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D E C I S I O N
of 22 February 2000

Case Number: T 0753/96 - 3.4.3

Application Number: 91307958.8

Publication Number: 0483958

IPC: H01L 23/525

Language of the proceedings: EN

Title of invention:
Electrically programmable antifuse incorporating dielectric and amorphous silicon interlayer

Applicant:
ACTEL CORPORATION

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 56

Keyword:
"Inventive step - no"

Decisions cited:
T 0393/94

Catchword:
-

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Case Number: T 0753/96 - 3.4.3

D E C I S I O N
of the Technical Board of Appeal 3.4.3
of 22 February 2000

Appellant: ACTEL CORPORATION
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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 15 April 1996 refusing European patent application No. 91 307 958.8 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: R. K. Shukla
Members: M. Chomentowski
M. J. Vogel

Summary of Facts and Submissions

I. European patent application No. 91 307 958.8 (Publication No. 0 483 958) was refused by a decision of the examining division dated 15 April 1996 on the ground that it did not meet the requirement of inventive step in accordance with Articles 52(1) and 56 EPC having regard to document D1 = DE-A1-39 27 033.

The following patent application documents formed the basis of the decision under appeal:

Description: Pages 1 to 5, 8 and 10 to 14 as originally filed;
Page 6 as filed with applicant's letter dated 31 January 1995;
Pages 7 and 9 as filed during the oral proceedings of 31 January 1996;

Claims: Nos. 1 to 20 as filed during the oral proceedings of 31 January 1996;

Drawings: Sheet 1/1 as filed with applicant's letter dated 18 October 1991.

Independent claims, i.e. claims 1 and 18, read as follows:

"1. An electrically programmable antifuse element disposed on a semiconductor substrate (10) in an integrated circuit comprising:

an insulating layer (12) covering active circuit

elements on said integrated circuit;

a first electrode (14) disposed over said insulating layer;

a first dielectric layer (20) disposed over said first electrode;

an antifuse layer (22) disposed over said first dielectric layer;

a second dielectric layer (24) disposed over a portion of said antifuse layer; and

a second electrode (26) disposed over said second dielectric layer; characterised in that:

said first electrode (14) comprises a metal."

"18. A method of forming an electrically programmable, low impedance antifuse element on a semiconductor substrate comprising the steps of:

forming an insulating layer (12) over active circuit regions on said substrate,

forming a first electrode (14) over a selected portion of said insulating layer,

forming a first dielectric layer (20) over said first electrode,

forming an antifuse layer (22) over said first dielectric layer, and

forming a second dielectric layer (24) over said antifuse layer

forming a second electrode (26) over a selected portion of said second dielectric layer; characterised in that:

said first electrode is formed of a metal."

In the decision under appeal, the examining division took the following position:

The objective problem associated with the only difference between the presently claimed device and that of Example 3 and Figure 4 of document D1, i.e. a first, lower electrode of metal instead of one of polycrystalline silicon (polysilicon), is to be seen in the desire to reduce the resistance introduced by the first electrode. The resistance of metallisation structures of semiconductor devices is a permanent concern in semiconductor device technology and, thus, it does not contribute to an inventive step. Moreover, its solution is trivial since it is common knowledge that metals have a better conductivity than semiconductor materials.

From the application as filed, which disclosed first electrodes of metal or of polysilicon, the skilled person would not have been prevented to use metal instead of polysilicon for the first electrode. Indeed, when replacing the polysilicon of said electrode by metal, it could be necessary to adjust the features of the neighbouring layers of the antifuse element; however, it is believed that this would be no problem for the skilled person.

The teaching of document D1, in its broadest scope, is clearly not limited to polysilicon for the first electrode; it is clear that the beneficial effects obtained by this known antifuse element are mainly related to its layer structure and not to the use of any specific material for one of its layers. Therefore, although it is not contested that document D1 discusses some advantages obtainable by using polysilicon for the first electrode, the skilled person would not have been prevented to consider replacement by a metal if circumstances had given highest priority to a reduction of the antifuse resistance in its conducting state.

Therefore, the subject-matters of claims 1 and 18 lack an inventive step.

II. The applicant lodged an appeal against this decision on 5 June 1996 paying the appeal fee the same day. The statement of the grounds of appeal was filed on 13 August 1996.

III. In the annex to the summons to the oral proceedings, the applicant was informed that the subject-matter of the application did not appear to involve an inventive step having regard to document D1 and US-A-4 823 181, a prior art document cited in the application as filed (see page 9, lines 6 to 14).

IV. Oral proceedings took place on 22 February 2000.

V. The appellant requested that the decision under appeal be set aside and that a patent be granted on the basis of the same patent application documents as set out in the decision under appeal, and provided essentially the

following arguments in support of his request:

1. From Example 3 and Figure 4 of document D1, there is known an electrically programmable antifuse element disposed on a semiconductor substrate in an integrated circuit comprising all the features of the pre-characterising portion of present claim 1. However, the first electrode of this Example does not comprise a metal, but polycrystalline silicon.

2. In this respect, it is to be noted that, in accordance with the established case law of the boards of appeal (cf. in particular the decision T 373/94 of 8 July 1999, unpublished, point 5.5 of the reasons), the disclosure of particular features in a prior art document must be considered in the technical context of the whole disclosure, so that the particular features cannot be selected in a manner which changes or contradicts the teaching of the document in question. Here, the teaching derivable from document D1 discourages from using metal for the first electrode.

3. The desirable properties of an electrically programmable antifuse element include: reliability in programming; low programming voltage; low resistance when programmed, low capacitance and high resistance when unprogrammed and reliability in manufacture, whereby in particular hillocks on the lower electrode which may pierce the antifuse layer and cause short circuits between the first and the second electrode are to be avoided.

4. It is believed that, as compared with the electrically programmable antifuse element of Example 3 and Figure 4 of document D1, the use of metal instead of polycrystalline silicon for the first electrode further improves reliability; it also improves programmed resistance, this latter effect being not only due to a reduction in the resistance in the lower electrode itself, but also because the metal first, lower electrode contributes material to form the filament(s) which short-circuit the antifuse when programmed.

5. The problem mentioned in the impugned decision is related with high value of the resistance of polycrystalline silicon lower electrode of the electrically programmable antifuse element as compared to such an electrode comprising metal. However, multiple advantages are mentioned in document D1 as resulting from the use of the polycrystalline silicon, in particular when using said material instead of a doped region of the semiconductor substrate, and it is the object of the invention of document D1 to provide an element of this type with *inter alia* a low resistance when programmed, so that a problem related to the resistance of polycrystalline silicon is not directly apparent from document D1.

6. Should the skilled person starting from Example 3 and Figure 4 of document D1 anyway see a problem with the value of the resistance of the electrically programmable antifuse element, then such a problem would not be restricted to the value of the resistance of the lower electrode of

the electrically programmable antifuse element, but would also concern the resistance of other parts of the electrically programmable antifuse element, which also contribute to the resistance of said element.

7. It is also to be noted with respect to the specific structure of the electrically programmable antifuse element that, because of the superposition of parts of different materials which are mentioned in document D1 as having a specific function in the element as a whole and as having an influence on the neighbouring parts, the replacement of the polysilicon electrode by a metal one is not a simple replacement, but would require compensating adjustments to the other parts of the device. Indeed, in addition to multiple advantages stressed in document D1 and resulting from the use of polysilicon for the lower electrode, in particular for replacing a doped semiconductor region with the same function, some of said advantages are mentioned as being related to the interaction between the polycrystalline silicon and the neighbouring parts of the antifuse element. In document D1 (see column 3, lines 2 to 8), in particular, the importance of the thickness of the isolating silicon film of the antifuse element for the low resistance in the programmed state and for the high resistance in the unprogrammed state is stressed, and temperatures of formation of the different layers of the antifuse element are also disclosed throughout the document, which are for obtaining said results and which are to be

understood in relation with the use of a lower polycrystalline electrode, and not in relation with other materials such as metal.

8. In any case, whereas for the second, upper electrode, a metal, i.e. aluminium, is mentioned in connection with the examples with a doped region, the only clear and positive teaching in document D1 for the first, lower electrode is an electrode consisting either of a doped region in the semiconductor substrate supporting the device or of polysilicon. Thus, the reasoning in the impugned decision based on the general teaching of, for instance, claims 1 and 5 of the document, whereby the material of the electrodes is not specified at all, cannot be accepted as an indication for the use of metal for the lower electrode in place of polysilicon.

The further prior art documents are less relevant. Therefore, the device of present claim 1 is not obvious to a skilled person and involves an inventive step. Method claim 18 also involves an inventive step for the same reasons.

Reasons for the Decision

1. The appeal is admissible.

2. *Inventive step*

2.1 In spite of the ambiguities in document D1 (see column 4, line 45 to column 5, line 2) about Example 3

("Beispiel 3") in the description and the related Figure 4, which in particular arise because of the inconsistent use of reference signs and which have been noted by the Examining Division and by the appellant, there is sufficient information for clearly deriving therefrom that the electrically programmable antifuse element is disposed on a semiconductor substrate in an integrated circuit comprising:

an insulating layer covering active circuit elements on said integrated circuit;

a first electrode disposed over said insulating layer;

a first dielectric layer disposed over said first electrode;

an antifuse layer disposed over said first dielectric layer;

a second dielectric layer disposed over a portion of said antifuse layer; and

a second electrode disposed over said second dielectric layer.

However, the first electrode of Example 3 and Figure 4 of document D1 does not comprise a metal, but polycrystalline silicon, and it has not been disputed by the appellant that this constitutes the only feature distinguishing the element of present claim 1 from that of this known example.

2.2 As submitted by the appellant in the statement of the

grounds of appeal (see item V.4 above), the metal electrode in the antifuse element according to the invention supplies material for the formation of the filament which short-circuits the antifuse element when programmed and thereby provides a reliable antifuse element having a low programmed resistance ("on-resistance").

2.3 The objective problem, which according to the established case law of the boards of appeal has to be established in relation to the closest state of the art, addressed by the present invention, can therefore be regarded as providing an electrically programmable antifuse element which is reliable and has a low programmed resistance.

2.4 In electrically programmable antifuse elements, as submitted by the appellant (see item V.3 above), the reliability in programming and a relatively low programmed resistance are known to be desirable properties. There is thus no contribution to inventive step in the recognition of the above problem in the field of electrically programmable antifuse elements.

2.5 As acknowledged in the present application (see page 3, lines 13 to 15; page 5, lines 10 to 12 and 17 to 19), the use of metal electrodes for antifuse of both the types, i.e. (a) the first type employing an interlayer of silicon dioxide and silicon nitride and (b) the second type employing an interlayer of amorphous silicon, is well known in the art.

Also, as acknowledged in the present application (see page 3, lines 15 to 25), it is well known in the art

that during the programming of the first type of antifuse the dielectric between the metal electrodes breaks down at weak points due to the programming voltage and that a conductive link is established between the electrodes.

As further generally known, such a conductive link can be formed by the conductive material from the electrodes which flows during the breakdown of the dielectric, see, e.g., column 3, line 20 to column 4, line 45, of US-A-4 823 181, cited in the application as filed (see page 9, lines 6 to 14).

Since in document D1 a composite layer comprising a dielectric layer is employed, to a skilled person concerned with the objective problem of reducing the programmed resistance of the antifuse device, it would be obvious that an electrode comprising metal or formed of a metal instead of a polysilicon electrode would not only reduce the programmed resistance of the device but would also provide the conductive material for the link which is to be established when the dielectric breaks down during the programming. It is true, as argued by the appellant (see item V.7 above), that document D1 emphasizes the advantages of providing a silicon insulating film, in particular a silicon oxide film on a polycrystalline lower electrode in controlling the "on-resistance" and "off-resistance" of the antifuse element (cf. column 2, line 65 to column 3, line 8; column 7, lines 25 to 56). The Board, however, does not agree with the submission of the appellant that in view of these advantages resulting from the use of the polysilicon for the lower electrode the skilled person would not depart from the teaching of document D1 and

replace the polysilicon lower electrode by an electrode comprising a metal. This is mainly because the skilled person must be presumed to be aware of the generally well known fact that the material of the electrode in document D1, i.e. polysilicon, would also contribute to the programmed-resistance, so that the skilled person faced with the above objective problem would consider the use of metal for the lower electrode in the antifuse element of document D1 for the above reasons. Moreover, as can be seen from the advantages listed in column 7, lines 35 to 56, document D1 recommends the use of polysilicon with a view to simplifying the formation of the oxide film and having a relatively low programming voltage. The present invention, on the other hand, does not address these problems, and is concerned mainly with providing low programmed resistance.

The Board agrees with the appellant (cf. item V.2 above) (cf. T 373/94 of 8 July 1999) that the disclosure of particular features in a prior art document must be considered in the technical context of the whole disclosure, so that the particular features cannot be selected in a manner which changes or contradicts the teaching of the document in question. Thus, the use of polysilicon in document D1 has to be seen in the context of the problems addressed in document D1. In the opinion of the present Board, the teaching derivable from document D1 as a whole is that the use of polysilicon as a lower electrode is to be preferred over the use of a single crystal silicon lower electrode when the formation of the oxide film is to be simplified and a low programming voltage is desired. There is no suggestion in document D1 that a

lower electrode of metal would be incompatible with the structure of the antifuse element disclosed therein.

2.6 Concerning the appellant's argument about a technical prejudice against the use of a metal, it is first to be noted that such a prejudice is not derivable from document D1, because all the advantages of using polysilicon in Example 3 therein are in comparison with the use of a single crystal silicon as an electrode, and not as compared to a metal electrode. Moreover, it is the established case law of the Boards of appeal that to demonstrate a technical prejudice in the art the disclosure in one document is in general not enough.

2.7 The arguments in the statement of grounds of appeal (see item V.7 above) about the difficulties in adapting the method of forming an antifuse element of document D1 to the use of a lower metal electrode are not convincing since methods for forming metal electrode layers, dielectric layers and antifuse layers are generally known in the relevant art of antifuse elements and there is no indication that the methods used in fabricating the antifuse element of claim 1 in suit are different therefrom or that there was a particular difficulty in selecting or adapting said generally known method steps when the lower electrode comprises a metal.

2.8 For the foregoing reasons, in the Board's judgement, the subject-matter of present claim 1 does not involve an inventive step in the sense of Article 56 EPC.

Moreover, since claim 18 concerns a method of forming a device having the same features as claim 1, and since the method steps *per se* are conventional, claim 18 also does not involve an inventive step (Article 56 EPC).

Therefore, the patent application has to be refused (Article 97(1) EPC).

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

D. Spigarelli R. Shukla