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D E C I S I O N
of 5 February 2003

Case Number: T 0785/99 - 3.4.3

Application Number: 95100707.9

Publication Number: 0727818

IPC: H01L 23/16

Language of the proceedings: EN

Title of invention:
Zirconia-added alumina substrate with direct bonding of copper

Applicant:
FUJI ELECTRIC CO., et al

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 56

Keyword:
"Inventive step (yes - after amendments)"

Decisions cited:
-

Catchword:
Under the present circumstances, it is not obvious to recognise that a material property (here mechanical strength), which in itself is not directly related to the problem to be solved (improving thermal conductance), may lead to its solution.

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Beschwerdekammern | Boards of Appeal | Chambres de recours

Case Number: T 0785/99 - 3.4.3

D E C I S I O N
of the Technical Board of Appeal 3.4.3
of 5 February 2003

Appellant: FUJI ELECTRIC CO., LTD.
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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 8 March 1999 refusing European patent application No. 95 100 707.9 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: G. L. Eliasson
Members: V. L. P. Frank
M. J. Vogel

Summary of Facts and Submissions

I. European patent application No. 95 100 707.9 was refused by the decision of the Examining Division of 8 March 1999. The ground for refusal was that the application did not meet the requirement of inventive step having regard *inter alia* to the prior art documents

D1: US-A-3 994 430;

and

D4: US-A-4 316 964.

II. The appellant (applicant) lodged an appeal on 17 May 1999, paying the appeal fee the same day. The statement setting out the grounds of appeal was filed on 16 July 1999.

III. At the oral proceedings before the Board held on 5 February 2002 the appellant submitted amended claims 1 and 2 and amended pages of the description.

IV. The appellant requests that the decision under appeal be set aside and a patent be granted on the basis of the following patent application documents:

Claims: 1 and 2, filed during the oral proceedings,

Description: columns 1 and 2, filed during the oral proceedings,
columns 3 to 5, as published,

Drawings: Figures 1 to 3, as published.

The wording of the only independent claim is as follows (emphasis added by the Board to show the amendments introduced in the course of the appeal proceedings with respect to the independent claim 2 on which the decision of the Examining Division was based):

"1. A substrate for a semiconductor device, comprising a ceramic substrate consisting of 70-90 wt% alumina and 10-30 wt% zirconia, wherein said zirconia is partially stabilised by dispersing at least one of yttria, calcia, magnesia and ceria; and further comprising a copper plate directly bonded to the ceramic substrate, **wherein said substrate has a thickness of from 0.05 to 0.32 mm.**"

V. In the decision under appeal the Examining Division essentially argued as follows:

From document D1 a substrate for a semiconductor is known which comprises an alumina substrate and a copper plate directly bonded to the substrate. The subject-matter of the claims differs from this prior art in that zirconia is added in an amount of 10 to 30 wt% to the alumina of the substrate and that the zirconia is totally or partially stabilised by yttria, calcia, magnesia or ceria.

The objective problem, therefore, was defined as the desire to increase the mechanical strength of an alumina based substrate and to facilitate its sintering.

From document D4 it was known, however, that the fracture toughness and strength of an alumina based ceramic to be used for electrical insulation was increased by the addition of zirconia (in an amount of 5 to 95 vol%) stabilised with yttria or ceria.

No exercise of inventive skill would have been required for the skilled person to make use of developments for alumina ceramic compositions as documented *inter alia* by document D4 when looking for improved mechanical strength and sintering properties of an alumina based substrate as was known from document D1. Even if the skilled person is not regarded as being an expert having detailed knowledge about ceramic materials, he would at least have been bound to contact such an expert when designing ceramic substrates for semiconductor devices. Therefore, he would have been informed about the progress made in the field of ceramics.

VI. The appellant argued essentially as follows in support of his request:

It is the object of the invention to improve the radiation performance of an alumina based ceramic semiconductor substrate. The sole prior art document relating to this particular art is document D1. All the other prior art documents cited by the Examining Division are scientific reports on results of ceramic related scientific work. However, they do not comprise any hint towards the incorporation of particular zirconia modifications into a semiconductor substrate. The inventors could therefore not rely upon these documents to find out the particular zirconia modifications which would solve the posed problem.

A power semiconductor imposes a heavy thermal stress on the substrate which is subjected to repeated thermal expansion and contraction. Cracks may occur in the ceramic substrate, due to the different thermal expansion coefficients of copper and alumina. The use of zirconia doped alumina allows the substrate to be thinner than in the case of alumina, since the former material has a higher mechanical strength than the latter. As the thermal conductivity of both ceramic materials is similar, a larger amount of heat generated by the power semiconductor device can be conducted away through the thinner substrate.

However, a skilled person would not have considered the replacement of the alumina ceramic employed in the semiconductor substrate disclosed in document D1 by zirconia doped alumina, since document D4 does not disclose the thermal properties of this compound, but merely discloses its mechanical properties.

Reasons for the Decision

1. The appeal is admissible.

2. *Amendments*

In the decision under appeal, there were no objections raised against the claims under Article 123(2) EPC, and the Board is also satisfied that the claims as amended during the examination proceedings complied with Article 123(2) EPC.

In the course of the appeal proceedings the independent claim has been amended to specify that the thickness of the substrate is from 0.05 to 0.32 mm. This thickness range is *inter alia* disclosed in column 5, lines 19 to 20 of the published application.

The Board is, therefore, satisfied that the requirements of Article 123(2) EPC are fulfilled.

3. *Inventive step*

The only remaining issue is that of inventive step.

3.1 The application in suit relates to a substrate for a semiconductor device consisting of a layer of a ceramic material onto which a copper plate is directly bonded (ie. a DBOC substrate). The ceramic material of the claimed device is made of alumina to which stabilised zirconia is added in an amount of 10 to 30 wt% , in contrast to a conventional DBOC substrate which is made of pure alumina. This kind of substrate is used eg. for power semiconductor devices which generate a large amount of heat that has to be removed in order to maintain the operating temperature of the device below a predetermined value. The heat conductance of the substrate is thus an important factor for determining the current capacity of the power semiconductor device (cf. column 1, lines 38 to 50 of the published application).

The heat conductance is proportional to the thermal conductivity of the material and inversely proportional to the length of the heat conduction path. In the present case of a planar substrate, this path is the thickness of the substrate. The heat conductance can,

therefore, be enhanced by employing a material having a higher thermal conductivity and/or by reducing the thickness of the substrate.

3.2 It is not in dispute that document D1 represents the closest state of the art. This document discloses a method for bonding metals to substrates by using a bonding agent which forms an eutectic alloy with the metal. In particular, a semiconductor circuit board assembly consisting of a copper plate directly bonded to an alumina ceramic substrate is disclosed (cf. Abstract; Figures 13 to 15; column 5, lines 24 to 28; column 13, line 32 to column 14, line 4).

3.3 The substrate according to claim 1 differs from that of document D1 in that:

(i) the ceramic material consists of 70 to 90 wt% alumina and 10 to 30 wt% zirconia;

(ii) the zirconia is partially stabilised by dispersing at least one of yttria, calcia, magnesia or ceria; and

(iii) the substrate's thickness is from 0.05 to 0.32 mm.

3.4 The Examining Division, considering the differences (i) and (ii) mentioned above, saw the objective problem solved by the invention as the desire to increase the mechanical strength of an alumina based substrate and to facilitate its sintering, since the addition of zirconia to alumina increases the mechanical strength of the ceramic material and the stabilization of zirconia by yttria, calcia, magnesia or ceria,

facilitates its sintering (cf. column 2, lines 44 to 49 and line 57 to column 3, line 1 of the published application).

3.5 Claim 1 as amended, however, further specifies that the ceramic substrate has a thickness between 0.05 and 0.32 mm (cf. feature (iii)). According to the application in suit, it is not possible to reduce the thickness of a DBOC substrate made of pure alumina to within the claimed range, since the substrate would crack under the thermal stress due to thermal expansion mismatch between copper and alumina (cf. column 2, lines 4 to 16). The increased mechanical strength of Zirconia Doped Alumina (ZDA) over pure alumina, however, makes it possible to use a thinner ceramic substrate than that in the device of document D1. Since ZDA of the claimed composition furthermore has about the same thermal conductivity as pure alumina, the ceramic substrate of the claimed device has a higher thermal conductance than that of the device of document D1 (cf. application as published, column 5, lines 4 to 11; Figure 3).

In view of the above considerations, the objective technical problem addressed by the application in suit thus relates to improving the thermal conductance of the alumina-based DBOC substrate known from document D1.

3.6 Document D4 discloses that the fracture toughness and strength of an alumina/zirconia ceramic is increased by incorporating metastable grains of tetragonal ZrO_2 in the structure. During cracking the metastable tetragonal ZrO_2 transforms to a stable monoclinic structure thus increasing the energy required for the

crack to propagate and retarding its growth. The ZrO_2 occupies from 5 to 95 vol% of the ceramic and has dissolved in it a rare earth oxide such as yttria or ceria to promote retention of the metastable tetragonal ZrO_2 (cf. Abstract). Document D4, however, does not contain any information about the thermal properties of the compound ceramics.

3.7 The Board concurs with the appellant in that a person skilled in the art, even after having consulted an expert in the field of ceramic materials, would not have regarded the ceramic material disclosed in document D4 as a possible solution to the problem of improving the thermal conductance of a DBOC substrate, since, as shown in Figure 3 of the application in suit, the thermal conductivity of the ZDA ceramic is the same as the one of pure alumina up to a content of about 25 wt% of zirconia. For this reason, the replacement of pure alumina by the ZDA would on its own not lead to an improvement of the thermal conductance of the DBOC substrate.

The problem of improving the thermal conductance of the DBOC substrate is only solved when the skilled person recognizes that the increased mechanical strength of the ZDA ceramic allows for the reduction of the ceramic layer's thickness. Under the present circumstances, the Board considers that it is not obvious to recognize that a material property, which in itself is not directly related to the problem, may lead to its solution.

3.8 It is furthermore noteworthy that document D1, disclosing DBOC substrates, dates from November 1976 and that document D4, disclosing ZDA ceramics, was

published in February 1982. The filing date of the application in suit, however, is January 1995.

Thus, nearly thirteen years lie between the date when the ZDA ceramics were disclosed and the date when the present inventors considered their use in a DBOC substrate. In the Board's view, this fact further supports the finding of the presence of an inventive step.

3.9 For these reasons, it is the judgement of the Board, that claim 1 involves an inventive step within the meaning of Articles 56 EPC.

The dependent claim 2 concerns a further particular embodiment of the invention which is patentable for the same reasons.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the first instance with the order to grant a patent according to the appellant's request.

The Registrar: The Chairman:

M. Zawadzka G. L. Eliasson