

**Internal distribution code:**

- (A)  Publication in OJ  
(B)  To Chairmen and Members  
(C)  To Chairmen  
(D)  No distribution

**Datasheet for the decision  
of 14 November 2006**

**Case Number:** T 1421/04 - 3.4.03

**Application Number:** 97935820.7

**Publication Number:** 0874399

**IPC:** H01L 23/14

**Language of the proceedings:** EN

**Title of invention:**

Silicon nitride circuit board and semiconductor module

**Applicant:**

KABUSHIKI KAISHA TOSHIBA

**Opponent:**

-

**Headword:**

Rare earth element/TOSHIBA

**Relevant legal provisions:**

EPC Art. 56, 123(2)

**Keyword:**

"Inventive step (no)"

**Decisions cited:**

-

**Catchword:**

-



Case Number: T 1421/04 - 3.4.03

**D E C I S I O N**  
of the Technical Board of Appeal 3.4.03  
of 14 November 2006

**Appellant:**

KABUSHIKI KAISHA TOSHIBA  
72, Horikawa-cho  
Saiwai-ku  
Kawasaki-shi  
Kanagawa-ken 210-8572 (JP)

**Representative:**

Kramer - Barske - Schmidtchen  
European Patent Attorneys  
Patenta  
Radeckestrasse 43  
D-81245 München (DE)

**Decision under appeal:**

Decision of the Examining Division of the  
European Patent Office posted 3 May 2004  
refusing European application No. 97935820.7  
pursuant to Article 97(1) EPC.

**Composition of the Board:**

**Chair:** R. G. O'Connell  
**Members:** G. Eliasson  
J. Van Moer

## Summary of Facts and Submissions

I. This is an appeal against the decision of the examining division refusing European patent application 97 935 820.7 for lack of an inventive step.

II. The following documents, among others, were cited in the decision under appeal:

D1: EP 0 660 397 A;

D5: EP 0 476 971 A;

D6: JP 07 149 588 A and associated computer generated translation in English;

D9a: EP 0 718 886 A.

III. At oral proceedings before the board, the appellant applicant requested that the decision under appeal be set aside and that a patent be granted on the basis of the main request filed 19 March 2004, or in the alternative, on the basis of the first auxiliary request filed 11 October 2006, or on the basis of the second to fifth auxiliary requests filed at the oral proceedings.

IV. Claim 1 of the main request reads as follows:

"1. A semiconductor module, comprising

a high thermal conductive silicon nitride substrate (10) having a thermal conductivity of 60 W/mK [sic] or more,  
a semiconductor element (7) mounted on said high thermal conductive silicon nitride substrate,

metal circuit plates (3) bonded to said high thermal conductive silicon nitride substrate at a side to which the semiconductor element is mounted, and a single metal plate (4a) bonded to said high thermal conductive silicon nitride substrate at a side to which the semiconductor element is not mounted but an apparatus casing or a mounting board is bonded, wherein said semiconductor module is fastened and fixed to said apparatus casing or the mounting board by means of an attaching screw (6a), or said semiconductor module is fixed by being pressed to said apparatus casing or the mounting board, and wherein a fastening force of said attaching screw or a pressing force is applied to said high thermal conductive silicon nitride substrate, and wherein the thickness of said silicon nitride substrate is in the range of 0.25 to 1.2 mm."

V. Claim 1 of auxiliary request I reads as follows (board's emphasis):

"1. A semiconductor module, comprising

a high thermal conductive silicon nitride substrate (10) having a thermal conductivity of 60 W/mK [sic] or more,

**wherein the high thermal conductive silicon nitride substrate contains a rare earth element in an amount of 8 to 17.5% by weight in terms of oxide thereof, and wherein said high thermal conductive silicon nitride substrate is made of a**

**silicon nitride crystal phase and a grain boundary phase, and a ratio of the crystal compound phase in the grain boundary phase is 20% or more based on the whole grain boundary phase,**

a semiconductor element (7) mounted on said high thermal conductive silicon nitride substrate, metal circuit plates (3) bonded to said high thermal conductive silicon nitride substrate at a side to which the semiconductor element is mounted, and

a single metal plate (4a) bonded to said high thermal conductive silicon nitride substrate at a side to which the semiconductor element is not mounted but an apparatus casing or a mounting board is bonded,

wherein said semiconductor module is fastened and fixed to said apparatus casing or the mounting board by means of an attaching screw (6a), or said semiconductor module is fixed by being pressed to said apparatus casing or the mounting board, and

wherein a fastening force of said attaching screw or a pressing force is applied to said high thermal conductive silicon nitride substrate, and

wherein the thickness of said silicon nitride substrate is in the range of 0.25 to **0.8** mm."

- VI. Claim 1 of auxiliary request II differs from that of auxiliary request I in that the amount of the rare earth element in the silicon nitride substrate is **10** to

17.5% by weight in terms of oxide of the rare earth element.

- VII. Claim 1 of auxiliary request III differs from that of auxiliary request I in that the second paragraph reads as follows (board's emphasis):

"wherein the high thermal conductive silicon nitride substrate contains a rare earth element **selected from the group consisting of Ho, Er and Yb** in an amount of 8 to 17.5% by weight in terms of oxide thereof, and wherein said high thermal conductive silicon nitride substrate is made of a silicon nitride crystal phase and a grain boundary phase, and a ratio of the crystal compound phase in the grain boundary phase is 20% or more based on the whole grain boundary phase,"

- VIII. Claim 1 of auxiliary request IV differs from that of auxiliary request III in that the amount of the rare earth element selected from the group consisting of Ho, Er and Yb in the silicon nitride substrate is **10** to 17.5% by weight in terms of oxide of the rare earth element.

- IX. Independent claims 1 to 5 of auxiliary request V differ from claim 1 of auxiliary request I in that the amount of rare earth element in the silicon nitride substrate is specified respectively as 8%, 10%, 12.5%, 15% and 17.5% by weight in terms of oxide of the rare earth element.

- X. The arguments of the appellant applicant can be summarized as follows:

(a) Main request

Document D6 did not disclose how the semiconductor module was mounted. A combination of documents D6 and D9a would not lead to the claimed invention, since in the module disclosed in document D9a, the fastening force of the attaching screws was applied to the housing, and not to the silicon nitride as in the claimed device.

(b) Auxiliary request I

The claimed range of 8 to 17.5 % by weight in terms of the rare earth oxide lay beyond the upper limit of 7.5% by weight disclosed in both of documents D6 and D1. Both these documents explicitly taught that more than 7.5% by weight of rare earth oxide would have a deleterious effect on the thermal and mechanical properties of the silicon nitride substrate. Instead, the recommended range in document D6 and D1 was 3.0 to 6.0 % by weight. In the light of this teaching, the skilled person would not contemplate using an amount of rare earth oxide falling within the claimed range.

(c) Auxiliary request IV

As shown in Table 1 of the application, the range of 10 to 17.5% by weight of oxides of Ho, Er or Yb had the effect of further improving the thermal and mechanical properties of the silicon nitride substrate. Therefore, in addition to solving the problem of improving the heat releasing properties of the semiconductor module, it also solved the problem of further improving the thermal and

mechanical properties of the silicon nitride substrate of the module.

The selected rare earth elements Ho, Er and Yb were not disclosed in document D6 as suitable additives for the silicon nitride substrate (paragraph 0017). Therefore, in order to arrive at the claimed device, the skilled person would not only have to choose an element which was not among the rare earth elements listed in document D6 as being suitable, but also use the chosen element in an amount which was contrary to the explicit teaching of documents D6 and D1.

## **Reasons for the Decision**

1. The appeal is admissible.
2. *Amendments*
- 2.1 *Main request - Amendments*

Claim 1 of the main request corresponds to a combination of claim 1 as originally filed with the features disclosed on page 16, lines 35 to 41 and page 8, line 14 of the application as published relating to the fixing of the semiconductor module to the apparatus casing or mounting board, and the thickness of the silicon nitride substrate, respectively.



## 2.2 *Auxiliary request I - Amendments*

Restricting claim 1 of the main request, claim 1 of auxiliary request I further specifies the features of claim 4 as originally filed (ratio of the crystal compound phase in the grain boundary phase) and that (a) the thickness of the silicon nitride substrate is in the range of 0.25 to 0.8 mm; (b) the silicon nitride substrate contains a rare earth element in an amount of 8 to 17.5% by weight in terms of its oxide. Feature (a) is disclosed on page 8, lines 14 to 15 of the application as published. Feature (b) is based on Samples 1 to 14 and 37 to 51 in Tables 1 and 3 disclosing oxides of Y, Ho, Er, and Yb in the range from 8 to 17.5% by weight.

## 2.3 *Auxiliary requests II and V - Amendments*

Restricting claim 1 of auxiliary request I, claim 1 of auxiliary request II specifies that the amount of the rare earth element in the silicon nitride substrate is in the range of **10** to 17.5% by weight in terms of its oxide.

Independent claims 2, 3, 4, and 5 of auxiliary request V specify that the amount of the rare earth element is 10, 12.5, 15, and 17.5%, respectively, by weight in term of it oxide.

As stated above with respect to auxiliary request I, Tables 1 and 3 of the application disclose various samples containing oxides of Y, Ho, Er, and Yb in the range from 8 to 17.5% by weight. The samples containing yttrium oxide ( $Y_2O_3$ ), however, only contain up to 8% by

weight of yttrium oxide (Tables 2 and 3, samples 15 to 39 and 48). As the prior art (see D1, page 7, lines 1 to 9; D6, paragraphs 0016 and 0017) discloses 7.5% by weight of  $Y_2O_3$  as an upper limit for practical purposes, the skilled person reading the application in the light of the prior art would assume that the invention as disclosed would not work when adding more than 8% by weight of  $Y_2O_3$ .

Therefore, the application as filed does not disclose a silicon nitride substrate containing yttrium oxide in the range of 10 to 17.5% by weight.

For the above reasons, claim 1 of auxiliary request II and claims 2 to 5 of auxiliary request V have been amended in such a way that they contain subject matter which extends beyond the content of the application as filed.

Therefore, auxiliary requests II and V do not comply with the requirements of Article 123(2) EPC.

#### 2.4 *Auxiliary requests III and IV - Amendments*

Restricting auxiliary request I, claim 1 of auxiliary request III specifies the rare earth element to be one of Ho, Er, and Yb. Similarly, claim 1 of auxiliary request IV contains the same restriction to Ho, Er and Yb together with the restricted range of 10 to 17.5% by weight in terms of the rare earth oxide. These amendments are supported by Samples 1 to 14, 40 to 48, 50 and 51 of Tables 1 and 3 of the application as published.

3. *Prior art*

3.1 Document D6 was considered closest prior art in the decision under appeal and discloses a semiconductor module 13 comprising a silicon nitride substrate 1a having a thermal conductivity of more than 60 W/m·K (see Figures 4 and 5; paragraphs 0026, 0047, 0048, 0052). A semiconductor element (power transistor) 11 is mounted on the silicon nitride substrate. Metal circuit plates 9 made of Cu are directly bonded (DBC) to the silicon nitride substrate 1a at the side where the semiconductor element 11 is mounted, and a single metal plate 10 made of Cu is directly bonded (DBC) to the opposite side of the silicon nitride substrate 1a where an apparatus casing or a mounting board may be bonded (paragraph 0052). The thickness of the silicon nitride substrate in one of the examples is 0.8 mm (paragraphs 0047 and 0052).

In the semiconductor module of document D6, the silicon nitride substrate contains a rare earth element in an amount of 2.0 to 7.5 % by weight in terms of its oxide for the purpose of aiding the sintering process (see abstract, paragraphs 0016 and 0017). Among possible rare earth elements Y, La, Sc, Pr, Ce, Nd, Dy and Gd are mentioned. Yttrium (Y) is disclosed as the preferred element and is the one used in the disclosed examples (paragraphs 0016, 0017, 0033, 0038, and 0047). It is furthermore mentioned that when the amount of rare earth oxide exceeds 7.5 % by weight, the grain boundary phase would be produced in an excessive amount, causing a reduction in the thermal conductivity and mechanical strength. The recommended range is between 3 and 6 % by weight (paragraph 0017).

It is furthermore disclosed in document D6 that the silicon nitride substrate contains a mixture of a crystal phase and a grain boundary phase and that 20% or more of the grain boundary phase is made up by the crystal phase (paragraph 0020).

- 3.2 Document D1 discloses a silicon nitride substrate containing a rare earth element such as Y, La, Sc, Pr, Ce, Nd, Dy, Ho, Gd "etc." in the range of 1.0 to 7.5% by weight in terms of its oxide, where Y is the preferred element. The silicon nitride substrate has a thermal conductivity of more than 60 W/m·K and contains a mixture of a crystal phase and a grain boundary phase where 20% or more of the grain boundary phase is made up by the crystal phase (abstract). As in document D6, it is furthermore mentioned that when the amount of rare earth oxide exceeds 7.5 % by weight, the grain boundary phase would be produced in an excessive amount, causing a reduction in the thermal conductivity and mechanical strength. The recommended range is between 3 and 6 % by weight (see page 6, line 57 to page 7, line 9).

Ce, Nd, Dy, and Yb were substituted for Y in Examples 13 to 16 which was used in the other Examples 1 to 12 (see Table 3). These samples were measured under "the same conditions as in Example 1" except for substituting the rare earth oxides (page 15, lines 1 to 9). The amount of  $Y_2O_3$  in Example 1 was 5% by weight (page 10, lines 54 to 58). Although Yb was not mentioned in the list of suitable rare earth elements listed in the sentence bridging pages 6 and 7, sample 15 containing  $Yb_2O_3$  instead of  $Y_2O_3$  had the highest

thermal conductivity and three-point bending strength of all the samples disclosed in document D1 (see Table 3).

The silicon nitride substrate of document D1 can be used in a semiconductor module where a semiconductor element 2 is bonded to the silicon nitride substrate 1 and lead frames 5 are joined to the substrate (Figures 1 to 5; Examples 17 to 19).

3.3 Document D5 discloses a silicon nitride substrate 1 to be used in a semiconductor module and contains a rare earth element as sintering additive (see abstract; Figures 1 to 5; page 7, lines 3 to 5; Table 1). In the examples presented in Table 1, the silicon substrates comprise  $Y_2O_3$  or  $Yb_2O_3$  or mixtures thereof in a total amount of 4.8 to 5.0 mol %.

3.4 Document D9a discloses a semiconductor module having a substrate 11 on which a semiconductor element 12 is mounted. The module is fixed to an apparatus casing or a mounting board by attaching screws through screw holes 4 of the module. Contrary to the appellant applicant's argument (see item X(a) above), the fastening force of the attaching screws is applied to the substrate, as the lower surface of the latter protrudes beyond the lower surface of the module (Figure 2; column 5, lines 30 to 36).

#### 4. *Inventive step - Main request*

4.1 Document D6 is considered to be the closest prior art as it has more structural features in common with the

claimed devices than is the case for documents D1 and D5.

The subject matter of claim 1 of the main request differs from the device of document D6 only in that (i) the module is fastened and fixed to the apparatus casing or a mounting board by means of an attaching screw, or it is fixed by pressing thereto. Document D6 on the other hand does not disclose how the module may be fastened and fixed.

4.2 The skilled person faced with the technical problem (I) of fastening the semiconductor module of document D6 to an apparatus casing or a mounting board would as a routine measure consider the use of one or more screws to be one obvious alternative means for fastening the module. Such an arrangement is also known from document D9a (see Figures 1, 2 and 4 with accompanying description).

4.3 For the above reasons, in the board's judgement, the subject matter of claim 1 of the main request does not involve an inventive step within the meaning of Article 56 EPC.

5. *Inventive step - Auxiliary request IV*

5.1 The subject matter of claim 1 of auxiliary request IV differs from the device of document D6 in that in addition to feature (i) referred to under item 4.1 above, that (ii) the silicon nitride substrate contains one of the rare earth elements Ho, Er, Yb; and (iii) the amount of the elements Ho, Er, Yb is 10 to 17.5% by weight in terms of its oxide. Document D6 discloses an

amount of 2.0 to 7.5% by weight in terms of its oxide and Y is used in all the examples.

5.2 According to the appellant applicant, in addition to solving problem (I) (see item 4.2 above), the claimed device solves the technical problem (II) of further increasing the thermal conductivity and bending strength of the substrate (see application as published, page 5, lines 52 to 56). It appeared from the Tables 1 and 3 of the application that a high percentage of rare earth oxides of Ho, Er and Yb had particularly advantageous properties (see item X(c) above).

5.2.1 The board does not agree with the appellant applicant as to the formulation of problem (II). Table 2 of the application shows samples 15 to 36 all having between 5 and 7.5 % in weight of yttrium oxide. Comparing the thermal conductivity and three-point bending strength of these samples with those of Table 1 and 3 which fall within the scope of claim 1 of auxiliary request IV, the board is not persuaded that the samples falling within the invention as claimed would have markedly better properties than those containing yttrium oxide. The board agrees with the appellant applicant that for samples containing holmium oxide ( $\text{Ho}_2\text{O}_3$ ), Table 1 shows that the optimum properties can be found when the samples contain at least 10% by weight. These optimum samples, however, do not have distinctly better properties than those containing 5% by weight of yttrium oxide.

5.3 It follows from the above that the technical problems with respect to features (ii) and (iii) relate to (II) finding an alternative rare earth element to yttrium;

- and (III) determining the optimum amount for the chosen rare earth element.
- 5.4 The technical problem (I) on one hand and problems (II) and (III) on the other are mutually independent thus allowing problem (I) to be treated separately from problems (II) and (III) in the assessment of inventive step (see "Case Law, 4th Edition", Chapter I.D.6.4.2).
- 5.5 As stated under item 4.2 above, the skilled person would consider the use of one or more screws to be one obvious alternative for fastening the module (problem (I)).
- 5.6 As to the solution to problem (II), it is to be noted that the none of elements Ho, Er and Yb specified in claim 1 of auxiliary request IV is disclosed in document D6 (see item X(c) above).
- 5.7 Both documents D1 and D5 disclose the use of  $\text{Yb}_2\text{O}_3$  as sintering aid in silicon nitride substrates which are intended to be used in semiconductor modules (see D1; Table 3; D5, Table 1). Since the thermal and mechanical properties of these substrates are at least as good as those using  $\text{Y}_2\text{O}_3$ , the board finds that the skilled person would consider Yb as an alternative to Y in the device of document D6.

Document D6 does not mention Yb as a suitable candidate for use as a sintering aid in silicon nitride: only Y was used in the examples of document D6. Therefore, the skilled person seeking an alternative to Y would in this respect attach more weight to the teachings of



documents D1 and D5, since they show experimental results of rare earth elements other than Y, such as Yb.

5.8 Having decided to substitute  $Y_2O_3$  by  $Yb_2O_3$  in the device of document D6, the skilled person is faced with problem (III) of finding the optimal amount of  $Yb_2O_3$  in the silicon nitride substrate.

5.9 Although document D6 contains a very explicit teaching against going beyond 7.5 % by weight (see paragraph 0017), the skilled person would nevertheless take note of the fact that only  $Y_2O_3$  was used in the examples disclosed in document D6.

Document D1 discloses the same upper limit as document D6. For the samples where Y was substituted by Ce, Nd, Yb, and Dy, it is stated at page 15 that they were measured under "the same conditions" as in Example 1 which had 5% by weight of  $Y_2O_3$ . This statement however leaves it open whether or not "same conditions" should refer to the proportion of rare earth oxides.

5.10 The only prior art document which provides an unambiguous disclosure about the content of  $Yb_2O_3$  is document D5: The molar percentage (4.8 mol %) of rare earth oxide was kept constant when  $Y_2O_3$  was substituted for  $Yb_2O_3$  (see Table 1).

As presented by the appellant applicant's representative at the oral proceedings, the value disclosed in Table 1 of document D5, 4.8 mol % of  $Y_2O_3$  having a molecular weight of 225.8, corresponds to 7.5% by weight of oxide which is the same as the upper limit disclosed in document D6 (and D1).

The same amount of Yb atoms (4.8 mol %  $\text{Yb}_2\text{O}_3$  having a molecular weight of 394.1 as in sample 14 in Table 1 of document D5) translates to 12.4% by weight in terms of  $\text{Yb}_2\text{O}_3$ , a value which falls within the claimed range, but above the upper limit of 7.5 % by weight disclosed in documents D1 and D6.

5.11 Faced with the question which teaching to follow, the skilled person taking into account that the rare earth oxide is introduced as a sintering aid, and that the rare earth elements are known to be chemically almost indistinguishable, would realise that the relevant parameter for this process ought to be the proportion of rare earth metal *atoms* in the silicon nitride substrate and not the proportion of rare earth oxides *by weight*. The different rare earth elements would be expected to have about the same effect in aiding the sintering process in silicon nitride in view of their almost identical chemical properties, and therefore, the concentration of rare earth atoms in the silicon nitride compound would have to be the relevant parameter. In other words, the unit "% by weight" used in document D6 (and D1), although practically useful in a recipe for producing a given compound, is only meaningful when it is indicated for which elements the stated amount is valid. When the atomic weights vary greatly, as in the present case where the atomic weight of Yb is much higher (173.0) than that of Y (88.9), the skilled person would see the need for "rescaling" the range disclosed in document D6.

5.12 Since document D5 is the only document which provides an unambiguous disclosure regarding the content of  $\text{Yb}_2\text{O}_3$

in a silicon nitride substrate, the skilled person would in the light of the above discussion choose to use the values from document D5 as a starting point for finding an optimum amount of  $\text{Yb}_2\text{O}_3$  rather than using the values disclosed in documents D6 and D1. As shown under point 5.10 above, the value disclosed in document D5 falls within the claimed range.

5.13 Therefore, contrary to the appellant applicant's arguments, the skilled person would not only select one of the elements Ho, Er, Yb specified in claim 1, but would also arrive without employing inventive skills at an amount of the rare earth oxide falling within the claimed range (see item X(c) above).

5.14 For the above reasons, in the board's judgement, the subject matter of claim 1 of auxiliary request IV does not involve an inventive step within the meaning of Article 56 EPC.

6. *Inventive step auxiliary requests I and III*

As claim 1 of each of auxiliary requests I and III subsumes claim 1 of auxiliary request IV, the above finding of lack of an inventive step within the meaning of Article 56 EPC applies *a fortiori* to auxiliary requests I and III.

**Order**

**For these reasons it is decided that:**

The appeal is dismissed.

Registrar

Chair

S. Sánchez Chiquero

R. G. O'Connell