BESCHWERDEKAMMERN DES EUROPÄISCHEN PATENTAMTS **BOARDS OF APPEAL OF THE EUROPEAN PATENT OFFICE** **CHAMBRES DE RECOURS DE L'OFFICE EUROPEEN DES BREVETS**

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DECISION
of 27 July 1995

Case Number: T 1103/92 - 3.4.1

Application Number: 81110111.2

Publication Number: 0053402

IPC: H01L 31/04

Language of the proceedings: EN

Title of invention:
pin photovoltaic cell having a hetero junction of amorphous siliconcompound and amorphous silicon

Patentee:
KANEGAFUCHI KAGAKU KOGYO KABUSHIKI KAISHA

Opponent:
Deutsche Aerospace Aktiengesellschaft

Headword:
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Relevant legal provisions:
EPC Art. 56

Keyword:
"Inventive step (no)"
"Obvious specification of material properties in the light of conventional values"
"Submission of evidence by proprietor during oral hearing, in an attempt to show that a document submitted by him three years earlier was not a prior publication, regarded as of very low evidential value and rejected as inadmissible"

Decisions cited:
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Catchword:
-

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Boards of Appeal

Office européen des brevets
Chambres de recours

Case Number: T 1103/92 - 3.4.1

DECISION
of the Technical Board of Appeal 3.4.1
of 27 July 1995

Appellant: (Opponent)	Deutsche Aerospace Aktiengesellschaft Patente Willy-Messerschmitt-Strasse, Tor 1 D-85521 Ottobrunn (DE)
Representative:	Ellerich, Klaus (authorised employee) Deutsche Aerospace Aktiengesellschaft
Respondent: (Proprietor of the patent)	KANEGAFUCHI KAGAKU KOGYO KABUSHIKI KAISHA 2-4 Nakanoshima 3-chome Kita-ku Osaka-shi Osaka-fu 530 (JP)
Representative:	Heunemann, Dieter, Dr VOSSIUS & PARTNER Postfach 86 07 67 D-81634 München (DE)

Decision under appeal: **Decision of the Opposition Division of the European Patent Office dated 2 November 1992 rejecting the opposition filed against European patent No. 0 053 402 pursuant to Article 102(2) EPC.**

Composition of the Board:

Chairman: G. D. Paterson
Members: H. J. Reich
Y. J. F. van Henden

Summary of Facts and Submissions

I. The Respondent is Proprietor of European patent No. 0 053 402.

Claim 1 as granted reads as follows:

> "1. A p-i-n amorphous silicon and silicon compound heterojunction photovoltaic cell, characterized by incorporating as either the p or n type side thereof exposed to the incident light an amorphous silicon compound having an optical bandgap, (Eg. opt) between 1.85 eV and 2.15 eV, an electric conductivity of not less than $10^{-8}(\Omega \cdot \text{cm})^{-1}$ at 20°C and a p-i-n junction diffusion potential, Vd, of not less than 1.1 volts."

Claims 2 to 10 are dependent on Claim 1.

II. This patent was opposed on the grounds mentioned in Article 100(a) and 100(b) EPC, in particular under Article 56 EPC with regard to documents:

D1: GB-A-2 030 766, and
D2: "Philosophical Magazine", vol. 35, 1977, pages 1 to 16.

In the proceedings before the Opposition Division the opponent also relied on document:

D3: US-A-4 109 271 cited in the patent specification;

and the proprietor cited inter alia documents:

- ND1: "Solar Energy Materials", vol. 3, No. 4, November 1980, pages 503 to 518;

ND2: "Solar Energy Materials", vol. 2, 1980,
pages 313 to 325; and
ND3: "Journal of Applied Physics", vol. 53, 1982,
pages 5273 to 5281

in order to defend its case.

III. The Opposition Division rejected the opposition on the ground that in view of the cited prior art it was not obvious to progress from the closest prior art according to document D1 in which the carbon content of the a(amorphous)-SiC window layer of the photovoltaic cell - and thus the width of its optical bandgap - is not specified, to the claimed optical bandgap range between 1.85 and 2.15 eV in combination with the other features of Claim 1 in order to increase the efficiency of the cell. Since the conventional cells according to document D1 and to document D3 (disclosing an optical bandgap range of about 2.2 eV to 3.2 eV) are based on the technical concept of using a high bandgap material in order to reduce the light absorption of entering photons in the window layer (i.e. the p- or n-zone of the p-i-n cell exposed to light) and to thereby improve the light conversion of the cell, it was not obvious to a skilled person, that a sacrifice of the transparency of the window layer results in a better cell efficiency, because it allows more efficient collection of the charge carriers generated by the incident light from the depleted i-zone via a high electrical conductivity in the window layer and a higher p-i-n junction diffusion potential. None of the cited prior art documents teaches an influence of the conductivity of the silicon compound window layer and of the cell diffusion potential on the conversion efficiency of a photovoltaic p-i-n cell. Moreover, in view of the large number of fabrication parameters involved, the claimed window layer properties cannot be arrived at by routine experimentation. Having regard to the opponent's objection under Article 100(b) EPC, a skilled person only needs to apply his routine competence in order to fabricate a window layer with the claimed properties on the basis of the experimental glow discharge parameters disclosed in the description of the patent in suit.

IV. The opponent lodged an appeal against the decision of the Opposition Division.

V. In a communication accompanying a summons to oral proceedings the Board informed the parties inter alia of facts on which the Board based its provisional view that the subject-matter of Claim 1 might possibly be regarded as an obvious specification of the parameters of the material of the conventional photovoltaic cell disclosed in document D3, in the light of the information in documents ND1 and ND2 about the usual values of these parameters which are known to result in an optimum conversion efficiency. The description of the patent in suit provides no evidence that the claimed parameter values, in particular the minimum value of the electrical conductivity of the window layer, delimits a region which provides an unforeseeable efficiency increase. Moreover, the corresponding doping of amorphous silicon compound material appears to be based on normal routine work.

VI. In preparing for oral proceedings the proprietor filed on 20 July 1995 arguments against the Board's preliminary view, citing document:

ND9: "Japanese Journal of Applied Physics", vol. 21, 1982 Supplement 21-2, pages 291 to 296.

VII. Oral proceedings were duly held on 27 July 1995. The opponent requested that the decision under appeal be set aside and that the European patent No. 0 053 402 be revoked. The proprietor requested that the appeal be dismissed and that the patent be maintained according to its main request as granted, or according to its auxiliary request, on the basis of Claim 3 combined with Claim 1.

VIII. In support of its request, the opponent made essentially the following submissions:

(a) A person skilled in the p-i-n photovoltaic cell art generally knows that the magnitude of the built-in potential (which is alternatively also termed diffusion voltage) created by the negative and positive space charges in the p- and n-regions which contact the cell electrodes, has to be sufficiently high in order to collect as electrical current possibly all movable charge carriers generated in the depleted i-zone by absorption of photons (see for instance document D3, column 3, line 52 to column 4, line 4). Document ND1 states on page 515, paragraph 1 that the built-in potential (the diffusion voltage) in p-i-n cells is usually on the order of 1.1 V (as claimed in Claim 1) and that it can be increased by moving either Fermi level closer to the respective band edge. This means, that it is known to increase the diffusion voltage by improving the electrical conductivity in the p- and n-layers via an appropriate doping.

(b) A skilled person derives from document D2, page 13, paragraph 3 in combination with page 1, paragraph 1 that the different electric properties of silicon carbide prepared by the glow discharge technique, result from a low density of (localised) gap states, which - as in a-Si - opens up the possibility of substitutional doping. Therefore, a skilled person would interpret the wording in document ND1, page 516 paragraph 1: "Many additives such as C_2H_2, O_2 and N_2 will increase the optical gap of a-Si:H, so that **if** the modified films could also be made conductive by doping, they might work well as doped layers in a p-i-n device" not in the sense of a prejudice, i.e. that it is impossible to dope amorphous silicon compound material, but as a realisable advantage which would invite corresponding experimental work.

(c) Document D3 discloses in column 4, line 56 to column 6, line 14 experimental parameters which demonstrate the dopability of amorphous silicon compound material. Furthermore, document D3 stresses in the abstract and in column 2, lines 20 to 34 and 66 that the doped material is highly conductive and provides in combination with the transparency of the window layer (i.e. by providing in the optical path of the entering photons an a-SiC material with an optical bandgap of about 2.2 eV to 3.2 eV which allows radiation up to this limit to enter the i-zone in a-Si without absorption and to shift therein electrons from the valence band to the 1.6 eV higher conduction band) an increased collection efficiency. On the basis of the generally known value of the a-Si density of 10^{22} atoms cm^{-3}, the fabrication parameters of the embodiment of the patent in suit at page 4, lines 38 and 39, result in a dopant concentration

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of 10^{19} atoms cm^{-3} in the window layer. The conventional a-SiC window layer of document D3 has the identical dopant concentration; see D3, column 4, lines 5 to 8. Moreover, document ND2, page 317, paragraph 1 stresses the necessity that the electric conductivity in the films of a p-i-n cell is of the order of $10^{-8}(\Omega \cdot cm)^{-1}$.

(d) The original application documents of the patent in suit only disclose the lower optical bandgap limit of 1.85 eV claimed in Claim 1 and do not contain any hint about the upper limit of 2.15 eV in present Claim 1. There is no teaching in the original application documents that such limitation is indispensable for enabling dopability and thereby the high conductivity of the window layer nor that it delimits a sharp increase in conductivity or efficiency. Furthermore, there is no technical justification disclosed in the patent in suit for keeping the optical bandgap in an amorphous silicon compound window layer below 2.15 eV. For instance, according to Table 1 of the patent under appeal, the efficiency at E_{gopt} = 2.27 eV is higher than at 1.85 eV. The proprietor first introduced the upper limit of 2.15 eV during oral proceedings before the Examining Division on 12 May 1987 as a disclaimer in order to avoid a novelty objection on the basis of document D3. The upper limit does not represent a purposeful selection, but a merely arbitrary distinction. The indication of the lower bandgap limit of 1.85 eV is trivial. It is only 0.05 eV higher than the E_{gopt} value of 1.8 eV for the i-a-Si:H material in the photon-carrier conversion region of the cell (depleted i-zone). Since it defines a use of the onset of the window transparency, the lower limit lies within the discretion of the skilled person. Hence, the delimination of the optical bandgap of a conventional doped amorphous silicon compound window layer to 1.85 to 2.15 eV does not represent a non-obvious dimensioning rule with unexpected results but is arbitrary.

(e) The claimed lower limit of $10^{-8}(\Omega \cdot \text{cm})^{-1}$ for the conductivity is also trivial and arbitrary since it does not involve a sharp increase of the cell efficiency; see Tables 1 and 2 of the patent in suit.

(f) The proportionality between diffusion voltage V_D and open circuit voltage V_{oc} such as disclosed in Figure 3 of the patent in suit is already derivable from document ND1, page 514, last two lines, and was not discovered by the proprietor.

IX. The above submissions were contested by the proprietor who argued essentially as follows:

(a) The increase in efficiency in the conventional p-i-n cells disclosed in document D1 and in particular in document D3 is based on the optical concept of introducing incident photons without absorption losses into the depleted i-zone where they generate the freely movable charge carriers of the photocurrent.

Document D3 uses a window layer of high thickness with an optical bandgap of 2.5 eV. In such a bandgap region the electrical conductivity of a-SiC is extremely low. Though document D3 discloses a dopant concentration of 10^{19} atoms cm^{-3}, the doped a-SiC material is still an insulator. The dopant concentration alone is no evidence how effectively the dopant contributes to the electrical conductivity. Though document D3 discloses ammonia and nitrogen as a n-type dopant gas and trimethyl aluminium as a p-type dopant gas for the window layer (see D3, column 5, lines 62 to 65 and column 6, lines 7 to 10), it does not teach how to increase the conductivity of a-SiC by such doping.

(b) The inventors of the patent in suit improved the efficiency of the cell by a different concept. They found that even if the transparency of the window layer is sacrificed to some extent, the conversion efficiency is remarkably improved by more efficiently collecting the charge carriers generated in the depleted i-zone reducing their recombination. This electric concept is based on the inventors' discovery of the dopability of a-SiC, i.e. of a "valence electron controllability" (i.e. the relative position of the valence band with regard to the Fermi level). The inventors' findings that in case of an optical bandgap of more than 2.2 eV the conductivity of a-SiC cannot be increased to more than $10^{-8}(\Omega\ .\ \mathrm{cm})^{-1}$ - even if the doping manner as found by the inventors is applied - would be a universal concept which is as well valid for other silicon compound materials.

(c) Evidence for the inventors' discovery of the dopability of a-SiC is given by the diagrams handed over during the oral proceedings and based on documents ND2 and ND3. The experimental results disclosed in document ND2 show a rather continuous increase of the electric conductivity in boron doped a-Si with decreasing width of the optical bandgap (see ND2, Figures 7 and 5); whereas in boron doped a-SiC a sudden increase of the electric conductivity below optical bandgap values of

2.15 eV was found; see in particular ND3, Figures 1 and 2. Boron doping increases the photoconductivity of ethylene based a-SiC to values which are one order of magnitude higher than those of the undoped material (Figure 2), and the photoconductivity of methane-based a-SiC to values which are three orders of magnitude higher than those of the undoped material (Figure 1). Furthermore, Figure 4 of document ND3 evidences in the example of a methane-based a-SiC/a-Si heterojunction solar cell that "a clear and sharp rise of the cell efficiency can be obtained starting at an optical bandgap of 2.15 eV in the direction towards lower bandgap values".

(d) Document ND1 concerns solar cells made of a-Si. The wording in document ND1, page 516, paragraph 1 "... **if** the modified films could also be made conductive by doping ..." represents a clear statement of the writer who is a competent authority in the solar cell art, that prior to the patent in suit amorphous silicon compound material was regarded as not dopable. It gives no teaching how to realise such doping, and thus narrows the technical information concerning the necessity of a conductive a-SiC window layer to a desideratum. All experimental dopant parameters disclosed in ND1 relate to a-Si and not to a-SiC. Though the authors of document D2 succeeded in decreasing the density of localised states by including hydrogen in a-Si to react with the dangling bonds of Si making thereby doping of a-Si possible, their attempts to apply the same technique to dope a-SiC and a-SiN failed. This fact is apparent from document D2, page 8, last paragraph and page 13, third paragraph, wherein the main carrier transport path is indicated to be hopping in localised states situated in the mobility gap. However, the inventors of the patent in suit found that, within an optical bandgap region of less than 2.2 eV, a-SiC can be doped with B_2H_6 or PH_3 by controlling the formation of C-H bonds. B_2H_6 or PH_3 act as catalysts which decrease the C-H bond formation. The amount of hydrogen atoms attached to carbon is a factor responsible for the observed photoconductivity recovery effect; see also document ND3, Chapter III.

(e) A letter of the "Universitätsbibliothek Hannover" dated 25 July 1995 (filed during the oral proceedings), together with a letter from the proprietors' representative to that library dated 24 July 1995, shows that document ND1 was only available to the public on 2 January 1981, i.e. after the earliest two of the four priority dates of the patent in suit (3 and 19 December 1980) and thus is not part of the state of the art.

(f) The introduction of the upper limit of 2.15 eV of the optical bandgap into Claim 1 after the filing date of the present invention represents an allowable amendment, since it is legally permissible to voluntarily limit the extent of protection claimed.

X. At the conclusion of the oral proceedings, the decision was announced that the decision of the Opposition Division is set aside, the appeal is allowed and European patent No. 0 053 402 is revoked.

Reasons for the Decision

1. *Inventive step - Claim 1 - main request*

1.1 From the closest prior art document D3, it is known in the wording of Claim 1:

"1. A p-i-n amorphous silicon and silicon compound heterojunction photovoltaic cell, characterized by incorporating as either the p or n type side thereof exposed to the incident light an amorphous silicon compound"; see D3, Figure 1 with the corresponding description and column 6, lines 2 to 10.

1.2 The technical problem underlying the patent in suit, namely, increasing the conversion efficiency of a p-i-n photovoltaic cell, represents a generally known and basic aim in the technical development of photovoltaic cells. Hence, the formulation of this problem does not contribute to an inventive step underlying the subject-matter of Claim 1.

1.3 According to Claim 1, the problem to increase the cell efficiency is solved in that the amorphous silicon compound material incorporated in the cell and exposed to the incident light (window layer), has the following properties:

(a) "an optical bandgap (E_{gopt}) between 1.85 eV and 2.15 eV";

(b) "an electric conductivity of not less than $10^{-8}(\Omega . cm)^{-1}$ at 20°C"; and

(c) "a p-i-n junction diffusion potential, Vd, of not less than 1.1 volts".

Hence, in the examination of inventive step, it has to be considered whether dimensioning rules (a), (b) or (c) were obvious to a skilled person or not.

1.4 With reference to dimensioning rule (a) above, and in particular with reference to the upper bandgap limit of E_{gopt} = 2.15 eV, the Board agrees with the submissions of the opponent as set out in paragraph VIII-(d) above, to the effect that this upper limit, having been introduced into the claim during the proceedings before the Opposition Division as a disclaimer with respect to document D3, cannot be regarded as a purposeful selection which provides a technical contribution to the claimed invention. As can be seen from Table 2 of the patent in suit, this value is merely an arbitrary upper limit which, while legitimately distinguishing from the disclosure of document D3 with respect to novelty (see D3, column 2, lines 32 to 34: 2.2 to 3.2 eV), does not help to provide an inventive step with regard to such disclosure. Therefore, it remains to be examined, whether the lower limit of the optical bandgap $E_{gopt} \geq 1.85$ eV represents a non-obvious dimensioning rule.

1.5 It is admitted by the proprietor (see paragraph IX-(a)) that in addition to the features mentioned in paragraph 1.1 above, document D3 also discloses a window layer of an amorphous silicon compound material which has an optical bandgap of $E_{gopt} > 1.85$ eV (i.e. 2.2 to 3.2 eV; see D3, column 2, lines 32 to 34). Any lowering of these conventional bandgap values to E_{gopt} = 1.85 eV has the foreseeable technical effect to narrow the transparent spectral region of the window layer towards lower photon energies, since incident photons with energies higher than E_{gopt} are absorbable in the window layer. The question to which spectral extent the transmissivity of the window layer is necessary and to which extent absorption of photons with energies higher than the bandgap can be tolerated, depends on practical needs. Hence, it is within the routine work of a skilled person to decide up to which photon energies he wants to make use of the technical measure known inter alia from document D3, to increase the p-i-n cell efficiency by reducing absorption losses of incident photons on their optical path into the depleted i-zone where they generate electric charge carriers.

For the above reasons, in the Board's view dimensioning rule (a) was obvious to a skilled person.

1.6 Dimensioning rule (a) may be understood as an **optical** concept of improving the conversion efficiency of a p-i-n cell. It determines the number of photons which are able to arrive in the depleted i-zone. Its influence on the conversion efficiency ends after the photon has generated moveable charge carriers. Dimensioning rules (b) and (c) concern electric material properties which have an effect on the generated moveable charge carriers and may therefore be interpreted as an **electric** concept of improving the conversion efficiency. The optical and electric concepts thus provide effects which are independent from each other. Document D3 discloses said optical concept of conversion efficiency improvement. Contrary to the proprietor's submissions in paragraphs IX-(a) and (b) above, it discloses as well the electrical concept underlying dimensioning rules (b) and (c) of paragraph 1.3 concerning an efficient collection of generated charge carriers as electrical current by reducing carrier recombination during the carrier diffusion to an electrode contacting the cell; see D3, column 3, line 52 to column 4, line 4 and column 4, lines 41 to 55. In the Board's view, document D3 draws the skilled readers' attention furthermore to the fact that the conventional a-Si window layer is highly conductive and provides an increased solar radiation collection efficiency and reduced internal resistance; see D3 the abstract, last sentence. It was obvious to a skilled person that a window layer with high conductivity contributes to an efficient transport of carriers from the depleted i-zone to the contacting electrodes. The importance of the magnitude of the built-in potential (the diffusion voltage) for the charge carrier collection as electrical current is derivable from D3, column 3, line 60 to column 4, line 4.

1.7 Document D3 is silent about the exact numerical value of the electric conductivity. The only experimental data disclosed in the embodiment of document D3 are a dopant concentration of the order of 10^{19} cm^{-3} (D3, column 4, lines 5 to 8) and nitrogen, ammonia and trimethyl aluminium as doping gases (D3, column 5, lines 62 to 65 and column 6, lines 7 to 10). However, in the Board's view, it is highly unlikely that the conventional doped a-SiC window layer material used in the p-i-n cell of document D3 is an electric insulator (see paragraph IX-(a)), since document D3 uses an embodiment wherein the electric contact to the window layer only "needs" to occupy a small area of the window layer surface; see D3, column 2, line 65 to column 3, line 2. The skilled reader would conclude from such extremely long carrier ways within the window layer that the window layer material must be highly conductive. Moreover, the proprietor has provided no experimental evidence that only diborane and not also trimethyl aluminium as dopant gas allows a valence electron controllability which the proprietor regards as indispensable for the dopability of silicon compound material. The Board is unable to recognise in the arguments submitted by the proprietor any technical facts or scientific reasons which make the proprietor's opinion plausible that the window layer of document D3 is not conductive. Document D3, ND3 and the description of the patent in suit disclose very similar experimental parameters for the glow discharge fabrication of the doped amorphous compound material. Moreover, boron and aluminium are both elements of the 3rd group of the periodic system and are generally known to be equivalents in the doping technology of silicon. Since diborane was used in document D3 for doping the p-layer in a-Si, a skilled person would have probably tried this doping gas also for p-doping a-SiC if trimethyl aluminium would not have been successful. For the above reasons, in the Board's view, document D3 discloses a p-i-n cell window layer with high electric conductivity. In filling out the gap of information in document D3 that the electric conductivity of the amorphous silicon compound material for the window should indispensably be according to dimensioning rule (b) of paragraph 1.3 above, i.e. "not less than $10^{-8}(\Omega\ .\ \mathrm{cm})^{-1}$ at 20°C, a skilled person only applies his general knowledge about numerical values of the electric conductivity which are usually applied in p-i-n cells for a practically acceptable conversion efficiency; see for instance document ND2, page 317, paragraph 1. The Board regards a skilled person to be able to conclude that the order of magnitude of the electric current has to be realised in the window layer independent from its optical absorption properties, so that values known from a-Si material would directly guide a skilled person to the values necessary in a-SiC. Moreover, the experimental data in Tables 1 and 2 of the patent in suit do not evidence a sudden increase of the conversion efficiency η starting at this lower limit of the claimed conductivity region. For instance, in SiC for $\sigma = 5.10^{-7}(\Omega\ .\ \mathrm{cm})^{-1}$ η is still 4.6% at E_{gopt} = 1.76 eV and increases to 7.2% only when

E_{gopt} is 2.1 eV. In SiN for $\sigma = 5.10^{-7} (\Omega . cm)^{-1}$ η is still 4.6% at E_{gopt} = 1.76 eV and increases to 6.5% only when E_{gopt} is 1.92 eV.

1.8 As recorded in paragraph IX-(e) above, the proprietor produced a letter dated 25 July 1995 from the Universitätsbibliothek Hannover for the first time during the oral proceedings on 27 July 1995. This letter was sent in reply to a request for information as to when document ND1 has been first made available to the public at that library, which had been sent to the library by the proprietor's professional representative on 24 July 1995. Copies of the letters dated 24 and 25 July 1995 had not been made available either to the opponent or to the Board before the oral proceedings.

The Board has noted that document ND1 was filed by the proprietor on 6 May 1992 during the proceedings before the Opposition Division, in order to show the state of knowledge concerning doping of a-SiC at the priority date of the patent in suit in December 1980. Document ND1 bears the date November 1980, and was referred to in paragraph 4 on page 10 of the decision of the Opposition Division as showing the state of knowledge at the priority date of the patent in connection with the use of additives to increase the optical gap of a-Si (that is, document ND1 was used by the Opposition Division in favour of the proprietor's case concerning the ground of opposition under Article 100(b) EPC).

In the statement of grounds of appeal, the opponent relied inter alia upon document ND1 as a prior published document which supported the ground of lack of inventive step. In the reply to this statement which the proprietor filed on 20 September 1993, the proprietor did not contest that ND1 was published before the earliest priority date of the patent in suit (3 December 1980). As stated in paragraph IX-(e) above, according to the evidence which the proprietor has filed, the first time that any enquiry was made as to when document ND1 was in fact made available to the public was three days before the date appointed for oral proceedings.

If a party to opposition or opposition appeal proceedings wishes to contest an issue of fact such as the date of publication of a document, any evidence relating to that issue should be filed as early as possible during the proceedings, and inquiries concerning the possible availability of relevant evidence should be commenced as soon as it becomes clear to that party that it is in its interest to contest the issue. Opposing parties must be given a proper opportunity to make their own inquiries in response to any evidence which is filed.

In the present case, prior to the oral proceedings the proprietor has accepted that document ND1 was published before 3 December 1980. The opponent was not informed until halfway through the oral proceedings that the proprietor intended to present evidence contesting the date of publication of document ND1. Such conduct is not in accordance with a fair and proper opposition procedure, and justifies a finding that the proprietor's evidence filed during the oral proceedings is inadmissible.

Furthermore, the evidence which the proprietor in fact presented during the oral proceedings, namely the letter for Universitätsbibliothek Hannover dated 25 July 1995, is of very low evidential value. The fact that document ND1 was only made available to the public in one particular library on 2 January 1981 may be explained in a variety of ways, and hardly begins to establish that document ND1 was first available to the public on 2 January 1981.

In the Board's view the date carried by document ND1, namely November 1980, prima facie establishes that the document was made available to the public before 3 December 1980, and the evidence filed by the proprietor during the oral proceedings on 27 July 1995 does not displace such prima facie finding.

1.9 In the Board's view, it was obvious to a skilled person to extend the information in document D3 concerning the numerical value of the diffusion potential necessary for an effective charge carrier collection as electric current, to values which are usually applied in the p-i-n photovoltaic cell art. The diffusion potential (built-in potential) of p-i-n cells is usually of the order of 1.1 V; see document ND1, page 515, paragraph 1. Since the necessary driving force for collecting charge carriers is independent from the optical properties of the window layer, it is obvious for a skilled person to postulate also for an amorphous silicon compound material according to dimensioning rule (c) of paragraph 1.3 above, that the diffusion potential, V_D, should be "not less than 1.1 V".

1.10 Document D3 is silent about the conversion efficiency of the p-i-n cell disclosed therein. Results of comparative tests have not been filed. Document ND1 discloses for p-i-n cells without transparent window layer conversion efficiencies up to 6.1%; see page 508, paragraph 2. A skilled person, in the Board's view, will expect that the reduction of photon losses in a transparent window layer allows to realise higher efficiencies than 6.1% when following the teaching of document D3 and simultaneously maintaining the conventionally known parameter optimisation of the electric aspect of the carrier collection mechanism as set out in paragraphs 1.7 and 1.9 above. Therefore, in the Board's view the maximum values of the conversion efficiency disclosed in Tables 1 and 2 of the patent in suit, i.e. 6.75% for SiN and 7.2% for SiC, do not represent a surprising effect. The proportionality between diffusion potential V_d and open circuit voltage V_{oc} is generally known in a-Si p-i-n cells (see for instance document ND1, page 514, last two lines). This proportionality is part of the electrical aspect of the carrier collection and not influenced by optical material properties. Therefore, in the Board's view, a skilled person will expect identical results for a p-i-n cell with an a-SiC or a-SiN window layer according to Figure 3 of the patent in suit. In view of the independency of the effects of the optical and electronic aspect of efficiency increase, a skilled person is furthermore regarded to expect that the maximum numerical values of the open circuit voltage known to be in the 0.9 V-region for an a-Si p-i-n cell (see Figure 8 of document ND1), can also be realised when the a-Si material of the window layer is replaced by a-SiC or a-SiN, as found in Tables 1 and 2 of the patent in suit.

1.11 The Respondent's discoveries, that the doping gases B_2H_6 and PH_3 in the glow discharge fabrication of a-SiC act as catalysts, control the formation of C-H bonds, and that a decrease in the C-H bond formation is responsible for the experimentally found rise of the photoconductivity and the decrease of the optical bandgap in a-SiC (see paragraphs IX-(c) and (d) above) are regarded as scientific merits which are without technical effect on the subject-matter claimed in Claim 1 and thus not relevant for supporting an inventive step underlying this claim. Moreover, Claim 1 is not narrowed to an amorphous silicon compound material which is produced by a particular doping method using B_2H_6 or PH_3. Furthermore, in the Board's view, the numerical values of the **photo**conductivity such as found according to document ND3 do not allow to draw therefrom a conclusive estimate of the **electric** conductivity (in the dark) which is claimed in Claim 1. The Respondent himself has published in document ND2, Figure 4 and page 317, paragraph 1 that numerical values of dark- and photo-conductivity differ from each other up to almost five orders of magnitude.

1.12 For the reasons stated above the Board regards the subject-matter of Claim 1 as the result of substituting in the electrical aspect of the conversion efficiency improvement disclosed in document D3 conventionally known parameter values for an effective carrier collection as electric current. In such substitution, a skilled person only has to fill out gaps in the technical information derivable from document D3 by the explicit usual values disclosed in documents ND1 and ND2. Approximating simultaneously the lower bandgap value of the window layer disclosed in document D3 to the photon energy necessary for generating carriers in the depleted i-zone, is a logical extension of the conventional optical concept and an obvious matter of discretion. Therefore, in the Board's judgment Claim 1 lacks an inventive step within the meaning of Article 56 EPC.

2. *Inventive step - Claim 1 - auxiliary request*

Claim 1 of the auxiliary request specifies that the amorphous silicon compound material shall be SiC or SiN. The Board has based its reasoning of lack of inventive step in paragraphs 1.1. to 1.12 above on a-Si and a-SiC material properties.

Hence, the reasoning in paragraphs 1.1 to 1.12 fully applies to the alternative of Claim 1 of the auxiliary request claiming a-SiC as material for the window layer. The substitution of a-SiC by a-SiN as window layer material is obvious in view of document ND1, page 516, paragraph 1 disclosing both - C_2 and N_2 - as an additive to a-Si which increases the value of the optical bandgap and produces a better photon transmissivity in the window layer. For these reasons, in the Board's judgment the subject-matter of Claim 1 of the auxiliary request is obvious to a skilled person and does not satisfy the requirements of Article 56 EPC.

3. Claims 2 to 10 of the main request and Claims 2 to 9 of the auxiliary request fall because of their dependency on an unallowable Claim 1.

Order

For these reasons it is decided that:

1. The decision of the Opposition Division is set aside, and the appeal is allowed.

2. European patent No. 0 053 402 is revoked.

The Registrar:	The Chairman:
M. Beer	G. D. Paterson