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D E C I S I O N
of 4 May 2000

Case Number: T 0949/97 - 3.4.3

Application Number: 92112768.4

Publication Number: 0529321

IPC: H01L 21/90

Language of the proceedings: EN

Title of invention:
Metallic material deposition method for integrated circuit manufacturing

Applicant:
APPLIED MATERIALS, INC.

Opponent:
-

Headword:
Sputtering deposition/APPLIED MATERIALS

Relevant legal provisions:
EPC Art. 56

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

Decisions cited:
-

Catchword:
-

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Case Number: T 0949/97 - 3.4.3

D E C I S I O N
of the Technical Board of Appeal 3.4.3
of 4 May 2000

Appellant: APPLIED MATERIALS, INC.
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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 29 April 1997 refusing European patent application No. 92 112 768.4 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: R. K. Shukla
Members: G. L. Eliasson
M. J. Vogel

Summary of Facts and Submissions

I. European patent application No. 92 112 768.4 was refused in a decision of the examining division dated 29 April 1997. The ground for the refusal was that the subject-matter of claims 1 to 10 according to the applicant's main request did not involve an inventive step with respect to the prior art documents

D1: US-A-4 970 176; and

D2: EP-A-0 440 377.

Furthermore, the examining division held in its decision that claim 1 according to the applicant's auxiliary request did not meet the requirements of Article 123(2) EPC, and that even if the claim was amended to meet this objection, the subject-matter of such an amended claim would not involve an inventive step for the same reasons as for the main request.

II. The appellant (applicant) lodged an appeal on 24 June 1997, paying the appeal fee the same day, and filed the statement of the grounds of the appeal on 29 August 1997.

III. In response to a communication annexed to the summons to oral proceedings from the Board, the appellant filed with his letter dated 4 April 2000 four sets of claims forming a main request and first to third auxiliary requests, respectively.

IV. During the oral proceedings held on 4 May 2000, the appellant filed amended claims and description of the third auxiliary request. 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 15 according to the main request filed with the letter dated 4 April 2000;

Description: pages 1 to 13 as filed;

Drawings: sheet 1/1 filed on 16 October 1992

First auxiliary request:

Claims: 1 to 12 according to the first auxiliary request filed with the letter dated 4 April 2000;

Description and **drawings** as for the main request;

Second auxiliary request:

Claims: 1 to 10 according to the second auxiliary request filed with the letter dated 4 April 2000;

Description and **drawings** as for the main request;

Third auxiliary request:

Claims: 1 to 9 filed during the oral proceedings;

Description: pages 1 to 13 filed during the oral proceedings;

Drawings: sheet 1/1 as filed on 16 October 1992

V. Claim 1 according to the main request reads as follows:

"1. A combined layer deposition process by sputtering with a first step of:

(a) sputter depositing a first layer (40) of a first material upon the substrate (12) at a temperature of the substrate between room temperature and 100° C [8,12] and at a first deposition rate, wherein said sputtered first material is passed through a collimation plate (32) prior to the deposition thereof upon said substrate (12) thereby providing a seed layer for better contact and thoroughly covering the bottom of grooves in the substrate;

characterized by
a second step of

(b) depositing a second layer (80) of a second material upon said first layer (40) at a second deposition rate and at a temperature approximately the flowing temperature [10,10] of said second material."

VI. Claim 1 according to the first auxiliary request differs from that of the main request in that it contains the statement

"wherein said first material is aluminum" at the end of paragraph (a) and the statement

"wherein said second material is aluminum" at the end of paragraph (b) of the latter claim.

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

"wherein the thickness of said first layer (40) is only a fraction of the thickness of said second layer (80) and

wherein said deposition rate of the second sputtering step is higher than the deposition rate of the first sputtering step."

VIII. Claim 1 according to the third auxiliary request reads as follows:

"1. A combined layer deposition process by sputtering with a first step of:

(a) sputter depositing a first layer (40) of a first material upon the substrate (12) at a temperature of the substrate between room temperature and 100° C and at a first deposition rate, wherein said sputtered first material is passed through a collimation plate (32) prior to the deposition thereof upon said substrate (12) thereby providing a seed layer covering the bottom of grooves in the substrate, wherein said first material is aluminum;

characterized by
a second step of

(b) depositing a second layer (80) of a second material without the use of a collimation plate upon said first layer (40) at a second deposition rate higher than the first deposition rate, wherein said second material is aluminum;

wherein the thickness of said first layer (40) is a fraction of the thickness of said second layer (80), and
wherein step (b) comprises:

depositing a first portion of the non-collimated second layer (80) of aluminum over the collimated first layer (40) during an increase of the substrate temperature to a first temperature;

depositing a second portion of the non-collimated second layer (80) of aluminum over the collimated first layer (40) during a rapidly ramp up temperature increase from said first temperature to a second temperature, this being approximately the flowing temperature of said second material; and

depositing a third portion of the non-collimated second layer (80) of aluminum on the first portion of the second layer at said second temperature."

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

(a) In the method according to the present invention, the first layer is thinner than the second layer. Document D1 on the other hand, discloses a two-step deposition process in which the first Al layer is deposited as a thick layer (ct. D1, column 3, lines 59 to 60). Thus, document D1 teaches away from the claimed method.

(b) Document D2 discloses a method of depositing a single layer through a collimator plate in a continuous process, i.e. where the temperature and deposition rate are changed during the deposition

without interruption. The maximum temperature is however substantially below the flowing temperature of aluminum. Since this process is very slow, it is not useful for commercial production.

(c) A skilled person would not consider using a collimator plate for the first deposition step in D1, since the relatively thick layer would then require a long deposition time and would therefore result in a low-throughput process. Moreover, document D2 teaches that a collimator plate is used in combination with a rather complex variation of deposition parameters. Thus, the skilled person would not consider a combination of documents D1 and D2, since they represent opposite approaches of sputter deposition of aluminum.

(d) As regards the third auxiliary request, the appellant argued that none of the prior art documents discloses a step of increasing the substrate temperature to an intermediate temperature before rapidly increasing the temperature to about the flowing temperature of aluminum. The method according to the third auxiliary request produces aluminum layers with better quality than that of document D1 while being faster than the method disclosed in document D2.

Reasons for the Decision

1. The appeal is admissible.

2. *Amendments - Main request, and first, second and third auxiliary requests*

Claim 1 according to the main request corresponds to a combination of the features of claims 2 and 3 as filed together with the features disclosed on page 7, lines 9 to 12 and page 8, lines 8 to 12 of the application as filed. Claim 1 of the first auxiliary request in addition contains the feature of claim 5 as filed. Claim 1 of the second auxiliary request contains in addition to the above features, the feature derivable from page 11, lines 3, 14, and 17 of the application as filed.

Claim 1 according to the third auxiliary request adds to the features of the second auxiliary request the features disclosed on page 9, lines 7 to 10 and page 11, lines 4 to 17 of the application as filed.

The claims of all the requests therefore meet the requirements of Article 123(2) EPC.

3. *Inventive step - Main request and first and second auxiliary requests*

3.1 Claim 1 of the second auxiliary request contains all the features of claim 1, respectively of the main request and first auxiliary request. The following discussion of inventive step in respect of the subject-matter of the claim 1 of the second auxiliary request therefore applies mutatis mutandis to claim 1 of both the main request and the first auxiliary request.

3.1.1 The wording of claim 1 of each of the main request, the first auxiliary request, and the second auxiliary request do not make it clear whether or not during the second deposition step, the second layer is deposited through a collimation plate.

During the oral proceedings, the appellant stated that he would amend claim 1 of these requests to make it clear that the second layer is deposited without a collimation plate in the event that the Board was to find in favor of presence of an inventive step in the amended claims. In the following discussion of inventive step, the wording of claim 1 is construed as containing the clarification that the second layer is deposited without a collimation plate, as originally disclosed in the application as filed (cf. Figure 3 and the corresponding description).

3.1.2 Document D2 which the Board considers as the closest prior art, discloses a process of depositing an aluminum layer on a tungsten substrate using sputtering with a collimation plate 63 positioned between the sputter source 26 and the substrate W (cf. D2, abstract). This method is described as being particularly suitable for filling openings in the substrate, such as contact holes, i.e. the method of document D2 is designed to solve the same technical problem as that stated in the application in suit (cf. the application in suit, page 3, line 15 to page 4, line 11).

3.1.3 The method of claim 1 according to the second auxiliary request differs from that of document D2 in that after a first layer is formed, a second layer is formed in a second deposition step carried out without the use of a collimator plate at a temperature approximately at the flow temperature of aluminum and at a higher deposition rate than that of the first deposition step.

Furthermore, the thickness of the first layer is specified in claim 1 to be only a fraction of the thickness of the second layer. In contrast, the method of document D2 forms the complete layer structure in one continuous step using the collimator plate during the entire deposition.

3.1.4 Although the process of document D2 appears to produce aluminum layers with a good step coverage and low level of voids, it has the disadvantage that it is slow: about 35 minutes are required to form a 1 μm thick layer (cf. D2, column 9, lines 12 to 24; Figure 11). Thus, the objective technical problem addressed by the present invention is to reduce the time required for depositing an aluminum layer while maintaining the quality of the deposited layers.

3.1.5 Document D1 discloses a two-step direct deposition process, i.e. a process where the deposition is not through a collimation plate, where an aluminum layer is formed on a substrate by sputtering and where the time required for forming an aluminum layer of 1 μm thickness is about 80 to 100 seconds, i.e. substantially shorter than that required using the method of document D2 (D1, column 3, line 38 to column 4, line 26; Figures 2 to 4). The process comprises a first step of depositing a first layer by sputtering at a relatively low temperature and a second step of depositing a second layer on the first layer by sputtering at a temperature at which the material of the second layer begins to flow.

3.1.6 Although the method of document D1 is substantially faster than that of document D2, it is apparent from Figure 2 of document D1 that the first step of deposition tends to create lateral overgrowth which is likely to prevent further sputtered material from entering the opening of a recess and thereby cause

voids in the aluminum layer deposited in the recess. The method of document D2, on the other hand, is designed with the specific aim of avoiding such lateral overgrowth (cf. D2, column 1, lines 23 to 30, column 5, lines 28 to 40 and Figure 3a).

3.1.7 A skilled person faced with the task of reducing the time required by the process of document D2 while at the same time ensuring a deposition without voids in the deposited layer would therefore form a first layer at a low temperature using a collimator as taught in D2, since this process step avoids lateral overgrowth and ensures a good step coverage. Subsequently, a second layer would be deposited without a collimator at a substrate temperature approximately equal to the flowing temperature of aluminum, as taught in document D1, since the presence of a collimator plate is generally known to slow down the deposition.

3.1.8 The appellant submitted that since document D1 teaches that the first layer has to be relatively thick (50 to 75% of the total layer thickness) in order to avoid the formation of voids in the deposited layer (cf. D1, column 3, lines 52 to 61), it teaches away from the present invention.

The Board, however, does not find this argument convincing. The first step of deposition according to the method outlined in point 3.1.7 above is slow due to the presence of the collimator plate, so that the skilled person in his attempt to reduce the overall process time would have no choice but to form the first layer as thin as possible. Otherwise, the time gained when forming a relatively thin second layer without a collimator plate would not make up for the added complication of having a collimator plate which has to be removed before forming the second layer. Furthermore, the Board also finds that the skilled

person would have reasonable expectations of succeeding in reducing the thickness of the first layer to a value substantially below that recommended in document D1, since it is taught in document D2 that a first layer formed using a collimator plate has a superior step coverage compared to one formed according to the method of document D1 and has less tendency to form voids at the side walls of a recess (cf. D2, column 5, lines 28 to 53; column 6, lines 13 to 20).

In the Board's judgement, therefore, the subject-matter of claim 1 according to the second auxiliary request does not involve an inventive step.

The above reasoning also applies mutatis mutandis to claim 1 of the main request and the first auxiliary request, so that these claims do not involve an inventive step within the meaning of Article 56 EPC.

3.2 Third auxiliary request

3.2.1 In relation to claim 1 of the second auxiliary request, claim 1 according to the third auxiliary request further specifies that the second step of depositing the film is carried out in three sub-steps: A first sub-step where the temperature is increased to a first temperature; a second sub-step where the temperature is rapidly increased from the first temperature to a second temperature which is approximately the flowing temperature of aluminum; and a third sub-step where the deposition of aluminum is carried on at the second temperature.

3.2.2 In the method described in document D1, it would appear that the temperature is increased rapidly from less than 200° C to about 400 to 500° C when changing from the first, low-temperature deposition step to the second, high-temperature deposition step (cf. D1, column 3, lines 52 to 56 and column 4, lines 1 to 7).

The deposition described in document D2 is carried out at 100° C for about 25 minutes. For the last ten minutes of the deposition, the temperature is gradually increased to about 350° C (cf. D1, Figure 11).

3.2.3 In the second step of deposition without the use of a collimation plate as defined in claim 1, the temperature during the deposition is gradually increased in the first and second sub-steps to approximately the flowing temperature of aluminum. At the point when the temperature has reached approximately the flowing temperature of aluminum, the deposited layer has a greater thickness than it had at the end of the first step of deposition. The resulting increase in thickness of the deposited layer deposited would reduce the tendency for void formation at the stage when the metal starts to flow. This enables one to form the layer in the first deposition step to be relatively thin, and thereby reduce the deposition time for the first layer, and hence the overall deposition time.

It is recognized in document D1 that a very thin layer formed in the first step of deposition may lead to void formation, but the solution provided therein is simply to form the first layer relatively thick, without paying any attention to the manner how the temperature is increased in the second step. (cf. (cf. D1, column 1, line 55 to column 2, line 3; column 3, lines 59 to 61).

Although document D2 discloses a slow increase of the temperature, the final temperature (260 to 360° C) is still substantially below the flowing temperature of aluminum which is about 450° C.

3.2.4 Thus, the Board finds that even if a skilled person would have considered combining the teachings of documents D1 and D2, as discussed under 3.1 above, there is no hint in the prior art that would have led the skilled person to modify the second deposition step of document D1 so as to arrive at the claimed method. Therefore, in the Board's judgement, the subject-matter of claim 1 according to the third auxiliary request involves an inventive step, as required in Articles 52(1) and 56 EPC.

3.2.5 Since claims 2 to 9 are dependent on claim 1 the subject-matter of these claims involves an inventive step as well.

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 on the basis of the appellant's third auxiliary request as follows:

Claims: Claims 1 to 9 as filed during the oral proceedings

Description: Pages 1 to 13 as filed during the oral proceedings

Drawings: Sheet 1/1 as filed on 16 October 1992.

The Registrar:

D. Spigarelli

The Chairman:

R. K. Shukla

11.7.2000
12.7.2000