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Bezeichnung der Erfindung: Process for producing semiconductor device
Title of invention:
Titre de l'invention :

Klassifikation / Classification / Classement : H01L 21/314, H01L 21/268

ENTSCHEIDUNG / DECISION

vom / of / du 23 February 1989

Anmelder / Applicant / Demandeur :

Patentinhaber / Proprietor of the patent /
Titulaire du brevet : FUJITSU LIMITED

Einsprechender / Opponent / Opposant : I Siemens AG
II TELEFUNKEN electronic GmbH

Stichwort / Headword / Référence :

EPÜ / EPC / CBE Article 56

Schlagwort / Keyword / Mot clé : "Inventive step, no"

Leitsatz / Headnote / Sommaire

Case Number : T 442/87 - 3.4.1

DECISION
of the Technical Board of Appeal 3.4.1
of 23 February 1989

Appellant : (Proprietor of the patent)	FUJITSU LIMITED 1015, Kamikodanaka Nakahara-ku Kawasaki-shi Kanagawa 211 (JP)
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Respondent : (Opponent I)	Siemens Aktiengesellschaft Berlin und München Postfach 22 16 34 D-8000 München 22 (DE)
Representative :	
Respondent : (Opponent II)	TELEFUNKEN electronic GmbH Theresienstrasse 2 Postfach 11 09 D-7100 Heilbronn (DE)
Decision under appeal :	**Decision of the Opposition Division of the European Patent Office dated 1 July 1987 revoking European patent No. 0 045 593 pursuant to Article 102(1) EPC.**

Composition of the Board :

Chairman : K. Lederer
Members : J. Roscoe
G. Paterson

Summary of Facts and Submissions

I. The Appellant is proprietor of European patent No. 0 045 593, which was granted on the basis of European patent application No. 81 303 366.9.

II. The Respondents (Opponents) having separately filed notices of opposition against the European patent, the Opposition Division revoked the patent on the grounds that Claim 1 in accordance with Appellant's main request offended against the provisions of Article 123(2) and (3) EPC whilst Claim 1 in accordance with both his first and second auxiliary requests failed to involve an inventive step having regard to the following documents:

SC: J.F. Gibbons, "Applications of Scanning CW Lasers and Electron Beams in Silicon Technology", Proceedings of the Symposium on Laser and Electron Beam Processing of Electronic Materials held on 15-18 October 1979 in Los Angeles, Proceedings edited by the Electrochemical Society, Volume 80-1, pages 1-25;

SD: US-A-3 609 470; and

T3: D.H. Auston et al., Semiconductor Annealing: "New Role for the Laser", Bell Laboratories Record, July/August 1979, pages 187-191.

III. The Appellant lodged an appeal against the decision.

IV. Following a communication of the Board wherein the attention of the parties was further drawn to the content of document DE-A-2 058 059 (D1), the Appellant filed a copy of a paper by R.C. Sun et al, "Effects of Silicon Nitride

Encapsulation on MOS Device Stability", presented at the IEEE Semiconductor Interface Specialists Conference held in April 1980 (D3) which is referred to in the introductory portion of the description of the impugned patent.

V. Oral proceedings were held before the Board, at the end of which the Appellant, as a main request, requested that the decision under appeal be set aside and that the patent be maintained on the basis of Claims 1 and 2 as filed on 17 February 1989 of which Claim 1, the sole independent claim, reads as follows:

"1. A process for producing a semiconductor device wherein semiconductor elements are formed on a substrate (1), a metallization layer pattern (7) composed mainly of aluminium is formed thereon, a porous passivation layer (8) is deposited on the surface of the device and covers the metallization layer, and the passivation layer is subsequently heat-treated, characterised in that the passivation layer (8) is made from silicon nitride deposited by plasma vapour-phase deposition at about 300-400°C, and that the passivation layer is scanned with an Ar laser beam, so as to eliminate porosity and hydrogen liberated during the reaction of the plasma vapour-phase deposition and chemically combined with or mechanically occluded as gas in the pores of the passivation layer, from the passivation layer without adversely affecting the underlying aluminium layer."

As an auxiliary request, the Appellant requested that the patent be maintained on the basis of an alternative set of Claims 1 and 2 as filed also on 17 February 1989, of which Claim 1, the sole independent claim, reads as follows:

"1. A process for producing a semiconductor device wherein semiconductor elements are formed on a substrate (1), a metallization layer pattern (7) composed mainly of aluminium is formed thereon, a porous passivation layer (8) is deposited on the surface of the device and covers the metallization layer, and the passivation layer is subsequently heat-treated, characterised in that the passivation layer (8) is made from silicon nitride deposited by plasma vapour-phase deposition at about 300-400°C, and that the surface of the passivation layer is instantaneously heated up to about 600°C and then rapidly cooled, by scanning the passivation layer with an Ar laser beam, whereby porosity and hydrogen liberated during the reaction of the plasma vapour-phase deposition and chemically combined with or mechanically occluded as gas in the pores of the passivation layer, are eliminated from the passivation layer without adversely affecting the underlying aluminium layer."

The Respondents both requested that the appeal be dismissed.

VI. Appellant's arguments in support of the allowability of his requests can be summarised as follows:

The nearest prior art is disclosed in document D1, which is the sole document on the file to relate to a process involving a physical treatment of the upper surface only of a passivation layer deposited over a metallization layer in a semiconductor device for increasing its density without in any way impairing the integrity of the underlying metallization layer. Document D1 however concentrates on the plasma treatment of passivation layers made of silicon oxide deposited under oxidising conditions, which do not comprise any substantial hydrogen content and which can therefore be satisfactorily densified under relatively mild ion bombardment and temperature conditions. In contrast, the claimed process uses silicon nitride as a passivation layer which is known to include up to 6% hydrogen when deposited by the low temperature plasma vapour-phase deposition technique, and there is no obvious hint in the prior art that elimination of such amounts of hydrogen could be achieved in addition to the desired densification by processing the passivation layer with a scanning Ar laser beam as is further set out in the claims.

Not only does the claimed process result from the selection of the Ar laser beam from among no less than 50 to 60 commercially available alternative laser systems, and lead to a considerable reduction of the time required for the treatment from several tens of minutes as needed for the known plasma treatment to some milliseconds only, but it is also noteworthy that none of the examples specifically disclosed in document T3, which is an up-to-date survey of the state of the art in the field of semiconductor laser processing, relates to the treatment of the surface of a structure comprising a non-metallic layer overlying a metallic surface as in the present invention.

Quite on the contrary, the general statement in document T3 that "in other experiments, laser heating has made it possible to form metallic silicides very quickly" (page 191, left-hand column, last but one sentence), and the reference in document SC to difficulties due to the reflection of light by metallic films when using a scanning argon laser to react layers of palladium with silicon to form palladium silicide and to the capacity of laser reflection from the front surface of the metal in a Si-Pd-Si sandwich to produce sufficient energy deposition in the top layer of silicon to promote silicide formation (SC, page 13, section 10) actually lead the skilled person away from contemplating the use of a laser beam also in the present circumstances in which such generation of heat and chemical reactions in the underlying metallization layer should clearly be avoided.

The advantages of the claimed process with respect in particular to the reduction of the treatment time can be obvious to the skilled person only after the idea of using a scanning Ar laser beam has occurred to him. For the above reasons, the skilled person not only had no reasonable ground to expect that satisfactory results could be achieved with such laser beam, but he even had to overcome a prejudice before envisaging its use and, accordingly, the apparent obviousness of the achieved advantages cannot be invoked against the patentability of the claimed subject-matter as has already been ruled by the Technical Board of Appeal 3.2.1 in its decision T 36/85 of 1 October 1987 (not published in the OJ EPO).

With regard to the additional distinguishing feature of the claimed process, which either inherently (main request) or explicitly (auxiliary request) calls for the surface of the passivation layer to be heated up to a relatively high temperature of about 600°C, this also cannot be deduced in an obvious manner from the prior art, which discloses substantially lower treatment temperatures (D1, 300°C; D3, 160°C) and stresses the necessity of avoiding heating up the passivation layer to the silicon-aluminium eutectic temperature, which is about 577°C (SD).

VII. These arguments were contested by both Respondents, who submitted that the nearest prior art was constituted by document D3, which disclosed the use in a semiconductor device of a silicon nitride passivation layer formed by plasma vapour-phase deposition over an aluminium metallization pattern. Since it was already known from document D1 that the upper surface of a passivation layer could be densified by subjecting its outer surface to a specific heat treatment by ion bombardment, and since laser scanning was stated by documents SC and T3 to enable localised and accurately controllable heat treatment of the upper portion only of scanned layers, the skilled person could hardly fail to envisage applying the latter technique to densify the silicon nitride passivation layers in the structure of document D3, the more so since the only further available alternative technique for heat treatment of semiconductor devices besides ion bombardment and laser scanning, namely heating within an oven, obviously could not avoid undue overheating of the underlying metallization layer. The selection of a suitable laser beam having regard to the optical absorption characteristics of the scanned layer and the determination of proper temperature conditions did not by themselves call for anything more than the performance of simple routine tests, which did not go beyond the normal competence of the skilled person either.

VIII. At the conclusion of the oral proceedings the decision was announced that the appeal was dismissed.

Reasons for the Decision

1. The appeal is admissible.

2. Main request.

2.1 Novelty.

2.1.1 Document D1 discloses a process for producing a semiconductor device as set out in the preamble of Claim 1, wherein semiconductor elements are formed on a substrate (40, Figure 6), a metallization layer pattern (44) composed mainly of aluminium is formed thereon, a porous passivation layer (45a) is deposited on the surface of the device and covers the metallization layer, and the passivation layer is subsequently subjected to a low temperature heat-treatment (page 15, last paragraph to page 17, first paragraph in conjunction with lines 3 to 10 of page 6 and lines 3 to 9 of page 11).

In this known process, the porous passivation layer is made for instance of silicon oxide deposited by thermal decomposition and oxidation of monosilane (SiH_4) and it is subsequently densified by submitting its surface to a plasma obtained by establishing a controlled discharge in an argon atmosphere (page 17, lines 1-5 in conjunction with page 11, first paragraph).

Thus, the subject-matter of Claim 1 is distinguished from this known process at least in that the passivation layer is made from silicon nitride deposited by plasma vapour-phase deposition at about 300-400°C, and in that the passivation layer is scanned with an Ar laser beam as set out in the characterising portion of the claim.

2.1.2 Document D3 implicitly discloses a process for producing a semiconductor device wherein semiconductor elements are formed on a substrate, a metallization layer pattern composed mainly of aluminium is formed thereon, and a passivation layer made of silicon nitride is deposited by plasma vapour-phase deposition (PDSN layer) on the surface of the device and covers the metallization layer, as may be readily deduced from the representation in Figure 2 of the resulting device (page 244). Since plasma vapour-phase deposition of silicon nitride is well known both to produce porous layers and to be normally performed at a temperature of about 300-400°C, as was agreed upon by the parties, the latter features must also be considered as implicitly disclosed in document D3, which further describes the performance of a subsequent heat-treatment (annealing) of the passivation layer (page 249, part II.D and Figure 19).

There is however no suggestion that this heat treatment involves scanning with an Ar laser beam.

2.1.3 Document SD discloses a process for producing a semiconductor device in which a passivation layer (23, Figure 2) made of glass frit is applied over a metallization layer (24) composed mainly of aluminium and subsequently fired to form a continuous protective film (column 6, lines 23 to 26).

This document neither discloses the use of a plasma vapour-phase deposited layer of silicon nitride as a passivation layer, nor its subsequent scanning with an Ar laser beam.

2.1.4 Documents SC and T3 both relate to the use of laser beams, in particular scanned Ar laser beams, in the production of semiconductor devices (SC, page 2, point 1, first and second sentences and page 18, Figure 1; T3, page 189, last paragraph in connection with the legend below the Figure on page 191).

These documents do not, however, describe the processing of porous passivation layers.

2.1.5 The remaining documents on the file do not come closer to the subject-matter of Claim 1.

2.1.6 For the above reasons, the subject-matter of Claim 1 is considered to be novel within the meaning of Article 54 EPC.

2.2 Inventive step.

2.2.1 In the Board's view, the nearest prior art is constituted by the process of document D3 which, in addition to the sequence of steps set out in the preamble of Claim 1 which is also disclosed in document D1, further involves the use of silicon nitride deposited by plasma vapour-phase deposition to form the passivation layer.

2.2.2 Although teaching that hydrogen included in such silicon nitride passivation layers causes instabilities in the electrical characteristics of semiconductor devices due to the formation of surface states and fixed charges in the channel region (page 244, abstract) which almost completely disappear after an annealing heat-treatment at 160°C for about one hour (page 250, left-hand column, first paragraph, page 249, Figure 19), document D3 gives no detail of how the heat-treatment was performed.

Since document D3 makes no explicit reference to the effect of the heat treatments it discloses on the porosity of the silicon nitride layer and the Board has no reason to doubt that the claimed process effectively eliminates the porosity of the layer and with it the hydrogen locked in the pores during deposition of the layer the two-part technical problem to which the invention affords a solution as objectively assessed in view of the nearest prior art is to find a practical and less time consuming technique for bringing about the same or greater improvements in the elimination of the surface states and the fixed charges in the channel regions as are achieved by the protracted annealing processes described in document D3 and at the same time to eliminate the porosity and the hydrogen locked in the pores of the nitride layer.

2.2.3 No contribution to inventive step can be seen in the mere recognition by the skilled person (a) of the need to improve on known processes or (b) of the desirability on the one hand of densifying a deposited layer which is known to be porous and is required to play a passivating role in a semiconductor device, attention to which is drawn on page 2 of document D1, or, on the other hand, of eliminating hydrogen from a PDSN layer, in view of the detrimental effects attributed to it in document (3).

2.2.4 In addition to the indication that hydrogen-induced instabilities are substantially eliminated through annealing at 160°C for one hour, the skilled person will find in document D3 the teaching that the extent and rate of stabilisation both increase with increasing annealing temperatures (Figures 19 and 20). Shortening the treatment times, however, is a most common concern in the fabrication of semiconductor devices and, accordingly, the skilled person in his search for an appropriate heat treatment technique can reasonably be assumed to contemplate also the use of techniques susceptible of achieving even higher annealing temperatures in the passivation layer, at least as far as they will not adversely affect the aluminium metallization layer beneath, which is well known to tend to fuse or undergo chemical reactions as a result of annealing the overlying passivation layer at excessive temperatures (D1, page 3, lines 16 to 30; SD, column 1, lines 15 to 22).

One such technique as described in document T3, which is specifically dedicated to high temperature processing of semiconductor devices (see page 187, abstract), involves laser beam scanning and is explicitly said in the document to allow rapid and selective heat delivery to thin layers without significantly heating the bulk of the material (page 188, left-hand column, second paragraph and right-hand column, third paragraph). A treatment temperature of about 950°C is exemplified in the document in connection with the healing of damage from ion implantation (page 189, sentence bridging the left-hand and the right-hand columns), but the suitability of the described laser annealing technique for the treatment of amorphous layers formed, as is the passivation layer of document D3, by chemical vapour deposition are mentioned as well (page 191, left hand column, second paragraph). Moreover, laser beam scanning is stated in document SC to achieve reduction of the surface state charge density in films intended for MOS device fabrication (page 13, point 9), which is also the primary object of the heat treatment in the process of document D3.

Having regard to these statements, the skilled person screening the prior art for a shorter heat treatment technique for achieving annealing of the passivation layer to produce the effects described in document D3 would, in the Board's view, hardly fail to realise the potential of the laser beam scanning technique as disclosed in documents T3 and SC to solve the first of his problems, which he could then readily confirm by way of simple routine tests well within his competence. These tests would also reveal that the treatment eliminated the layer porosity and hence also the hydrogen occluded in the layer. The choice of an argon type laser as further set out in Claim 1 cannot by itself justify a positive assessment of inventive step because this is a well known laser type, which is exemplified both in document T3, wherein it is even said to be the most frequently used in solid-phase annealing (page 189, right-hand column, second paragraph), and in document SC (page 18, Figure 1).

The Appellant's arguments based on the allegation of a technical prejudice against the capacity of the technique referred to in documents T3 and SC to anneal a passivation layer deposited over a metallization pattern could not convince the Board, because the skilled person cannot reasonably be expected to derive from the mere fact that laser beam scanning might produce chemical reactions like the formation of metal silicides between adjacent layers of metal and silicon when performed under specific conditions the general conclusion that such reactions will necessarily occur also under different operating conditions. On the contrary, the statement in document SC that the difficulties in controlling the laser reaction caused by the reflection of light by thicker metal films are overcome by forming a Si-Pd-Si sandwich of thin palladium and silicon layers in which laser reflection from the front surface of the metal can produce sufficient energy deposition in the top layer of silicon to promote silicide formation (page 13, point 10, first paragraph) suggests that reflection of the laser beam by a metal film normally prevents the latter from being directly heated, which the skilled person would rather recognise as an advantage in the contemplated application of laser beam scanning to the treatment of passivation layers deposited over metallization patterns which are not to be overheated.

Neither, can the Board see, in the choice of a most commonly used laser beam, the result of an inventive "selection" of the Ar laser type among the numerous types of laser systems which were actually available at the date of the invention, the more so since the Appellant neither demonstrated the existence of any superior or unexpected effect of the Ar laser beam as compared with others, nor even sought to do so.

2.2.5 For these reasons, the subject-matter of Claim 1 is considered to lack an inventive step within the meaning of Article 56 EPC and is therefore not patentable (Article 52(1) EPC).

2.3 Accordingly, the ground for opposition set out in Article 100(a) EPC prejudices the maintenance of the patent in amended form in accordance with Appellant's main request.

3. Auxiliary request.

3.1 Independent Claim 1, in accordance with Appellant's auxiliary request, is distinguished in substance from Claim 1 of his main request only in that it further specifies that the surface of the passivation layer is instantaneously heated up to about 600°C and then rapidly cooled.

3.2 Laser annealing, however, inherently causes instantaneous heating and subsequent rapid cooling of a thin layer on top of the treated material, as described for instance in document T3 (page 188, right-hand column, third paragraph), and the Appellant has not shown that determining the appropriate degree of heating would require more than the skilled person's normal competence. In particular, since the aluminium metallization layer is known to form an eutectic alloy with silicon at 577°C (document SD, first column, lines 24 to 27) and would not be expected to reach in the laser annealing process the temperature of the top surface of the passivation layer, setting the latter at about, or slightly above, the temperature of the Al-Si eutectic e.g. at 600°C obviously provides safe operating conditions avoiding any damage to the underlying metallization layer while simultaneously insuring substantial heating of the passivation layer well above the minimal temperature of 160°C as set out in document D3. Such considerations would be routine for a skilled person.

For these reasons, the subject-matter of Claim 1 in accordance with Appellant's auxiliary request is considered to lack an inventive step within the meaning of Article 56 EPC, and is therefore not patentable either (Article 52(1) EPC).

3.3 Accordingly, the ground for opposition set out in Article 100(a) EPC also prejudices the maintenance of the patent in amended form in accordance with Appellant's auxiliary request.

Order

For these reasons, it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

F. Klein K. Lederer