrate, comprising the steps of:

forming a layer of aluminum alloy that reacts with chlorine to form a residual chlorine component having a sublimation temperature higher than that of aluminum chloride (follows from Al-Cu (4%)) on a semiconductor substrate having an insulation layer thereon (D5, page 2, lines 16 to 18);

forming a resist pattern on said aluminum alloy layer (page 2 lines 23 to 25);

dry etching an exposed portion of said aluminum alloy layer with a gas containing chlorine, chosen from the group of ... carbon tetrachloride gas (page 2, lines 18 to 23) using said resist pattern as a mask, whereby said aluminum alloy is patterned and said residual chlorine component remains on the substrate (follows from the analogy of the known etching parameters with the embodiment of the present invention disclosed on page 5, lines 10 to 19): ...

heating the substrate ... at a temperature higher than 100°C but low enough to avoid damage to the aluminum alloy (page 2, last paragraph), whereby said residual chlorine component is removed from the substrate (page 3, paragraph 1; a skilled person derives this fact from the wording in D5 that the stabilised microcircuit was found to resist deterioration much longer and to be free of open circuits and short circuits, which means that the stabilisation reduced the generally known corrosion caused by chlorine compounds), said heating step being carried out after said stripping step (follows from the wording on page 2, last paragraph, that the microcircuit was stabilised);".

In the method disclosed in document D5, the heating step for the removal of the residual chlorine component is carried out under one atmospheric pressure of oxygen. In the method disclosed in D1 heating for removal of the residual chlorine compound is combined with the effect of an oxygen plasma. All the other documents cited in the European Search Report except document D1 do not even mention heating as a supplementary measure in chlorine residue removal.

Thus, the subject-matter of claim 1 is considered new in the sense of Article 54 EPC.

3. *Inventive step*

3.1 The Board sees the closest prior art in the method disclosed in document D5, see also paragraph 2.2 above. This method comprises a dry etching step of an aluminium **alloy** layer by a chlorine containing gas leading to residual chlorine components with a higher sublimation temperature than aluminium chloride (see paragraph III above). Since a passivation step is normally concerned with impeding diffusion of

atmospheric constituents into the chip and aluminium bodies are generally known to be covered with only an extremely thin oxide skin, a skilled person will have no doubt that the term "stabilization" is used in its normal meaning within the disclosure of document D5. The summary of document D5, being in technical accordance with the overall teaching derivable from document D5, reads: "Aluminium microcircuits which have been prepared by reactive-ion etching are **stabilized against open circuits** and short circuits by treating the micro circuits in an oxygen-containing atmosphere at a temperature of from 200°C to 450°". In the Board's view, "stabilization against open circuits" is a different linguistic characterisation of the same problem which is described in the terminology of the description by avoiding "continuous corrosion". Continuous corrosion leads to the observable effect of destroying the conductive properties of the cross section of an aluminium alloy wiring and thus produces an open circuit. The appellant submitted no evidence that the method disclosed in document D5 is less effective than that claimed in Claim 1.

In the Board's view, it can be reasonably be assumed that in the embodiment of document D5 the disclosed stabilisation time of 30 minutes represents an empiric minimum value which produces non-observable open-circuits - or non observable effects of a continuous corrosion - during the intended standard lifetime of the chip. It is evident to the skilled reader that a "preparation of aluminum microcircuits" inherently comprises a method step wherein the resist pattern used as a mask for the reactive ion etching, is stripped from the surface of aluminium alloy layer after etching. There is neither evidence on file nor a disclosure in the original application documents that the claimed stripping by downstream ashing has an effect on residue removal. Since the original

description, page 6, lines 13 to 15 reads "After finishing this stripping process, the substrate is heated so that the residual chlorine component is baked out.", the original description page 6, lines 29, 30 reading "the ... baking process ... may be combined with the stripping process" has to be interpreted as shortening the overall procedure. The original description, page 7, lines 6 to 9, reading: "... the combination of the heating and the downstream stripping is essential, because heating without stripping cannot remove the residual chlorine components under 400°C" will be interpreted by a skilled reader that the sublimated particles need a higher kinetic energy for being able to migrate through the resist layer.

3.2 For the above reasons, starting from the method disclosed in document D5, the objective problem underlying the present invention reduces to provide a less **time-consuming** method of forming a pattern of an aluminium alloy on a semiconductor substrate without corrosion problems caused by residual chlorine on the substrate; see also the original description, page 3, lines 17 to 21.

3.3 The above problem is solved by heating the substrate "in a vacuum". In the Board's view, a skilled person is unable to foresee, that changing the atmosphere for the backing step from one atmospheric pressure of oxygen (D5, page 2, last paragraph) to a vacuum of 0.27 to 0.4×10^2 Pa (original description, page 6, line 20) shortens the baking time at approximately the same temperature - i.e. 350°C in the prior art and 300°C in the invention - from 30 minutes to 2 minutes. Having regard to the generally known mechanism of reaction and

sublimation processes involved in the baking step, a skilled person would not expect that pumping produces such advantageous shortening of the time needed for producing non-corrosive wiring patterns from aluminium alloy films.

3.4 In the method disclosed in document D1 baking and plasma removal of residue are applied in combination. Document D2 is silent about the problem of residues from reactive ion etching. All further documents cited in the European Search Report concern not baking but plasma removal of residue and are thus not relevant.

3.5 For the above reasons the subject-matter of claim 1 is considered to involve an inventive step in the sense of Article 56 EPC.

4. Thus, Claim 1 satisfies Article 52(1) EPC. Dependent Claims 2 to 6 concern particular embodiments of the method claimed in Claim 1 and are, therefore, allowable.

5. The case is remitted to the Examining Division in order that the description should be adapted to the prior art, in particular as disclosed in document D5.

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 to 6 filed 29 July 1994 with a description to be adapted to the prior art.

The Registrar: The Chairman:

M. Beer H. J. Reich