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D E C I S I O N
of 5 May 2003

Case Number: T 0114/99 - 3.4.3

Application Number: 91310146.5

Publication Number: 0485130

IPC: H01L 21/285

Language of the proceedings: EN

Title of invention:
Method for forming a metal contact

Applicant:
STMicroelectronics, Inc.

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 56, 84, 123(2), 113(1)
EPC R. 67, 29(2)

Keyword:
"Inventive step (yes)"
"Reimbursement of the appeal fee (no) - no substantial
procedural violation"
"New arguments in the oral proceedings before the examining
division based on a prior art document cited in the written
proceedings"

Decisions cited:
T 0248/92, T 0484/89, T 0783/89
Case Law EPO 4th Ed. VI.B.2.

Catchword:
-



Case Number: T 0114/99 - 3.4.3

D E C I S I O N
of the Technical Board of Appeal 3.4.3
of 5 May 2003

Appellant: STMicroelectronics, Inc.
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Representative: Palmer, Roger
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Decision under appeal: Decision of the Examining Division of the
European Patent Office posted 15 July 1998
refusing European patent application
No. 91 310 146.5 pursuant to Article 97(1) EPC.

Composition of the Board:

Chairman: R. K. Shukla
Members: G. L. Eliasson
M. B. Günzel

Summary of Facts and Submissions

I. European patent application No. 91 310 146.5 was refused in a decision of the examining division dated 15 July 1998. The ground for the refusal was that the application did not meet the requirement of inventive step having regard to prior art documents

D1: Solid State Technology, vol. 33,
No. 3, March 1990, pages 73 to 79; and

D2: EP-A-0 107 259.

II. The appellant (applicant) lodged an appeal on 14 September 1998, paying the appeal fee the same day. A statement of the grounds of appeal was filed on 16 November 1998 with a request *inter alia* that the decision under appeal be set aside and that the application be remitted to the examining division with an order to grant a patent on the basis of the claims forming the basis of the decision under appeal.

III. In response to communications of the Board raising objections against the independent claims of the appellant's requests pursuant to Articles 123(2) and 84 EPC, the appellant filed amended application documents with the letters dated 12 August 2002, 13 January 2003, and 22 January 2003.

The appellant requests 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 19 according to the main request filed with the letter dated 13 January 2003;

Description: Pages 1, 7, 8, 10 to 12 as originally filed,
Pages 2, 3, 6, 9, 13 filed with the letter dated 13 June 1995,
Pages 5a, 12 filed with the letter dated 12 August 2002,
Pages 4, 5 filed with the letter dated 22 January 2003;

Drawings: Sheet 1/1 as originally filed.

Auxiliary request:

Claims: 1 to 18 according to the first auxiliary request filed with the letter dated 13 January 2003;

Description and Drawings as for the main request.

The appellant requested oral proceedings as a precaution against an adverse decision of the Board, and reimbursement of the appeal fee on the ground that a substantial procedural violation was committed during the examination proceedings.

IV. Independent claims 1 and 9 according to the appellant's main request read as follows:

"1. A method for forming a metal contact in a semiconductor integrated circuit, comprising the steps of:

forming an insulating layer (12) over a conducting layer;

forming an opening (14) through the insulating layer (12) to expose a portion of the conducting layer;

depositing a barrier metal layer (16) over the surface of the integrated circuit;

increasing the temperature of the integrated circuit;

and

depositing aluminum on the integrated circuit at a low rate whereby surface migration of deposited material fills the opening (14) in the integrated circuit;

characterised in that the temperature of the integrated circuit is increased from a first temperature of approximately 350°C or below to a second temperature of between approximately 380°C and 500°C, and in that the step of depositing aluminum is simultaneous with the increase in the temperature, and that the deposition rate is less than approximately $(0.7 \times T) - 250 \text{ \AA/s}$."

"9. A method for forming a metal contact in a semiconductor integrated circuit, comprising the steps of:

forming an insulating layer (12) over a conducting layer;

forming an opening (14) through the insulating layer (12) to expose a portion of the conducting layer;

depositing a barrier metal layer (16) over the surface of the integrated circuit;

raising the temperature of the integrated circuit from below approximately 350°C to a value

between approximately 400°C and approximately 500°C;

during said temperature raising step, depositing aluminum on the integrated circuit;

after said temperature raising step, continuing to deposit aluminum on the integrated circuit to form a layer (18) of desired thickness, the temperature remaining constant; and

during said desired thickness depositing step, controlling the rate at which aluminum is deposited to be less than approximately $(0.7 \times T) - 250 \text{ \AA/s}$ to allow the deposited material to migrate into the opening (14) so as to provide a substantially complete fill thereof."

V. The reasoning in the decision under appeal for refusing the application can be summarized as follows:

- (a) Document D1 which is considered the closest prior art discloses a method of forming a metal contact in a semiconductor integrated circuit where a thin layer of aluminum is formed at a low temperature and the remainder of the film is formed at higher temperature. Aluminum is deposited continuously as the temperature is raised.
- (b) The method of claim 1 differs from that disclosed in the closest prior art document D1 in that (i) numerical temperature ranges are specified for the initial and final deposition temperatures; and (ii) the final deposition rate is less than $0.7 \times T - 250 \text{ \AA/s}$, whereas document D1 does not mentioned any specific deposition rate.
- (c) The above differences solve the technical problem

of improving the electromigration resistance and improving the via filling. The method disclosed in document D1 on the other hand, has the drawback that it eventually becomes unreliable as dimensions shrink.

- (d) Document D2 teaches that in order to form a continuous and uniform aluminum layer on a substrate having a surface with a step, the deposition rate of sputtered or evaporated aluminum should be reduced to enable adsorbed aluminum atoms to travel across the surface and become fixed on surface portions that are partly shadowed. It is thus necessary at any given temperature to control deposition rate whereby it is obvious that the deposition rate can be higher at higher temperatures because of the higher natural mobility of aluminum atoms impinging the surface at higher temperatures.

- (e) Once it is established that there exists a limiting deposition rate above which voiding problems might occur and that this limiting deposition rate is higher at higher temperatures, the exact values are the result of perhaps tedious but nonetheless routine experimentation. Therefore, the subject matter of claim 1 does not involve an inventive step. The same reason applies to the other independent claims as well.

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

- (a) The technical problem of improving electromigration resistance and ensuring a good

via filling as posed by the examining division, is only a partial statement of the underlying problem addressed by the application in suit. The remaining specific aspects of the claimed invention relate to minimizing grain size of aluminum throughout the deposition process, and avoiding blocking of the openings of the via holes before the via hole is filled. These problems are solved by controlling deposition rate as well as the temperature of deposition in the manner as claimed.

- (b) Document D1 mentions the problem of shadowing caused by large grains at the opening of a via hole, but does not address the problem of large grains blocking the opening of a via hole. The solution suggested in document D1 is based on the assumption that once a thin nucleating film has been formed, large aluminum grain sizes cease to be a problem, which is directly contrary to the teaching of the application in suit.

- (c) Document D2 relates to the deposition of a layer of aluminum on an uneven surface of a chip and is not related to the filling of via holes. Once the deposition of the nucleating layer is complete, the deposition rate is increased in order to maximize throughput, since according to document D2, no further benefit is gained by reducing the deposition rate (cf. page 9, lines 17 to 32, page 10, lines 11 to 13 and 21 to 24). Thus, the teaching of document D2 is in contradiction to the conclusions made in the decision under appeal, where it was held that document D2 taught that the deposition rate had to be controlled at any given

temperature.

- (d) Therefore, documents D1 and D2 do not address the problems of reducing the grain size and avoiding bridging and deposition rate-limited migration. Both documents teach that once the nucleating layer is completed, there is no need to control grain size or deposition rate.

- (e) The appellant requests reimbursement of the appeal fee, since the appellant's representative was given only 25 minutes at the oral proceedings to consider a new objection based on documents D1 and D2. Reference is made to T 783/89 where it was considered that the time given to a party (of 10 minutes) at the oral proceedings to consider a new version of the main claim was not enough so that the party's right to be heard was not respected resulting in a substantial procedural violation.

Although document D2 was introduced in the first communication dated 9 December 1990, the complicated mathematical analysis therein was not referred to in the first communication.

Furthermore, the communication under Rule 71(1) EPC referred to the objection of lack of inventive step raised in the first communication but only in so far as "a contact directly on silicon was not excluded from the scope of the claims". Since the appellant had amended the claim to exclude this alternative, the appellant believed that the inventive step objection involving document D2 would no longer be maintained.

The appellant therefore asserts that the principle of good faith should have obliged the EPO to alert the appellant of the new objection before the oral proceedings.

Reasons for the Decision

1. The appeal meets the requirements of Articles 106 to 108 and Rule 64 EPC and is therefore admissible.

Furthermore, for the reasons given below, the appeal is allowable, since the application documents according to the main request meet the requirements of the EPC.

2. *Amendments and clarity - main request:*

Claim 1 is based on claim 1 as filed together with the features disclosed in conjunction with Figures 1 to 3 of the application as filed. Regarding the lower limit of 380°C for the second temperature, it is disclosed on page 8, second paragraph of the application as filed that temperatures "a little below 400 °C can be used", and the value 380°C is disclosed in claim 6 as filed. The expression $(0.7 \times T) - 250 \text{ \AA/s}$ for the upper limit of the deposition rate is disclosed in Figure 3 and claim 16 as filed.

Independent claim 9 is based on claims 15 and 16 as filed together with the feature disclose on page 6, last paragraph of the application as filed.

Dependent claims 2 to 8 and 10 to 12, and 17 are based on claims 6 to 12, 17, 19, 4, 10 as filed,

respectively. Claims 13, 14 and 15, 16 are based on the disclosure on page 9, second paragraph and page 6, last paragraph of the application as filed, respectively. Claims 18 and 19 are based on the embodiments of Figure 4(b) and (c).

Therefore, in the Board's judgement, the requirements of Article 123(2) EPC are met by the claims according to the main request. The Board is furthermore satisfied that the claims according to the main request meet the requirements of Article 84 EPC. In particular, the Board accepts the appellant's submissions that in the present case, it is justified to maintain the two independent claims 1 and 9 of the same category under Rule 29(2)(c) EPC.

3. *Inventive step - main request:*

3.1 Document D1 was considered the closest prior art in the decision under appeal. It discloses a method of filling via holes for ULSI with aluminum using sputtering. A refractory metal barrier layer is first deposited in the via hole in order to better control the aluminum deposition (cf. page 76, right hand column, last paragraph to page 77, left hand column, second paragraph; Figure 6(b)). The initial deposition of aluminum is carried out at a low temperature of the substrate to form a thin nucleating layer. After the nucleating layer is formed, the substrate is heated up during deposition to a temperature of about 450°C, and the remainder of the aluminum layer is formed at the higher temperature.

3.2 Document D2 is concerned with the deposition of aluminum using evaporation on substrate surface having

a single step (cf. abstract). In order to obtain a good step coverage even when part of the step is shadowed from the evaporation source, it is taught in document D2 that the deposition rate should be reduced at the initial stage in order to form a stable nucleating layer on the step (cf. page 9, line 18 to page 10, line 5). After that the nucleating layer has been formed, it is not necessary to keep the deposition rate low and the final deposition rate is at least twice the initial deposition rate (cf. page 10, lines 11 to 13). The initial deposition rate is about 0.4 to 0.6 nm/s (cf. claim 3), and the higher deposition rate is about 1.5 nm/s (cf. page 10, lines 33 to 36; Figure 6). Both the deposition steps are carried out at a temperature between room temperature and 400°C, preferably about 300°C (cf. page 9, lines 18 to 20).

- 3.2.1 Thus, the Board agrees with the appellant's assessment of document D2 that the deposition rate of aluminum is reduced only at the first stage of the deposition process. In the decision under appeal, on the other hand, it was inferred from document D2 that the deposition rate had to be controlled at any given temperature (cf. items V(d) and VI(c) above).

- 3.3 From the above discussion it follows that document D1 represents the closest prior art, since it relates to deposition of aluminum in a via hole. The method of claim 1 according to the main request differs from that of document D1 in that (i) numerical temperature ranges are specified for the initial and final deposition temperatures; and (ii) the final deposition rate is less than $0.7 \cdot T - 250$ Å/s, where T is the deposition temperature, whereas document D1 does not mention any specific deposition rate.

3.4 As discussed in the decision under appeal, the method of document D1 has the disadvantage that it is increasingly difficult to fill via holes reliably as the aspect ratio (the ratio of depth over width of the via hole) is increased, since sputtering methods, such as the method of document D1, tend to create large aluminum grains on the upper surface of the insulating layer which may block the via before it is completely filled (cf. page 1, last paragraph, and item VI(a) above).

The appellants have discovered that when the final deposition rate is less than the empirical value $0.7 \cdot T - 250$ Å/s depending on the temperature T of the integrated circuit, the above-mentioned aggregation of aluminum at the opening of a via hole is avoided, and the via hole can be filled without voids. Thus, the claimed method, which specifies the limit of $0.7 \cdot T - 250$ Å/s for the final deposition rate, provides a method of filling via holes reliably without forsaking speed.

The technical problem addressed by the application in suit therefore relates to finding a method of reliably filling via holes completely with aluminum also for via holes having a large aspect ratio (cf. the application as filed, page 2, first paragraph; page 3, last paragraph to page 4, third paragraph).

3.4.1 In the decision under appeal, the problem addressed by the application in suit was considered to relate to improving electromigration resistance and improving via hole filling (cf. item V(c) above). As discussed in the application as filed, poor electromigration resistance is caused by uneven thickness of the aluminum layer in

the via holes (cf. application as filed, page 2, second paragraph). Therefore, the problem as formulated above is consistent with that stated in the decision under appeal.

3.5 Contrary to the findings in the decision under appeal regarding the disclosure of document D2, however, the Board agrees with the appellant that document D2 teaches that it is not necessary to reduce the deposition rate once the formation of the nucleating layer is completed. Therefore, a skilled person seeking to improve the method of document D1 would not be led towards the claimed invention by the teaching of document D2.

3.6 For the above reasons, in the Board's judgement, the subject matter of claim 1 according to the main request involves an inventive step within the meaning of Article 56 EPC.

3.7 The method of independent claim 9 according to the main request differs from that of document D1 in the same features (i) and (ii) referred to under item 3.3 above. Thus, the subject matter of independent claim 9 involves an inventive step within the meaning of Article 56 EPC for same reasons as for claim 1.

4. *Substantial procedural violation and reimbursement of the appeal fee*

The appellant has requested reimbursement of the appeal fee for the reason that the examining division committed a substantial procedural violation (Rule 67 EPC). Essentially, the appellant argued that his right to be heard under Article 113(1) EPC was violated for

the following reasons:

- (i) The representative was only made aware of a new inventive step objection based on documents D1 and D2 during the oral proceedings and was given only 25 min to consider the objection. This short time was clearly inadequate for presenting comments on the complicated mathematical analysis disclosed in document D2.
- (ii) Document D2 was cited in the first official communication, but without the complex arguments raised in the oral proceedings. The appellant was furthermore led to believe from the communication accompanying the summons to the oral proceedings that the inventive step objection involving document D2 would be dropped once the claimed methods comprised the step of forming a barrier layer.
- (iii) In view of the complexity of document D2, the EPO should have alerted the representative in response to the new claims filed before the oral proceedings that document D2 would be discussed in detail.

4.1 From the appellant's own submissions, it is evident that the new arguments based on document D2, which was already considered in the assessment of inventive step in the written proceedings, were presented by the examining division during the oral proceedings. The appellant contends that the time given to him (25 minutes) to study the complicated mathematical analysis disclosed in document D2 was not adequate to respond to the new arguments. In the minutes of the oral

proceedings, however, there is no record of any request from the appellant for more time to study document D2, nor is there any record of rejection of such a request. Under these circumstances, an implicit assumption on the part of the examining division that about half an hour was enough to study a document which already formed part of the written proceedings, was in the Board's view justified.

It therefore appears that the examining division was entitled to conclude that the matter had been sufficiently discussed and that a decision could be taken (cf. T 248/92, reasons, 2, and T 484/89, reasons, 2.1, both cited in "Case Law of the Boards of Appeal of the EPO", 4th Edition, Chapter VI.B.2, page 265).

- 4.2 Regarding grounds (ii) and (iii) above, the Board notes that the purpose of the communication under Rule 71a(1) EPC is to draw attention to the points which in the examining division's opinion need to be discussed during the oral proceedings. Such a communication can, however, only deal with points which appear relevant having regard to the requests being on file at the time when the summons for oral proceedings are issued. In the present case, the appellant filed new claims giving rise to a further examination which may raise new issues. It is also noted that although the final date under Rule 71a(1) EPC for making written submissions and amendments was 24 February 1998, the appellant nevertheless filed two sets of claims (A and B) on Wednesday 18 March 1998 for the oral proceedings scheduled for Monday 23 March 1998.

Considering the late filing of the new claims by the appellant, further discussion of document D2 during the

oral proceedings was completely justified and even necessary.

4.3 The case T 783/89 referred to by the appellant related to the introduction of a new claim containing substantial amendments, whereby the time given to the opponents to study the amendments was not considered to be sufficient by the Board. In the present case, the appellant was himself responsible for the late filing of the new claims and, moreover, document D2 already formed part of the written proceedings so that the appellant could be reasonably expected to be aware of its content and to be prepared that his amended claims would be discussed in the oral proceedings in the light of the overall content of document D2. The circumstances of T 783/89 are therefore not comparable to the present case.

4.4 Therefore, the Board finds that the decision of the examining division has not been in violation of Article 113(1) EPC. Hence, the request for reimbursement of the appeal fee is rejected.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.
2. The case is remitted to the department of the first instance with the order to grant a patent on the basis of the documents according to the main request as specified under item III above.

3. The request for reimbursement of the appeal fee is rejected.

The Registrar:

The Chairman:

M. Zawadzka

R. K. Shukla