Case Number: T 0253/99 - 3.4.2

D E C I S I O N of 14 March 2002
correcting error in the decision
of the Technical Board of Appeal 3.4.2
of 31 January 2002

Appellant: (Opponent)
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Decision under appeal: **Decision of the Opposition Division of the European Patent Office posted 15 January 1999 rejecting the opposition filed against European patent No. 0 509 215 pursuant to Article 102(2) EPC.**

Composition of the Board:

Chairman: E. Turrini
Members: M. P. Stock
V. Di Cerbo

In application of Rule 89 EPC the page 14 of the Decision in the case T 0253/99 - 3.4.2 is corrected by inserting of "containing alloys are more critical with" after the word "Ge" in the last line of the page.

The Registrar: The Chairman

P. Martorana E. Turrini

Internal distribution code:
(A) [ ] Publication in OJ
(B) [ ] To Chairmen and Members
(C) [X] To Chairmen
(D) [ ] No distribution

D E C I S I O N
of 31 January 2002

Case Number: T 0253/99 - 3.4.2

Application Number: 92102977.3

Publication Number: 0509215

IPC: H01L 31/075, H01L 31/20

Language of the proceedings: EN

Title of invention:
Multi-layered photovoltaic element having at least three unit cells

Patentee:
CANON KABUSHIKI KAISHA

Opponent:
RWE Solar GmbH

Headword:
-

Relevant legal provisions:
EPC Art. 56

Keyword:
"Inventive step (no)"

Decisions cited:
-

Catchword:
-

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D E C I S I O N
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of 31 January 2002

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Representative:	Berngruber, Otto, Dr. Dipl.-Chem. Patentanwälte Haft, von Puttkamer Berngruber, Czybulka Franziskanerstrasse 38 D-81669 München (DE)
Respondent: (Proprietor of the patent)	CANON KABUSHIKI KAISHA 30-2, 3-chome, Shimomaruko Ohta-ku Tokyo (JP)
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Decision under appeal:	**Decision of the Opposition Division of the European Patent Office posted 15 January 1999 rejecting the opposition filed against European patent No. 0 509 215 pursuant to Article 102(2) EPC.**

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Summary of Facts and Submissions

I. The appellant (opponent) lodged an appeal against the decision of the opposition division rejecting the opposition against the European patent number 0 509 215 (application number 92 102 977.3).

II. Opposition was filed against the patent as a whole and based on the ground that the subject-matter of the patent is not patentable within the terms of Articles 52 to 57, in particular Article 56 EPC.

The opposition division considered the subject-matter of the single claim of the patent as granted to be new and involve an inventive step with regard to the disclosure of the documents cited.

III. In the written statement setting out the grounds of appeal the appellant mentioned insufficiency of disclosure as a new ground for opposition (Article 100(b) EPC). In his letter of reply the respondent indicated that he did not agree to the introduction of this new ground for opposition (G 10/91). In an annex to the summons to the oral proceedings the board stated that this new ground for opposition per se would not be discussed, unless the patent were to be amended.

IV. Oral proceedings before the board took place on 31 January 2002 in the presence of the appellant and the respondent. In the oral proceedings reference was made to the following documents:

D1: EP 0 304 145 A2

D2: Proceedings of the 19th IEEE PVSC, 1987, pages 749-755

D3: Proceedings of the 20th IEEE PVSC, 1988, pages 241-246

D4: Proceedings of the 9th E. C. PVSEC, 1989, pages 271-274.

D5: PATENT ABSTRACTS OF JAPAN vol. 11, No. 286 (E-541)[2733], 16 September 1987 & JP-A-62-084571

D6: IEEE TRANSACTIONS ON ELECTRON DEVICES, vol. 36, No. 12, December 1989, pages 2775-2780

D6a: Proceedings of the 20th IEEE PVSC, 1988, pages 139-142

D7: THIN SOLID FILMS, vol. 119, No. 1, September 1984, pages 31-54

D8: Proceedings of the 20th IEEE PVSC, 1988, pages 79-84

At the end of the oral proceedings the decision of the board was given.

V. The appellant requested setting aside of the decision and revocation of the patent in its entirety.

The respondent (patent proprietor) requested that the appeal be dismissed and the patent be maintained as granted (main request), auxiliarily that the decision under appeal be set aside and the patent be maintained on the basis of the auxiliary request filed with letter dated 23 October 1998.

The wording of the single claim of the respondent's main request reads as follows:

"1. A multi-layered photovoltaic device comprising:

a substrate having a surface pattern which has a maximum height falling within a range of 50 nm to 500 nm to cause irregular reflection at said surface;

a first photovoltaic cell on said surface of said substrate having an i-type semiconductor layer having a band gap falling within a range of 1.3 eV to 1.45 eV and a thickness falling within a range of 100 nm to 300 nm;

a second photovoltaic cell on said first photovoltaic cell including an i-type semiconductor layer having a band gap falling within a range of 1.45 eV to 1.6 eV and a thickness smaller than that of said i-type semiconductor layer of said first photovoltaic cell, said i-type semiconductor layer consisting essentially of a silicon germanium amorphous material;

a third photovoltaic cell on said second photovoltaic cell including an i-type semiconductor layer having a band gap falling within a range of 1.6 eV to 2.2 eV and a thickness smaller than that of said i-type semiconductor layer of said second photovoltaic cell, said thickness falling within a range of 50 nm - 200 nm; and

a transparent electrode on said third photovoltaic cell providing a light incident surface."

The claim according to the auxiliary request reads as follows:

"1. A multi-layered photovoltaic device comprising:

a substrate having a surface pattern which has a maximum height falling within a range of 50 nm to 500 nm to cause irregular reflection at said surface;

a first photovoltaic cell on said surface of said substrate having an i-type semiconductor layer consisting essentially of silicon germanium amorphous material and having a band gap falling within a range of 1.3 eV to 1.45 eV and a thickness falling within a range of 100 nm to 300 nm;

a second photovoltaic cell on said first photovoltaic cell including an i-type semiconductor layer consisting essentially of a silicon germanium amorphous material and having a band gap falling within a range of 1.45 eV to 1.6 eV and a thickness smaller than that of said i-type semiconductor layer of said first photovoltaic cell, said second photovoltaic cell having a carbon concentration of 1×10^{19} atoms /cm^3 or less, a nitrogen concentration of 1×10^{19} atoms/cm^3 or less, an oxygen concentration of 5×10^{19} atoms/cm^3 or less, a phosphorus concentration of 1×10^{19} atoms/cm^3 or less, and a boron concentration of 2×10^{17} atoms/cm^3 or less;

a third photovoltaic cell on said second photovoltaic cell including an i-type semiconductor layer consisting essentially of silicon amorphous material and having a band gap falling within a range of 1.6 eV to 2.2 eV and a thickness smaller than that of said i-type semiconductor layer of said second photovoltaic cell, said thickness falling within a range of 50 nm - 200 nm; and

a transparent electrode on said third photovoltaic cell providing a light incident surface."

VI. In the oral proceedings the appellant did not pursue the ground for opposition under Article 100(b) EPC mentioned in the appeal, but put forward arguments with respect to the ground of lack of an inventive step under Article 100(a) EPC. These arguments can be summarised as follows:

D5 and D7 disclose triple cell photovoltaic devices whose bottom cells have bandgaps (1.1 and 1.0 eV, respectively) which are lower than the range 1.3 to 1.45 eV defined in claim 1 of the contested patent. The thickness of the bottom layer (500 nm) indicated in D5 is larger than that according to claim 1 (100 to 300 nm).

The problem to be solved by the patent concerns increased efficiency and stability. D5 proposes an amorphous Ge material (a-Ge) for the bottom cell which is, however, not suitable for practical use for the reasons indicated in D1, page 4, lines 40 to 44, and D4, page 272, left-hand column, third paragraph, and Figure 3. However, according to D4, page 272, left-hand column, first paragraph, for the absorption of long-wavelength photons a bandgap below 1.5 eV is desirable. This is also mentioned in D2, page 749, left-hand column, last sentence. It can be derived from D7, page 46, Figure 12(c) that efficiency optimisation in a triple cell as shown in Figure 12(a), would yield a bandgap E_{g3} of the bottom cell falling in a range of 1.2 to 1.4 eV, if the bandgap E_{g2} of the middle cell were chosen to be 1.6 eV in accordance with D5. However, this range overlaps the claimed range of 1.3 to 1.45 eV. Moreover, D6 discussing various reports on triple cells makes reference (see page 2776, right-hand column, last paragraph) to D6a indicating (see page 142, left-hand column, first paragraph and Figure 7 at page 141) that an a-SiGe material having a bandgap of 1.3 eV and a thickness of 100 nm increases the efficiency of triple cells.

Since the contested patent does not exclude profiled bandgaps, D8 would also be relevant, disclosing (see page 83, left-hand column, second sentence) 1.45 eV as the minimum for a graded band gap in the bottom cell. This corresponds to a value of 1.43 eV, which can be obtained from the longer wavelength edge of an efficiency curve for a triple cell shown in Figure 7 of D3 also using a graded bandgap in the bottom cell (see Annex B of the written statement setting out the grounds of appeal). It is the minimum energy of the bandgap which is important for the absorption of a maximum wavelength. Profiling only allows further optimisation.

As to the selection of the thicknesses of the cells, reference is made to D6 generally teaching (see page 2778, left-hand column, penultimate paragraph) that thin i-layers in stacked junction cells improve stability. The relative thicknesses of the layers are obtained by fulfilling the condition of current matching in the cells, see D4, page 273, left-hand column, last paragraph.

The surface pattern of the substrate, as defined in claim 1 of the contested patent, causes longer light paths due to irregular reflection, as is explained in the patent specification, page 5, lines 4 to 7. However, this effect is described in D3 (see page 241, right-hand column, first paragraph), in D1 (see page 8, lines 28 to 34) and in particular in D7 (see page 40, first paragraph in connection with Figure 8(a) at page 41) where it is indicated that the texturing should have characteristic dimensions in the order of the wavelength of visible light within the semiconductor, which falls within the claimed range. The conclusion was drawn that D5, D7 and D6 lead to the triple cell claimed.

The appellant made reference to the preliminary opinion of the board annexed to the summons to the oral proceedings, and confirmed that the i-layer (104) of all experiments and examples described in the contested patent (see page 9, lines 40 to 43; page 10, line 43 and page 11, line 1) has a bandgap of 1.53 eV lying outside the claimed range. Figure 9 neither hints towards the claimed range of the bottom cell because the conclusion drawn therefrom is again related to the bandgap of the middle cell, on which the emphasis is put in the patent, see page 10, lines 16 and 17.

Claim 1 according to the auxiliary request specifies upper limits of the concentration for the impurities C, O, N, P and B in the middle cell. It is general knowledge of the skilled person that impurity concentrations should be low. D6, see page 2778, left-hand column, second paragraph, mentions upper limits of 10^{20} cm^{-3} of concentrations of impurities such as C and O. It is evident that impurities which are used as dopants, such as N, P and B must be very low.

VII. The arguments of the respondent can be summarised as follows:

If D7 is taken as the closet prior art, there are five differences between the subject-matter of claim 1 and what is disclosed in D7:

1. Texturing disclosed in D7 is different from what is meant by the invention, see patent, page 7, line 48 to 55.

2. The bottom cell in D7 has a bandgap of 1.0 eV which is below the claimed range of 1.3 to 1.45 eV.

3. D7 does not specify the thickness of the i-layer in the bottom cell.

4. It cannot be derived from D7, page 43, last paragraph, with certainty that SiGe is the low bandgap material proposed for the middle cell.

5. D7 does not specify the thickness of the i-layer in the top cell.

Moreover, it is derived from Figure 12(c) at page 46 of D7, that for the proposed bandgap E_{g3} = 1.0 eV of the bottom cell the highest efficiency is achieved for a bandgap E_{g2} of the middle cell between 1.3 and 1.4 eV which is considerably lower than the claimed range of 1.45 to 1.6 eV.

The patent addresses the problem of high stability at high efficiency. Therefore only documents being concerned with this problem are relevant. For instance, in D8, see page 81, right-hand column, last paragraph, improved stability is obtained by profiling, i.e. using graded bandgaps in the bottom cell. However, the average of the graded bandgap of the bottom cell is above 1.45 eV specified as upper limit in the contested claim 1. The same holds for D6 disclosing a graded bandgap at page 2776, right-hand column, lines 5 to 7. If the bandgap range in claim 1 of the bottom cell were meant to define the width of profiling, then this range would also not be anticipated by the prior art.

Texturing of the substrate is mentioned in D3, D7 and D1. However, figures for the roughness are not given. In D1, see page 8, lines 32 to 37, a silver layer is sputtered on a stainless steel substrate whereby the temperature determines the reflection properties.

D6a discloses a layer of 1.3 eV and 100 nm which cannot be taken out of the context.

D5 discloses top and bottom cells having i-layer thicknesses of 40 and 500 nm, respectively, which lie outside the claimed ranges. The bandgap 1.1 eV of the bottom cell of D5 is lower than claimed and there is no texturing.

As to the discrepancy between bandgaps of the bottom cell in the description and the claim of the patent in suit, the respondent emphasised that he did not agree to the introduction of the opposition ground under Article 100(b).

The additional features of claim 1 according to the auxiliary request offer further advantages in combination with the other features. Specified is a special selection of impurities and their upper limits, which is useful information for the skilled person under the aspect of costs. This information is not derivable from prior art. D6, see page 2778, left-hand column, second paragraph, mentions C and O, however, for Si and not for SiGe, i.e. the material of the middle cell according to the patent.

Reasons for the Decision

1. Admissibility of the appeal

The appeal complies with the provisions of Articles 106 to 108 and Rule 64 EPC and is therefore admissible.

2. *Inventive step of the claimed subject-matter (main request)*

2.1 Either D5 or D7 can be taken as the closest prior art, because both documents disclose multi-layered photovoltaic devices (triple cells) whose second (middle) cell comprises an i-layer consisting of a-SiGe having bandgaps (D5: 1.6 eV; D7: 1.45 eV) coinciding with the limits of the claimed range of 1.45 to 1.6 eV (see D5, abstract and figure, and D7, page 43, last paragraph, lines 15 to 20, and Figure 12(a) at page 46). Moreover, both in D5 (see layer 2) and D7 (see Figure 12(a) at page 46: "ITO") there is a transparent electrode on the third cell (top cell), as is defined in claim 1 as the last feature.

The respondent has questioned that D7 discloses at page 43, last paragraph, a-SiGe as the material for the middle cell. However, it is indicated at this location that the bandgap of the middle cell is E_{g2} = 1.45 eV and that alloys of the type a-$Si_{1-x}N_x$ and a-$Si_{1-x}C_x$ are considered as high bandgap materials and alloys of the type a-$Si_{1-x}Sn_x$ and a-$Si_{1-x}Ge_x$ are considered as low bandgap materials. It can then be derived from Figure 12(d) at page 47, that the bandgap of a-Si (about 1.7 eV) lies between the high and low bandgaps of the alloys. Therefore it was clear that according to D7 a bandgap of 1.45 eV was obtained by a-SiGe according to one alternative described in the document.

2.2 The most appropriate starting point is, in the board's view, D7, since it discloses the possibility of using a textured substrate. The respondent argued that texturing disclosed in D7 would not be the same as according to the patent in suit, see page 7, lines 48 to 55. However, it is indicated at page 40 of D7 (see first paragraph) that the surface pattern (texturing) of the substrate has "characteristic dimensions of the order of the wavelength of visible light within the semiconductor". These dimensions fall within the claimed range of maximum height. Figure 8(a) at page 41 of D7 shows clearly that irregular reflection is produced, as is further specified in claim 1 under consideration.

2.3 The skilled person would of course have to select the thicknesses of layers for the triple cell of D7, which she or he would find in D5. Therefore the combination of D7 with D5 results in a triple cell from which the subject matter of claim 1 differs essentially by the selected bandgap and thickness of the first (bottom) cell. In D5 and D7, the bandgaps of the bottom cell (D5: 1.1 eV; D7: 1.0 eV) lie below the claimed range of 1.3 to 1.45 eV. The thickness of the i-layer in D5 (500 nm) is larger than defined in claim 1 (100-300 nm).

2.4 The problem solved by the differing features addresses the adaptation of the parameters of the bottom cell for optimisation of a triple cell device with respect to efficiency and stability.

2.5 As far as the selection of the bandgap of the bottom cell is concerned, it has become general knowledge that an amorphous semiconductor material having a high content of Ge or being pure Ge has a relatively high density of defects (dangling bonds), see D1, page 4, lines 39 to 45, and D4, page 272, left-hand column, third paragraph. On the other hand it was also known that for absorption of the long wavelength region of the spectrum, the bandgap should be below 1.5 eV, see D4, page 272, left-hand column, first paragraph, and D2, page 749, left-hand column, last sentence. Therefore, the skilled person is clearly directed to the selection of a material containing a lower amount of Ge than in D5 or D7, and still having a bandgap below 1.5 eV, thus falling within the claimed range. Moreover, such a material, namely a-SiGe having a bandgap of 1.3 eV, has ben proposed for increasing the efficiency of the bottom cell in a triple cell device by D6a, see page 142, left-hand column, first and last paragraphs.

2.6 As to the selection of the thickness of the layers, it is generally known, that the thickness of the i-layers in a triple cell device is a function of the bandgap, i.e. the thickness increases from the top cell to the bottom cell. It is further known that the layers should be as thin as possible to minimise light-induced degradation, i.e. to improve stability, see D6, page 2778, left-hand column, second paragraph. The relative thicknesses of the layers are obtained by fulfilling the condition of current-matching in the cells, see D4, page 273, left-hand column, last paragraph. D6a proposes a thickness of 100 nm for the 1.3 eV layer, which falls within the range specified for the bottom cell of claim 1 under consideration.

The respondent has argued that the thickness disclosed in D6a could not be taken out of the context since it was not clear how this layer had to be combined with the other layers, and that D5 discloses a thickness of 40 nm for top layer which is smaller than the lower limit claimed.

However, this argument ignores the general considerations for the selection of the layer thicknesses, as mentioned above. If one layer is selected, as e.g. the layer of the middle cell in D5, the remaining layers have to be adjusted in an unambiguous manner.

2.7 The respondent argued further that for the problem of high stability at high efficiency, the prior art offered as solution profiled bandgaps, see D8, page 81, right-hand column, last paragraph, and D6, page 2776, right-hand column, lines 5 to 7.

This argument cannot be accepted since D6a cited in D6, too (see page 2776, right-hand column, last paragraph), provides a solution employing a non-profiled bandgap for the bottom layer. Moreover, it would not be the average bandgap, which would have to be compared, but the minimum value which determines the absorption edge. In D6 and D8 these minimum values (1.45 eV) coincide with the upper limit claimed for the bottom cell.

2.8 The respondent summarised his arguments by stating that it was the special combination of all features that would not be obvious from the cited prior art. The invention was based on the experiments and examples presented in the patent specification. The bandgap range of 1.3 to 1.45 eV for the bottom cell was only selected after completion of experiments carried out with a bottom cell of 1.53 eV. However, Figure 9 of the patent points towards the claimed range of 1.3 to 1.45 eV.

This argument is also not convincing. The main purpose of the examples and experiments presented in the patent was to optimise the middle cell under the aspect of stability, see page 11, lines 43 to 50. The conclusion drawn in the patent specification (see page 10, lines 16 to 17) from Figure 9 is also directed to the selection of the bandgap range of the middle cell. It is evident that the parameters of the top and bottom cell were considered being of secondary importance. However, as was shown above, the material, bandgap and thickness of the middle cell were known and there was clear indication how to adapt the top and bottom cell as regards bandgap and thickness.

2.9 In view of the foregoing it is concluded that the subject-matter of claim 1 according to the main request does not involve an inventive step within the meaning of Article 56 EPC. Therefore, the grounds for opposition prejudice the maintenance of the patent as granted, see Article 102(1) EPC.

3. *Auxiliary request*

3.1 Claim 1 according to the auxiliary request specifies in addition that the materials of the i-layers of the first cell (bottom cell) and the third cell (top cell) are a-SiGe and a-Si, respectively, and that the content of C, N, O, P and B in the second cell (middle cell) has certain upper limits.

3.2 As to the selection of the material of the i-layers, a-Si is used for the top cell in most cited documents including D5, and, as was shown above, a-SiGe is proposed by D6a for the bottom cell.

3.3 As to the content of certain elements in the middle cell, it is generally known that the concentration of impurities should be low. For instance, it is indicated in D6, see page 2778, left-hand column, second paragraph, that impurities such as O and C should be below 10^{20} cm^{-3} in the i-layers of a-Si solar cells in order to minimise light-induced degradation. This is comparable to the limits 1×10^{19} cm^{-3} and 5×10^{19} cm^{-3}, respectively, indicated in claim 1 for these elements. Moreover, it was evident that the content of elements also serving as dopants must be carefully controlled. This applies to N, P and B. Therefore the skilled person was able to select the claimed limits in an obvious manner.

3.4 The respondent submitted that the selection of impurities and their upper limits provides special and useful information for the skilled person under the aspect of costs. D6 mentions C and O impurities for a-Si and not for a-SiGe.

However, the board feels that the control of impurities falls within the routine expertise of the skilled person who knows also that the reference to a-Si solar cells in D6 includes cells employing a-SiGe layers. Since the skilled person is aware of the fact that Ge respect to the density of defects, see paragraph 2.5 above, she or he would expect that the control of impurities is particularly important.

3.5 For these reasons, the subject-matter of claim 1 as amended in accordance with the respondent's auxiliary request does not involve an inventive step within the meaning of Article 56 EPC. The requirements of Article 102(3) EPC for the patent being maintained with a so amended claim are not met, accordingly.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The patent is revoked.

The Registrar: The Chairman:

P. Martorana E. Turrini