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D E C I S I O N
of 12 May 1999

Case Number: T 0751/94 - 3.4.3

Application Number: 89112987.6

Publication Number: 0350961

IPC: H01L 21/302

Language of the proceedings: EN

Title of invention:
Semiconductor device having thin film resistor and method of producing same

Applicant:
Denso Corporation

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 54, 56

Keyword:
"Novelty (yes): overlapping ranges of a parameter"
"Inventive step (yes): purposive selection of a combination of parameters"

Decisions cited:
T 0026/85, T 0666/89

Catchword:

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Case Number: T 0751/94 - 3.4.3

D E C I S I O N
of the Technical Board of Appeal 3.4.3
of 12 May 1999

Appellant: Denso Corporation
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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 25 March 1994 refusing European patent application No. 89 112 987.6 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: R. K. Schukla
Members: M. Chomentowski
W. Moser

Summary of Facts and Submissions

1. European patent application No. 89 112 987.6 (publication No. 0 350 961) was refused in a decision of the examining division on the ground that the subject-matter of claim 1 lacked an inventive step over D2 = WO-A-8 300 256 or over D1 = US-A-4 569 742.

   Claim 1 forming the basis of the decision reads as follows:

   "1. A method of producing a semi-conductor device having a thin film resistor comprising chromium, silicon and nitrogen, formed on a substrate, the thin film resistor forming process consisting essentially of the steps of preparing a target containing at least chromium and silicon, wherein the weight percentage of the silicon to the total weight of the chromium and silicon is 41 to 57 weight %, and reactive sputtering a substrate, utilizing said target in an atmosphere of an inert gas containing 1-2% nitrogen gas, whereby said thin film resistor thus produced becomes amorphous, and has the same energy band construction as that of metal, wherein a thermal treatment is applied to said thin film resistor after said thin film resistor is formed which thermal treatment is carried out at a temperature of less than 500°C, to thereby maintain the amorphous condition of said thin film resistor."

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

   The method of claim 1 was distinguished over D2 in the selection of the particular range of the silicon

content of the target, the amount of nitrogen in the atmosphere of inert gas, and the maximum temperature of the thermal treatment of the film. These parameters were selected so that the thin film resistor was amorphous and had the energy band structure of a metal, this resulting in little change of the resistance for large variations of the temperature thereof, i.e. having a low temperature coefficient of resistance (TCR) of said thin film resistor.

The identification of the problem, i.e. the need for producing thin film resistors with smaller TCR, did not contribute to an inventive step. The solution to this problem consisted in selecting

(a) a particular range of the silicon content, i.e. 41 to 57% weight of silicon in the target,

(b) a relatively low nitrogen gas content (1 to 2%) of the inert atmosphere, and

(c) a temperature for thermal treatment of less than 500°C of the produced thin film resistor.

However, in view of the plurality of compositions of the resistors mentioned in D2, the claimed corresponding composition of the target was implicitly disclosed. The other features to be selected could be the result of straightforward routine trials to obtain thin film resistors with small TCR whereby, with the same features being used for the claimed method and for the method at which the skilled person would arrive in an obvious way from D2, the same structural features of the produced resistors (amorphous state, metal bandgap

structure) would be automatically obtained.

Besides, from D1, which showed a method of forming by sputtering Cr-Si-N resistors with small TCR wherein an atmosphere with about 5% nitrogen gas was used and was understood as having a key role in the process, the skilled person would be incited to analyse more closely the relation between the nitrogen content and the basic structure of the film. Thus, by normal, routine experimentation, he would arrive in an obvious way at the thin film resistors having the properties mentioned in the present application.

Therefore, the subject-matter of claim 1 did not involve an inventive step.

II. The appellant lodged a notice of appeal against this decision, paid the appeal fee and filed a statement setting out the grounds of appeal.

III. During the oral proceedings before the Board of 12 May 1999, a new set of two claims and a new page 6 of the description were filed. The appellant requested that the decision under appeal be set aside and that a patent be granted on the basis of the following patent application documents:

Claims: Nos 1 and 2 filed during the oral proceedings;

Description: Pages 1 to 3 filed with appellant's letter dated 3 August 1994 (statement of grounds of appeal);
Pages 4, 5, 7 to 11 and 13 to 20 of the

application as originally filed;
Page 6 filed during the oral proceedings;
Page 12 filed with appellant's letter dated 8 April 1999;

Drawings: Sheets 1/20 to 20/20 of the application as originally filed.

Claim 1 of the request is distinguished from claim 1 forming the basis of the impugned decision only in that it specifies that the thermal treatment concerns the thermal history of the thin film resistor after its forming process, and it reads as follows:

"1. A method of producing a semiconductor device having an amorphous thin film resistor which is formed on a substrate, has the same energy band construction as that of metal and comprises chromium, silicon and nitrogen, the amorphous thin film resistor forming process consisting essentially of the steps of preparing a target containing chromium and silicon, wherein the weight percentage of the silicon to the total weight of the chromium and silicon is 41 to 57 weight %, and reactive sputtering said substrate, utilizing said target in an atmosphere of an inert gas containing 1-2% nitrogen gas, wherein a thermal history of said amorphous thin flim resistor applied after said thin film resistor forming process up to the final processing step is at temperatures less than 500°C, to thereby maintain the amorphous condition of said thin film resistor."

Claim 2 is a dependent claim.

IV. The appellant submitted essentially the following arguments in support of his request:

The object of the present invention is to provide a method of producing by sputtering a thin film resistor having a very low TCR. This is obtained by selecting three parameters, i.e. the silicon content (41 to 57% weight of silicon) of the chromium-silicon target, the nitrogen content (1 to 2%) of the inert gas atmosphere, and thermal treatment at a temperature lower than 500°C after the formation of the thin film. The combination of the selected parameters ensures that the structure of the thin film resistor is and remains amorphous, and that it has the bandgap structure of a metal.

Starting from D2, which teaches ranges of the parameters, some being much broader and/or different from those of the present application, there is no incitation for the skilled person to analyse and select said parameters in order to arrive at an amorphous structure wherein the bandgap is that of metal, whereby resistors with small TCR are obtained, as in the presently claimed method.

The method of D1 is not for producing thin film resistors with small TCR (see the examples), but with high resistivity, and, moreover, it uses ranges of the parameters, in particular for the nitrogen (at least 5%) in the inert atmosphere, which are quite different from those of the claimed method (1 to 2%).

Therefore, the skilled person would not arrive in an obvious way at the claimed method, which, therefore, involves an inventive step.

Reasons for the Decision

1. The appeal is admissible.

2. *Admissibility of the amendments*

The present claim 1 concerns a method of producing a semiconductor device having a thin film resistor, and is based on the independent claim 3 of the application as filed. According to the application as filed, the thin film resistor produced by the method steps as set out in claim 3 is amorphous and has the energy band structure as that of a metal (see page 7, lines 29 to 34; page 8, line 20 to page 9, line 30), as stated in claim 1 under consideration.

Claim 2 has been amended to make it clear that the thermal history of the film includes a sintering step, in consistency with the description of the application as filed.

The further amendments in the application as filed mainly concern the adaptation of the latter to the new main claim.

Therefore, the Board is satisfied that the present application complies with the requirement of Article 123(2) EPC that a European patent application may not be amended in such a way that it contains subject-matter which extends beyond the content of the application as filed.

3. *Clarity of the claims*

The Board is satisfied that present claim 1 clearly defines the matter for which protection is sought. Moreover, there are no inconsistencies between the present claims and description concerning the information about the boundary temperature of the thermal history of the method and the extent of said thermal history, including in particular the sintering step of the wirings of the thin film resistor. Therefore, claim 1 is clear in the sense of Article 84 EPC.

4. *Novelty*

A method of producing a semiconductor device having a thin film resistor formed on a substrate is known from document D2, wherein the thin film resistor forming process consists essentially of the steps of preparing a target containing chromium and silicon and reactive sputtering the target in an inert atmosphere containing nitrogen at a partial pressure within the range of 1 to 20% to form the thin film resistor. Subsequently, thermal treatment is applied to the thin film resistor at a temperature between 400 and 1000°C, preferably 400 to 800°C, for example at 525°C (cf. D2, page 4, lines 32 to 36; page 15, line 17 to page 16, line 12).

In the only example of a target composition disclosed in document D2, the silicon content amounts to 73 atomic %, which corresponds to 59 weight % of Si (see page 14, lines 4 to 6). The silicon content thus falls just outside the range of 41 to 57 weight % of Si claimed in present claim 1. Document D2, however, also

specifies compositions of the resistive material produced by the reactive sputtering of the Cr-Si target, wherein the constituent elements Cr, Si and N vary over the rather broad ranges of 5 to atomic 75%, 5 to 85 atomic % and 1 to 60%, respectively. In the preferred narrower ranges of the composition disclosed, Cr is 25 to 29 atomic %, Si is 55 to 67 atomic % and nitrogen is 8 to 16 atomic %.

According to the decision under appeal (see page 7, second paragraph), since there was one to one correspondence between the composition of the resistor and the composition of the target, and since a large number of resistor compositions were disclosed in document D2, a target having silicon content falling within the claimed range of silicon content was implicitly disclosed in the document. In the Board's view, however, there is no disclosure or indication in the document that in the formation of the thin film resistor by reactive sputtering a target the proportion of silicon in relation to chromium in the target necessarily corresponds to that in the resistor. Consequently, a composition of the target falling within the claimed composition of the target cannot unambiguously be derived from the disclosed compositions of the resistors.

Contrary to the method according to the present claim 1, the method of document D2 is not disclosed as producing a thin film resistor which is amorphous or which has the same energy band construction as that of metal. Also, the thermal treatment of the thin film in document D2 is not carried out to maintain the amorphous condition of the thin film resistor, as in

the method according to the invention.

As already stated above, the reactive sputtering of the target is carried out in an atmosphere of an inert gas containing 1 to 20% nitrogen gas, the ranges below 6% nitrogen gas and above 10% partial pressure nitrogen gas resulting in a non-linear dependence of the resistivity with respect to temperature, the value 6% nitrogen gas resulting in resistivity which almost does not vary with temperature (see Figure 3 of document D2; page 16, lines 30 to 33). Thus, the claimed range of 1 to 2% nitrogen gas overlaps the range of 1 to 20% disclosed in document D2.

It is further to be noted that, in the method of document D2, thermal history of the thin film resistor applied after said thin film resistor forming process up to the final processing step is not restricted to temperatures less than 500°C, but rather can be applied at temperatures from 400 to 1000°C, preferably between 400 and 800°C. Thus, the lowest annealing temperature of 400°C is below the upper limit of 500°C claimed in claim 1 of the present application.

In assessing the novelty of the claimed subject-matter in relation to the prior art where there is an overlap of numerical ranges of a parameter between a claim and the prior art, in accordance with the established case law of the Boards of appeal (see T 26/85, OJ 1990, 22; T 666/89, OJ 1993, 495), it has to be considered whether the person skilled in the art would, in the light of the technical facts at his disposal, seriously contemplate applying the technical teaching of the prior art document in the range of overlap.

Applying the above principle in the present case, it needs to be considered whether following the overall teaching of document D2, the skilled person would use nitrogen gas partial pressure in the range of 1 to 2%. As already stated above, according to the teaching of document D2, below 6% partial pressure of nitrogen, and particularly for values near 1% partial pressure, the normalized sheet resistivity exhibits non-linear dependence on temperature. Since document D2 is concerned with providing a resistor with a resistivity which is either constant or varies in a predictable linear manner (see page 17, lines 23 to 28), it is clear that method according to the document is not to be carried out in the overlapping range of 1 to 2% nitrogen resulting in a resistor having non-linear dependency of resistivity on temperature. Thus, in the Board's judgment, the nitrogen partial pressure of 1 to 2% during sputtering is not made available to the public within the meaning of Article 54(2) EPC.

It further follows from the above that a combination of the parameters, i.e., the silicon content of the target and the nitrogen concentration, within the respective ranges as specified in claim 1 is not clearly derivable from document D2.

The subject-matter of claim 1 is thus new pursuant to Article 54(2) EPC.

5. *Inventive step*

5.1 Having regard to the above distinguishing features of the claimed invention in relation to the closest prior art document D2 and the detailed description of the

invention (see paragraphs 5.2 and 5.3 below), the present invention can be regarded as addressing the problem of providing a method of forming a thin film resistor having a low TCR which is substantially constant over a relatively broad range of temperatures.

5.2 From Figure 9 and the corresponding description it follows that by selecting the nitrogen partial pressure in the range of 1 to 2% during the sputtering of a target having a 47% weight % of Si, a thin film resistor having a very low value of TCR which is substantially constant over a relatively large temperature range (-50°C to +150°C) is obtained.

5.3 Figure 12 and the corresponding description discuss the resistance - temperature characteristic of the thin film resistor when both the composition of the target and the nitrogen gas concentration are varied. As shown in the Figure, both the primary coefficient á and the secondary coefficient â are close to zero (whereby the TCR is close to zero) when the silicon weight percent is 41 to 57% and the nitrogen concentration is 1 to 2%.

5.4 In view of the foregoing, in the Board's view, the present invention represents a purposive selection, as against an arbitrary selection, of the target composition and the nitrogen concentration with a view to forming a resistive film having a low TCR which is substantially constant over a relatively broad temperature range, and cannot be regarded as resulting from routine experiments.

It is also to be noted that the invention also provides a method wherein the produced thin film resistor is

amorphous and has the same energy band construction as that of metal, and the amorphous condition of said thin film resistor is maintained. Indeed, taking into account the present application (see in particular Fig. 11 and the corresponding text), concerning in particular the nitrogen gas concentration below 1% nitrogen gas in the inert atmosphere for a specific target, a microcrystalline structure, i.e. a non-amorphous structure is obtained; on the other hand, above 2% of nitrogen gas, a bandgap similar to that of a semiconductor and thus with rapid changes in resistivity with respect to temperature is obtained. These features of the amorphous, metallic-like bandgap structure of the produced thin film resistor, as well as the resulting low TCR of the thin film resistor, are credibly related and are to be achieved by the specific selection of the three above-mentioned parameters, in particular the nitrogen gas content in the inert atmosphere. In this respect, it is to be noted that, as argued by the appellant, the results of measurements provided in Fig. 9 of the present application show that, whereas nitrogen gas contents of 1 to 2% result in small TCR, other values of nitrogen gas content in the inert atmosphere, for instance 0% or 3%, result in much higher values of said TCR.

As convincingly argued by the appellant, in document D2, there is no indication about obtaining an amorphous structure with a bandgap construction as that of metal by selecting the values of the parameters in the ranges as in claim 1 of the present application.

5.5 A method of producing a semiconductor device having a thin film resistor which is formed on a substrate, said

thin film resistor comprising chromium, silicon and nitrogen and having small TCR, is also known from document D1 (see in particular column 1, lines 65 to 69; column 2, lines 4 to 48). However, the values of the content of the nitrogen gas in the inert atmosphere in document D1 (see column 2, lines 22 to 26) are indicated as being approximately 5% nitrogen gas concentration. Argon flow rate and nitrogen gas flow rate of 39.7 sccm and 1.75 sccm, respectively, i.e. more than 4% nitrogen gas, are mentioned for Example 1 of document D1. In all the other Examples of document D1, said ratio is higher and can be about 10%, as for instance in Example 1, where the flow rates for Argon and nitrogen gas are 37 sccm and 3.8 sccm, respectively. Thus, the value of 1.0 sccm for nitrogen gas flow rate, which is stressed in document D1 (see the Figures), is not related to the 1% nitrogen gas of present claim 1, but must be read in relation with the Argon flow rate and corresponds to a ratio of at least about 5% nitrogen gas, i.e. much more than the range of 1 to 2% in present claim 1. Moreover, the method of document D1 is not specifically for producing resistors with small TCR, as in the present application or in document D2, but for producing thin film resistors of high resistivity.

5.6 For the foregoing reasons, in the Board's judgment, the subject-matter of present claim 1 is not obvious to a person skilled in the art, so that it involves an inventive step in the sense of Article 56 EPC.

Consequently, claim 1 is patentable in the sense of Article 52(1) EPC.

Claim 2 depends from claim 1 and concerns a particular embodiment of the method of claim 1. Therefore, it is also patentable.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the Examining Division with the order to grant a patent on the basis of the following patent application documents:

Claims: Nos. 1 and 2 submitted during oral proceedings;

Description: Pages 1 to 3 filed on 3 August 1994;
Pages 4, 5, 7 to 11 and 13 to 20 of the application as filed;
Page 6 submitted during oral proceedings;
Page 12 filed on 8 April 1999;

Drawings: Sheets 1/20 to 20/20 of the application as filed.

The Registrar: The Chairman:

D. Spigarelli R. Shukla