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D E C I S I O N
of 25 September 2002

Case Number: T 0551/99 - 3.4.3

Application Number: 90307377.3

Publication Number: 0407202

IPC: H01L 21/285

Language of the proceedings: EN

Title of invention:
Manufacturing semiconductor devices

Applicant:
SONY CORPORATION

Opponent:
-

Headword:
Salicide process/SONY

Relevant legal provisions:
EPC Art. 56

Keyword:
"Inventive step (yes - after amendments)"

Decisions cited:
-

Catchword:
-

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Case Number: T 0551/99 - 3.4.3

D E C I S I O N
of the Technical Board of Appeal 3.4.3
of 25 September 2002

Appellant: SONY CORPORATION
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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 29 December 1998 refusing European patent application No. 90 307 377.3 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. 90 307 377.3 was refused in a decision of the examining division dated 29 December 1998. The ground for the refusal was that the application did not meet the requirement of inventive step having regard to the prior art documents:

D1: EP-A-0 305 147;

D3: Extended Abstracts, Spring Meeting 88-1, 15 to 20 May 1988, Princeton, NJ, US, page 126; and

D5: Extended Abstracts, Spring Meeting 87-1, 1987, Philadelphia, PA, US, page 342.

II. Claim 1 according to the main request under consideration in the decision under appeal reads as follows:

"1. A method of manufacturing a semiconductor device, the method comprising the steps of:

forming a SiO_2 film (3) on a silicon substrate (1), the SiO_2 film (3) having a thickness of less than 50 angstroms;

forming a Ti film (4) on the SiO_2 film (3);

performing a first annealing step at a temperature within a range of 600°C to 700°C to form a silicide layer comprising Ti_5Si_3 and TiSi (5) on the silicon substrate (1) and a TiO_2 layer of the Ti film (4); and

performing a second annealing step at a temperature within a range of 800°C to 1000°C to convert the silicide layer (5) into a $TiSi_2$ silicide layer (6) which has a low resistance."

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

(a) Document D1 is the closest prior art. The method of claim 1 according to the main request differs from that of document D1 in that (i) the composition of the silicide layer after the first annealing step is specified as comprising Ti_5Si_3 and TiSi on the Si substrate and a TiO_2 layer on the Ti film, whereas in document D1, Ti silicide is formed on the Si substrate and TiN is formed on the Ti film; and (ii) a second annealing step is performed at 800 to 1000°C to convert the silicide layer into $TiSi_2$ which has low resistance.

(b) Difference (i) is an indication that in the claimed method, the first annealing step is carried out in an essentially nitrogen-free ambient. From the teaching of document D1, it follows that the claimed method cannot be used to form contact barrier or local interconnect, since TiN is required for both these applications.

(c) Document D1 proposes a method of forming barrier layers for a contact structure instead of a salicide structure. The skilled person is however aware from document D3 that it is possible to take advantage of the selective formation of the silicide over the contact areas and to proceed in

a salicide process. This line of action is taught in document D5 where after a first low temperature anneal, all compounds except titanium silicide are removed, and in a second anneal, the sheet resistance of the silicide layers is lowered. Document D5 furthermore teaches that the annealing can be carried out with or without the presence of nitrogen.

IV. The appellant lodged an appeal on 19 February 1999 and paid the appeal fee on 23 February 1999. A statement of the grounds of appeal was filed on 27 April 1999 together with claims forming a main request and an auxiliary request.

V. In response to a communication of the Board, the appellant filed new claims forming second and third auxiliary requests with the letter dated 11 June 2002.

VI. In response to a telephone consultation on 29 July 2002, the appellant withdrew the main request and the first auxiliary request with the letter dated 1 August 2002.

The appellant requests that the decision under appeal be set aside and that a patent be granted on the basis of one of the following requests:

Main request:

Claims: 1 to 4 according to "auxiliary request 2" filed with the letter dated 11 June 2002;

Description: pages 1, 5, 6 as originally filed,

pages 3 and 4 filed with the letter dated 2 October 1996,

page 2 filed with the letter dated 11 June 2002;

Drawings: Sheets 1/3 to 3/3 filed with the letter dated 4 September 1990.

Auxiliary request:

Claims: 1 to 3 according to "auxiliary request 3" filed with the letter dated 11 June 2002;

Description and **Drawings** as for the main request.

Oral proceedings were requested in the event the above requests were not allowed by the Board.

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

"1. A method of manufacturing a semiconductor device, the method comprising the steps of:

selectively forming a SiO_2 field insulating film (2) on a silicon substrate (1);

forming a SiO_2 film (3) on the selectively formed SiO_2 field insulating film (2) and a surface of the silicon substrate exposed by the SiO_2 field insulating film (2), the SiO_2 film (3) having a thickness of less than 50 angstroms;

forming a Ti film (4) on the SiO_2 film (3);

performing a first annealing step at a temperature within a range of 600°C to 700°C to form a silicide layer comprising Ti_5Si_3 and TiSi (5) on the silicon substrate (1) and a TiO_2 layer of the Ti film (4); and

performing a second annealing step at a temperature within a range of 800°C to 1000°C to convert the silicide layer (5) into a $TiSi_2$ silicide layer (6) which has a low resistance."

VIII. The appellant's arguments can be summarized as follows:

(a) The present invention relates to the use of titanium and silicon films in salicide technology in which a metal silicide is formed on diffused layers and gate electrodes. In contrast, document D1, which was considered the closest prior art in the decision under appeal, is concerned with the technology of contact barriers. Thus, it is questionable whether a skilled person seeking to solve a problem in the technical field of salicide technology would start from document D1 which relates to contact barriers.

(b) Document D3 makes it clear that there are three different applications for TiN and TiSi: (1) as silicides: (2) as contact barriers; and (3) as local interconnects. A two-step anneal is mentioned in document D3 in relation to salicide but not in relation to contact barriers to which document D1 relates. Therefore, the skilled person would not have combined the teaching of document D1 with that of document D3.

(c) All the cited documents involve the incorporation of nitrogen into the structure. Contrary to the position held in the decision under appeal, document D5 does not teach that annealing is commonly performed with or without nitrogen atmosphere, but indicates instead that pure N_2 is commonly used. Document D5 seeks to replace the use of N_2 with NH_3.

Reasons for the Decision

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

2. *Amendments and Clarity*

Claim 1 according to the main request contains the features of claims 4 and 9 to 12 as filed together with the features disclosed on page 5, lines 1 to 5 and 8 to 10.

Claim 1 as amended furthermore specifies the step wherein a SiO_2 field insulating film (2) is selectively formed on a silicon substrate (1), a feature considered essential in light of the technical problem of lateral growth of titanium silicide on the field insulating film, which is addressed by the application in suit (cf. column 2, lines 25 to 35).

Therefore, in the Board's judgement, the requirements of Articles 84 and 123(2) EPC are met.

3. *Inventive step - Main request*

Inventive step was the only issue in the decision under appeal.

3.1 The application in suit relates to the so-called salicide process of forming titanium silicide layers on contact regions of a semiconductor device. In a typical prior art salicide process, a silicon substrate is masked with a SiO_2 field insulating film exposing only contact areas, and a titanium layer is formed over the substrate. After an annealing step, titanium silicide is formed where titanium is in contact with silicon. The unreacted titanium may be selectively removed leaving silicide (TiSi) on the contact areas.

The problem addressed is that silicon may creep along the SiO_2 field insulating films adjacent the exposed contact areas, so that TiSi regions may grow laterally on the SiO_2 field insulating films which may cause short-circuits.

The claimed method solves the above problem by forming a thin oxide layer (less than 5 nm thick) on the wafer before the Ti-layer is formed. The thin oxide layer is thin enough to allow the formation of TiSi phases on the contact regions, but prevents diffusion of Si atoms along the oxide layers. This requires a second annealing step to allow the formation of a low-resistivity phase of $TiSi_2$ after the unreacted Ti has been removed.

3.2 Document D1, which was considered the closest prior art in the decision under appeal, discloses a process of forming titanium silicide/titanium nitride. Prior to the deposition of titanium, a control layer made of SiN_xO_y and having a thickness of 2 to 5 nm is formed.

After annealing in ammonia atmosphere, a TiSi region 30 is formed at the silicon contact regions. The TiSi region is covered with a $Ti_uO_vN_w$ layer 32 which acts as a barrier layer against diffusion of aluminum from wiring layers which are subsequently formed.

3.3 Document D3 describes essentially the same process as in document D1: Ti is deposited, followed by annealing at 600°C in nitrogen/ammonia ambient. As a result, TiN is formed on the surface and TiSi is formed where Ti is in direct contact with silicon. A second annealing step at 850°C converts the TiN and TiSi to their respective low-resistivity phases. As in document D1, TiN is used for preventing Al from diffusing into silicon. Document D3 also discloses the conventional salicide process.

3.4 Document D5 addresses the same problem as that of the application in suit, ie. to prevent the lateral diffusion of silicon on the SiO_2 field insulating films. In order to solve this problem, the method of document D5 comprises the step of forming a mask layer of silicon oxide where a native oxide layer is automatically formed on the exposed silicon regions; forming a Ti layer on the native oxide film and the mask layer; performing a first annealing step at 600 to 700 °C in ammonia plasma ambient to form TiSi on the silicon surface and a TiN layer on the Ti film; and performing a second annealing step at higher temperature to lower the sheet resistance.

The annealing steps in ammonia ambient promotes the formation of TiN on the Ti surface which suppresses the Si diffusion.

3.5 Document D1 addresses the problem of forming a low-

resistance titanium silicide/nitride contact, which also acts as an effective barrier against diffusion of aluminum, whereas the application in suit relates to the problem preventing diffusion of silicon on the SiO_2 field insulating films. Therefore, the Board agrees with the appellant's submissions that document D1 is not relevant for solving the problem addressed by the application in suit (cf. item VIII(a) above).

Since document D5 relates to the same technical problem as the application in suit, the Board considers document D5 to represent the closest prior art.

3.6 The method of claim 1 according to the main request differs from that of document D5 in that the first annealing step is performed to form Ti_3Si_5 and TiSi on the silicon regions and TiO on the Ti film, whereas in document D5, "titanium silicide" is formed on the silicon regions and TiN film is formed on the Ti layer.

3.6.1 In the decision under appeal it was held that document D5 teaches to perform annealing with or without nitrogen ambient (cf. item III(c) above). The Board is however unable to follow this finding, since it is stated in document D5 that either pure nitrogen or **forming gas** (=hydrogen + inert gas (nitrogen or argon)) is commonly used (cf. left hand column, first paragraph). Thus, document D5 does not suggest the use of a nitrogen-free ambient for the first annealing step, since a titanium nitride film is necessarily formed in the method of document D5.

3.7 The objective technical problem thus relates to finding an alternative solution to the problem of avoiding lateral growth of TiSi in the salicide process.

3.8 A skilled person faced with the problem of finding an alternative to the approach suggested in document D5 would however not consider the documents D1 or D3, since both documents are concerned with avoiding the diffusion of Al into the Si substrate and not with the salicide process.

3.9 Therefore, 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.

Order

For these reasons it is decided:

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 according to the main request as specified under item VI above.

The Registrar: The Chairman:

R. Schumacher R. K. Shukla