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File No.: T 0694/91 - 3.4.1
Application No.: 85 300 516.3
Publication No.: 0 151 004
Classification: H01L 21/283
Title of invention: Schottky barrier diodes

D E C I S I O N
of 17 March 1993

Applicant: TEKTRONIX, INC.

Proprietor of the patent:

Opponent:

Headword:

EPC: Art. 56, 83 and 84

Keyword: "Inventive step (yes, after amendments)" - "Original disclosure of the invention (yes)"

Headnote
Catchwords



Case Number: T 0694/91 - 3.4.1

D E C I S I O N
of the Technical Board of Appeal 3.4.1
of 17 March 1993

Appellant: TEKTRONIX, INC.
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Decision under appeal: Decision of the Examining Division 048 of the
European Patent Office dated 18 April 1991
refusing European patent application
No. 85 300 516.3 pursuant to Article 97(1) EPC.

Composition of the Board:

Chairman: G.D. Paterson
Members: U.G.O.M. Himmler
Y. van Henden

Summary of Facts and Submissions

I. This European patent application concerns a Schottky barrier diode and a method of making such a diode, and was refused by a decision of the Examining Division which was based on Claims 1 to 3 as filed with the Applicant's letter of 5 July 1990 and Claim 4 as amended during oral proceedings (main request). As an auxiliary request the Applicant filed a new independent Claim 1 during the oral proceedings before the Examining Division accompanied by Claims 2 to 4 according to the main request.

The reason for the refusal was that the subject-matter of the independent Claims 1 and 3 according to the main request lacked an inventive step having regard in particular to document US-A-3 560 809 (D1), as well as to documents US-A-4 119 446 (D2) and EP-A-0 021 869 (D3). Independent Claim 1 according to the auxiliary request was not allowed because it contained subject-matter that had not been disclosed originally, contrary to Article 123(2) EPC.

II. The claimed invention is concerned with improving the consistency of the properties of such diodes by causing so-called "outdiffusion" of silicide beyond the semiconductor opening, such outdiffusion being said to prevent the formation of parasitic diodes. The application describes how to form a diode according to the invention in which vanadium is the metal used to form the silicide, but refers to the possible use of other metals such as tungsten.

III. The Appellant filed three new requests with the grounds of appeal, and also requested oral proceedings. In a communication accompanying the summons to oral

proceedings, the Board expressed a provisional opinion stating that:

- the amendments to Claim 1 of all three requests introduced subject-matter which extended beyond the content of the application as filed, contrary to Article 123(2) EPC;
- however, even after rectification of Claim 1 of the main request in accordance with Article 123(2) EPC the subject-matter of Claims 1 and 3 of the main request might lack novelty over document D1, on the basis that although D1 does not specifically refer to the causing of outdiffusion of silicide to form a thin layer preventing the formation of a parasitic diode, this would inevitably occur when following the teaching of D1;
- further, according to the Board's provisional view, such claims were not allowable, as they might not define subject-matter properly supported by the description (Article 84 EPC), and because the description did not disclose how to carry out the claimed invention (Article 83 EPC). This view was based upon a passage in the Grounds of Appeal which suggested that achieving the necessary controlled outdiffusion using tungsten involves extreme practical difficulties.

IV. In reply, the Appellant filed three sets of new claims (main request called "replacement claims", first and second auxiliary requests called "claims A" and "claims B"). These new requests included amendments to take account of the objections raised under Article 123(2) EPC.

The text of Claims 1 to 3 of the main request is as follows:

"1. A method of manufacturing a Schottky barrier diode utilising a silicon substrate (2), comprising:

forming a layer of dielectric material (4) on a major surface of said substrate (2), said layer (4) defining a restricted opening through which the substrate (2) is exposed;

forming within said opening at said major surface a body (6') of a single phase compound of silicon and a first metal, and

depositing a layer (8) of a refractory metal over the dielectric layer (4) and said body (6'),

characterised in that the body (6') has an intrinsic barrier height within the range from 0.6 eV to 0.8 eV, in that silicon diffuses from said substrate into the first metal to form the body more rapidly than the first metal diffuses into the substrate, and in that the body is intrinsically stable at temperatures up to 600°C and is formed in such a way as to produce a thin layer portion (14) of the body (6') which lies on the dielectric layer (4) around the perimeter of the body (6') due to outdiffusion of the silicon into the first metal, which thin layer portion (14) inhibits the formation of a parasitic diode by the refractory metal.

2. A method according to Claim 1, wherein said first metal is vanadium.

3. A Schottky barrier diode comprising a substrate (2) of silicon, a layer (4) of dielectric material on a major surface of the substrate (2), said layer (4) defining a restricted opening, and a body (6') of a single phase compound of silicon and a first metal formed within said opening, the diode further comprising a layer (8) of refractory metal deposited over the layer

(4) of dielectric material and the body (6'), characterised in that said compound is intrinsically stable at temperatures up to 600°C, in that combination of silicon with the first metal is favoured over combination of silicon with the refractory metal, in that a thin layer portion (14) of said body (6') is disposed on the dielectric layer (4) around the perimeter of the body (6'), said thin layer portion (14) having been formed as a result of silicon diffusing from the substrate (2) into the first metal more rapidly than the first metal diffused into the substrate (2), and in that the work function of the first metal is sufficiently high that it does not cause an accumulation of charge carriers at the interface between said body (6') and the substrate (2)."

Claim 1 of the first auxiliary request is restricted to the use of vanadium as the first metal (as Claim 2 of the main request). Claim 1 of the second auxiliary request specifies that the unreacted first metal is removed prior to the deposition of the refractory metal and that the first and refractory metals are different.

V. The Appellant essentially put forward the following arguments in support of his main request:

A. The novelty objection on the basis of D1 could only apply for the case where tungsten is the refractory metal as well as the first metal. However, this objection is not justified, because D1 does not disclose "the thin layer portion (14) of the body (6') which lies on the dielectric layer (4) around the perimeter of the body (6')".

The suggestion that this result would necessarily be obtained by following the teaching of D1 is incorrect,

because such a result is only obtained by a strictly controlled process which was not known in 1968 (the priority date of D1).

- B. The objection under Articles 83 and 84 EPC is not justified. According to the established jurisprudence of the Boards of Appeal it is sufficient that one clear example shows how the invention is to be carried out. This example is given for vanadium in the application. In such cases it is even sufficient that the features of the claim are functionally defined. In any event, the grounds of appeal referred to the difficult practical problem at the **priority date of D1** (1968) to produce the thin layer 14 using tungsten. However, the skilled person could perform the claimed invention using tungsten instead of vanadium at the priority date of the application in suit (1984).

Reference was made to decisions T 68/85 (OJ EPO 1987, 228), T 292/85 (OJ EPO 1989, 275) and T 19/90 (OJ EPO 1990, 476).

Reasons for the Decision

1. The set of Claims 1 to 4 in the main request is allowable for the reasons which follow.
2. *Admissibility of the amendments*

Claim 1 is based on the originally filed Claims 1 and 2; it further incorporates the following additional features:

- (a) "silicon diffuses from said substrate into the first metal to form the body more rapidly than the first metal diffuses into the substrate";
- (b) the body "is formed in such a way as to produce a thin layer portion of the body which lies on the dielectric layer around the perimeter of the body due to outdiffusion of the silicon into the first metal";
- (c) the "thin layer portion inhibits the formation of a parasitic diode by the refractory metal".

These features are disclosed in the originally filed description on page 4, lines 22 to 25 [feature (a)], on page 4, lines 26 and 30 to 31 [feature (b)] and on page 4, lines 27 to 29 and 32 to 34 [feature (c)].

Although this specific description discloses features (a), (b) and (c) in combination with vanadium as a first metal, the description explains on page 5, lines 30 to 34, that other metals than vanadium may be used, provided they have the required properties. As one example of another possible metal tungsten is mentioned.

3. *Novelty*

The Board accepts that document D1 does not explicitly disclose the production of a Schottky barrier diode in accordance with Claim 1 or Claim 3 and including the feature of a "thin layer portion of the body which lies on the dielectric layer around the perimeter of the body due to outdiffusion of the silicon into the first metal, which thin layer portion inhibits the formation of a parasitic diode by the refractory metal". Furthermore, as a matter of law the disclosure of document D1 must be interpreted at its own date for the purpose of

determining its effect upon the novelty of the present application. There is no evidence that at that date the disclosure of D1 would inevitably have been carried out with the necessary control so as to achieve the above feature of Claim 1 of the present application. Thus, in the Board's judgment, the claims of the present application are novel within the meaning of Article 54 EPC having regard to D1.

4. *Sufficiency*

As discussed above, this objection was raised having regard to the fact that the claimed invention includes the possibility of using metals other than vanadium as the "first metal", in particular **tungsten**, and also having regard in particular to the submission made by the Appellant that "achieving the necessary controlled outdiffusion using **tungsten**, although possible in theory, involves extreme practical difficulties, ...".

The Board does not accept the Appellant's submission that, as a general principle in accordance with the jurisprudence of the Boards of Appeal, it is always enough that the description of the invention includes one example (in this case using vanadium as first metal) showing how to carry it out. In the Board's view the extent of description as to how to carry out the invention which is necessary for compliance with Articles 83 and 84 EPC depends upon the circumstances of each case, and may depend in particular upon the scope of the claims.

Thus, in the present case, having regard to the fact that the claims cover the use of tungsten in place of vanadium as "first metal", and in view of the specific reference to the use of tungsten in place of vanadium in the last paragraph of the description, objections under

Articles 83 and 84 EPC could arise if carrying out the invention using tungsten in place of vanadium involved an undue burden for the skilled person.

However, the Appellant explained during the oral proceedings that the above-quoted passage from the grounds of appeal was concerned with the circumstances at the date of document D1 (1968 or thereabouts), and that by the filing date of the present application a skilled person would have been able to perform the claimed invention using tungsten in place of vanadium as "first metal", without undue burden.

The Board therefore accepts that there is no evidence before it on which objections under Articles 83 or 84 EPC could properly be based.

5. *Inventive step*

5.1 The claim differs from the prior art described in document D1 by the following features of the characterising portion of the claim, i.e. that

- the body is formed in such a way as to produce a thin layer portion of the body
 - which lies on the dielectric layer around the perimeter of the body,
 - which is due to outdiffusion of the silicon into the first metal,
 - which inhibits the formation of a parasitic diode by the refractory metal.

5.2 According to the description of the application and the state of the art it was well known that oxide-isolated

Schottky barrier diodes fabricated on a silicon substrate and including a metal silicide body had the drawback that these devices did not have consistent and reliable properties. It was believed that one of the main reasons for these poor properties of conventional Schottky barrier diodes was the build-up of parasitic metal-silicide/SiO₂/Si diodes formed around the perimeter of the silicide body.

The conventional solution to this known problem was a guard ring in the silicon wafer around the silicide body, as shown in documents D2 and D3. Such guard rings complicate the manufacturing process and may undesirably enhance the capacitance of the device.

The inherent problem of the application may therefore be seen in manufacturing an unguarded metal-silicide/silicon Schottky barrier diode with consistent and reliably reproducible characteristics, avoiding in particular any detrimental parasitic MIS structure.

5.3 The Board accepts that a controlled outdiffusion takes place only under very specific conditions involving new annealing techniques which were developed shortly before the priority date of the present application and were not available at the priority date of D1. This process step of a controlled outdiffusion is responsible for building-up the thin layer portion of the body lying on the dielectric layer around the perimeter of the body and inhibiting the formation of a parasitic diode.

As D1 is concerned with a completely different problem, i.e. to provide a variable capacitance element which can produce a desired capacitance variation with low voltages (cf. column 1, lines 39 to 41 and column 2, lines 14 to 15) this document would not suggest how to make a Schottky barrier diode avoiding the formation of

parasitic diodes, and therefore providing good forward and reverse characteristics.

5.4 In the Board's view, the functional results to be achieved, as required in the characterising portion of Claim 1, i.e. to produce a thin layer portion of the body

- which lies on the dielectric layer around the perimeter of the body,
- which is due to outdiffusion of the silicon into the first metal,
- which inhibits the formation of a parasitic diode by the refractory metal

would not be obtained by any method, but are obtained only when following a specially adapted sequence of method steps. There is no indication or hint in document D1 that it would be desirable to achieve these results. Consequently the person skilled in the art had no incentive to use specially selected method steps in order to arrive at the above-mentioned results. Document D1 does not teach the skilled person what has to be achieved. Therefore, in spite of the fact that all the necessary annealing techniques were available to the skilled person at the priority date of the present application, it was not obvious at that date to apply these techniques so as to achieve the claimed results.

For the above reasons, in the Board's judgment, the subject-matter of Claims 1 and 3 is inventive in comparison with the state of the art considered by the Examining Division.

For the foregoing reasons, the subject-matter of the claims in accordance with the main request is considered to involve an inventive step within the meaning of Article 56 EPC.

Order

For these reasons, it is decided that:

1. The decision of the Examining Division is set aside.
2. The case is remitted to the first instance with the order to grant a patent with description and claims as filed during oral proceedings on 17 March 1993, and drawings as originally filed.

The Registrar:

The Chairman:

M. Beer

G.D. Paterson