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D E C I S I O N
of 23 January 2004

Case Number: T 0517/02 - 3.4.3

Application Number: 90307234.6

Publication Number: 0407133

IPC: H01L 23/532

Language of the proceedings: EN

Title of invention:
Semiconductor device and method of manufacturing such semiconductor device

Applicant:
KABUSHIKI KAISHA TOSHIBA

Opponent:
-

Headword:
Electrode line/TOSHIBA

Relevant legal provisions:
EPC Art. 54, 56

Keyword:
"Inventive step - main request (no)"
"Inventive step - auxiliary request (yes)"

Decisions cited:
-

Catchword:
-

Case Number: T 0517/02 - 3.4.3

D E C I S I O N
of the Technical Board of Appeal 3.4.3
of 23 January 2004

Appellant: KABUSHIKI KAISHA TOSHIBA
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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 11 December 2001 refusing European application No. 90307234.6 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: R. K. Shukla
Members: G. L. Eliasson
P. H. Mühlens

Summary of Facts and Submissions

I. European patent application No. 90 307 234.6 was refused in a decision of the examining division dated 11 December 2001. The ground for the refusal was that the subject matter of claim 1 filed with the letter dated 15 February 2001 was not new having regard to the prior art document

D2: WO-A-81 01629.

II. Claim 1 which formed the basis for the decision to refuse the application reads as follows:

"1. A semiconductor device comprising:

a semiconductor substrate having active regions electrically isolated from each other on a predetermined surface thereof, and

a single layer or multilayer electrode line arranged on said semiconductor substrate through an insulating layer,

wherein at least one layer of said electrode line is a metal polycrystal layer consisting of crystal grains and at least 95% of the crystal grains are arranged so that the normal direction of the close-packed planes of said crystal grains forms 80° or less with the normal line direction of the bottom surface of said electrode line."

III. The reasons given in the decision under appeal can be summarized as follows:

Document D2 discloses that "essentially all" (page 2, lines 15 to 17) or "all" (page 4, lines 31) of the

grains are oriented so that the (111) plane is parallel to the plane of the deposition surface, and therefore, the skilled person would consider this to mean that at least 95% of the grains have the above-mentioned crystal orientation. Therefore, the subject matter of claim 1 is not new.

IV. The appellant (applicant) lodged an appeal on 11 February 2002, paying the appeal fee the same day. A statement of the grounds of appeal was filed on 15 April 2002.

V. In response to a communication of the Board accompanying summons to oral proceedings, the appellant filed new claims with the letter dated 20 December 2003 and filed further submissions with the letters dated 20 December 2003, 29 December 2003 and 19 January 2004. The appellant also referred to the US-family document of document D2:

D7: US-A-4 438 450.

VI. At the oral proceedings held on 23 January 2004, the appellant requested that the decision under appeal be set aside and a patent be granted on the basis of one of the following requests:

Main request:

Claims 1 to 3 according to the main request filed with the letter dated 20 December 2003;

First Auxiliary request:

Claims 1 to 3 according to the first auxiliary request filed with the letter dated 20 December 2003,

Description pages 1 to 78 filed at the oral proceedings,

Drawings Sheet 1/25 to 25/25 as originally filed.

VII. Claim 1 according to the main request has the same wording as that which formed the basis of the decision under appeal (cf. item II above).

VIII. Claim 1 according to the first auxiliary request reads as follows (emphasis added by the Board):

"1. A semiconductor device comprising:

a semiconductor substrate having active regions electrically isolated from each other on a predetermined surface thereof, and

an electrode line arranged on said semiconductor substrate through an insulating layer,

wherein said electrode line **comprises a lamination of electrode line layers comprising** a metal polycrystal layer consisting of crystal grains and at least 95% of the crystal grains are arranged so that the normal direction of the close-packed planes of said crystal grains forms 80° or less with the normal line direction of the bottom surface of said electrode line, **and a second polycrystal layer which is provided below said metal polycrystal layer, said second**

polycrystal layer having a hexagonal crystal structure."

IX. The appellant's arguments in support of patentability can be summarized as follows:

(a) At the priority date of document D2, it was not possible to produce highly oriented aluminium films. In the films grown according to the method disclosed in document D2, the (111) plane of the grains are parallel to the *growth surface* which is not necessarily parallel to the bottom surface of the electrode, resulting in a polycrystalline structure which is not highly ordered. It appears from Figure 4 of document D2 that only 2/3 of the grains had their upper surfaces parallel to the bottom surface of the electrode line (reference is made to Figure 4 of Document **D7** where the individual crystal grains are more visible than in Figure 4 of document D2).

(b) Comparative experiments conducted on behalf of the appellant by ULVAC Inc., JP, using the method of document D2 show that films produced according to the method of document D2 lie outside of the scope of claim 1 according to the main request. Although a rather high degree of ordering of the crystal grains is obtained using the method of document D2, the results show that less than 95% of the crystal grains in the films produced using the method according to document D2 satisfy the strict orientation condition of claim 1. As shown in Figure 18 of the application in suit, a significant difference in lifetime is observed

between the claimed electrode line structure and one having up to 93% of its crystal grains with {111} orientation. Since document D2 does not disclose the significance of having at least 95% of the crystal grains with the preferred orientation, the features of claim 1 are not directly and unambiguously derivable form document D2.

(c) Although document D2 discloses that the aluminium grains should be oriented with one of the {111} planes parallel to the deposition surface, this was not practically achievable with the deposition techniques available at the time document D2 was written. In the present invention, on the other hand, the inventors have investigated how far the grains can be tilted with respect to a perfect alignment of a close-packed plane with respect to the deposition surface. Document D2 does not contain any teaching on this aspect. Instead, the statement on page 7, lines 5 to 14 that "other orientations than {111} are possible" reveals that it was not understood at the time document D2 was written which role *close-packed* planes play for improving the electromigration resistance.

(d) Furthermore, document D2 contains numerous errors which render the disclosure nonsensical. For example, the sentence on page 4, lines 30 to 32 states the grains "are all oriented with the {111} direction perpendicular to the surface of the SiC_2 layer". This is a nonsensical statement, since the brackets {111} used denote a plane and not a direction. In addition, the underlayer (SiC_2) is

incorrect. Therefore, no sensible meaning would be attributed to this statement by a man skilled in the art.

Reasons for the Decision

1. The appeal complies with Articles 106 to 108 and Rule 64 EPC and is therefore admissible.

2. Claim 1 according to both the main request and the auxiliary request contains the feature that at least 95% of the crystal grains are arranged so that "the normal direction of the close-packed planes of said crystal grains forms 80° or less with the normal line direction of the bottom surface of said electrode line". This feature will be referred to in the following as "the orientation requirement of claim 1". According to the application in suit, the orientation requirement is to be interpreted to mean that the normal direction of **each** of the closed packed planes of the crystal grains forms an angle of 80° or less with the normal line direction of the bottom surface of the electrode line (cf. application as published, page 3, lines 40 to 44).

In accordance with the standard notation employed in the art and in the application in suit, (111) indicates a specific crystal plane, whereas {111} will indicate the family of the planes (111), $(\bar{1}11)$, $(1\bar{1}1)$, $(11\bar{1})$, $(\bar{1}\bar{1}1)$, $(1\bar{1}\bar{1})$, $(\bar{1}1\bar{1})$, and $(\bar{1}\bar{1}\bar{1})$. Similarly, <111> indicates the normal direction to the plane (111).

2.1 As shown by the appellant, in the case of aluminium having FCC crystal structure, the {111} planes are close-packed where the normal directions of the different {111} planes intersect each other at an angle of 70.5°. Thus, for an aluminium crystal grain the orientation requirement of claim 1 is met when the normal direction of one of its {111} planes forms an angle of 9.5° or less with respect to the normal line of the bottom surface of the electrode line.

3. *Main Request*

Novelty

3.1 Document D2 is considered the closest prior art. According to this document, failure due to electromigration in a polycrystalline metal layer made of aluminium-copper alloy is reduced when "most" or "almost all" crystal grains of the metal layer are oriented with the (close-packed) (111) plane parallel to the deposition surface (cf. D2, page 2, lines 24 to 27), i.e. "most" or "almost all" of the crystal grains have the normal direction of one of the {111} planes parallel to the normal direction to the bottom surface of the electrode.

3.1.1 It follows from the discussion under item 2.1 above that aluminium crystal grains having the normal direction of the (111) plane parallel to the normal direction to the bottom surface of the electrode lines meet the orientation requirement of claim 1.

3.1.2 In the only embodiment disclosed in document D2, electrodes made of an aluminium-copper alloy are formed on a silicon oxide layer using electron gun evaporation followed by annealing (cf. D2, page 4, line 18 to page 5, line 3). In Figure 4, a micrograph of an electrode line shown (due to the poor quality of reproduction of Figure 4 in document D2, reference is made to Figure 4 of document D7). All the four grains 42 to 45 in Figure 4 are oriented with the normal direction of the (111) plane parallel to the normal direction of the underlying oxide layer (cf. D2, page 4, lines 5 to 34).

It is observed in the document that the electrode lines produced according to this method have dramatically long lifetimes at narrow line widths compared to those of conventional electrode lines (cf. page 6, lines 12 to 31; Figure 8).

3.2 In the decision under appeal it was held that since document D2 discloses that "essentially all" (page 2, lines 15 to 17) or "all" (page 4, lines 31) of the grains are oriented so that the (111) plane is parallel to the plane of the deposition surface, the skilled person would consider this to mean that at least 95% of the grains should have the above-mentioned crystal orientation, and therefore, all the features of claim 1 are disclosed in document D2 (cf. item III above).

3.3 The appellant contested the finding of lack of novelty arguing that the method according to document D2 was not capable of producing a polycrystalline film with such high degree of orientation as required by claim 1 (cf. item IX(a) above). Figure 4 of document D2 (D7)

which shows a micrograph of a film where the four grains 42, 43, 44, and 45 are all oriented with the normal direction to one of the {111} planes perpendicular to the surface of the deposition surface, thereby meeting the orientation requirement as set out in claim 1 (D2, page 4, lines 30 to 32). As the appellant correctly pointed out, however, the film portion shown in Figure 4 has at least six grains and document D2 is silent as to the orientation of the other grains than those labelled 42 to 45. Since it was not possible to estimate the crystalline orientation of the other grains, the question remained open whether or not at least 95% of the grains in the layer shown in Figure 4 met the orientation requirement of claim 1.

3.3.1 The results of the experiments provided by the appellant, on the other hand (cf. item IX(b) above), cannot be regarded as relevant to the issue of novelty for the following reasons:

(i) The starting material for the formation of the Al-Cu film in the experiment carried out by ULVAC Inc., JP, was Al-3% Cu, and there is no suggestion in the experimental details provided that the final film had a composition Al-0.5% Cu as in the method of document D2.

(ii) There is no mention in the experimental details that after the formation, the Al-Cu film was subjected to an annealing treatment. In the method of document D2, however, such an annealing treatment is essential for obtaining a highly oriented film (cf. D2, page 4, line 37 to page 5, line 3; page 5, lines 21 to 25).

In view of the above, the experiment carried out by ULVAC cannot be regarded as according to the method described in document D2 in its essential aspects. The results of the experiment therefore cannot be taken into account to draw a conclusion regarding the percentage of crystal grains of the Al-Cu film of document D2 having the orientation as claimed.

3.4 However, as stated in item 3.3 above, in view of Figure 4 showing the grains of the layer and its description, the Board finds, contrary to the finding of the examining division, that the feature "at least 95% of the crystal grains..." is not unambiguously derivable from document D2. Accordingly the subject matter of claim 1 according to the main request is new within the meaning of Article 54 EPC.

Inventive step

3.5 The skilled person following the teaching of document D2 and faced with the task of improving the electromigration resistance of an Al-Cu electrode line would however in the Board's view arrive at the subject matter of claim 1 according to the main request without employing inventive skills, since document D2 firstly teaches that "almost all" of the crystal grains should be oriented with a respective (111) crystal plane parallel to the bottom surface of the electrode line, thus implying that a very high proportion of grains is intended; and secondly, document D2 teaches that electrode lines having very high degree of orientation of the crystal grains have much higher lifetimes than corresponding electrode lines produced with

conventional methods. Therefore, the skilled person seeking to improve the electromigration resistance would be motivated by the teaching of document D2 to maximize the number of crystal grains which are oriented with a respective (111) plane parallel to the bottom surface of the electrode line (cf. D2, Figure 8; page 6, lines 2 to 31).

3.6 As to the contradictions and errors in document D2 referred to by the appellant (cf. item IX(d) above), the Board finds that they are not of such nature that they would prevent the skilled person from carrying out the teaching of document D2 relating to electrode lines made of aluminium alloys. In particular, the skilled person would immediately realise from the rest of the disclosure that nothing else than silicon dioxide could have been meant by "SiC_2" in the sentence on page 4, lines 30 to 32 referred to by the appellant. Similarly, the Board cannot see that the skilled reader would have any difficulties in realizing that "the {111} direction" in the above-mentioned sentence can only mean "the direction normal to the (111) plane", since no other interpretation would make technical sense.

3.7 Therefore, in the Board's judgement, the subject matter of claim 1 according to the main request does not involve an inventive step within the meaning of Article 56 EPC.

4. *Auxiliary Request*

4.1 Amendments and clarity

With respect to claims 15 and 16 as filed, claim 1 according to the auxiliary request does not specify any ratio of the c-axis to the a-axis of the second polycrystal layer having a hexagonal crystal structure. In claim 16 as filed, this ratio is specified to be 1.60 or more.

As convincingly argued by the appellant, however, Table 3 of Embodiment 15 of the application in suit show that also structures where the second polycrystal layers has a c/a ratio below 1.60 fall within the scope of claim 1. Therefore, the ratio of the c-axis to the a-axis of the second polycrystal layer is not to be considered an essential feature in the sense that this feature is a prerequisite for obtaining a semiconductor device which falls within the scope of claim 1.

Claim 1 according to the auxiliary request therefore meets the requirements of Article 123(2) EPC. The Board is furthermore satisfied that the requirements of Article 84 EPC are met.

4.2 Inventive step

4.2.1 In addition to the specification that at least 95% of the crystal grains of the metal polycrystal layer should meet the orientation requirement, the subject matter of claim 1 according to the auxiliary request further differs from the device of document D2 in that a second polycrystal layer having a hexagonal crystal

structure is provided below the metal polycrystal layer. In the device of document D2, the metal polycrystal layer is formed directly on a silicon oxide layer (cf. D2, Figure 5).

4.2.2 The presence of a second polycrystal layer having a hexagonal crystal structure has the effect of improving the orientation of the crystal grains of the metal polycrystal layer formed on the second polycrystal layer (cf. application as published, page 13, line 37 to page 14, line 3).

4.2.3 Although document D2 mentions that a layer of another metal between the silicon oxide surface and the electrode layer can be used to permit other orientations of the crystal grains than (111), this is in connection with a proposal of orienting the crystal grains along other directions than (111), i.e. not close-packed planes, and for an Al-Cu electrode layer this would result in a device which does not fulfil the orientation requirement of claim 1 (cf. page 7, lines 5 to 14). There is also no reference to hexagonal crystal layers in this respect. As the other available prior art is silent in this respect, the Board finds that the subject matter of claim 1 according to the auxiliary request involves an inventive step within the meaning of Article 56 EPC. Claim 1 according to the auxiliary request therefore meets the requirements of Article 52(1) EPC.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the first instance with the order to grant a patent in the following version:

Claims: 1 to 3 of the first auxiliary request filed with letter dated 20 December 2003;

Description: Pages 1 to 78 filed in the oral proceedings;

Drawings: Sheets 1/25 to 25/25 as originally filed.

The Registrar: The Chairman:

D. Meyfarth R. K. Shukla