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D E C I S I O N
of 23 September 2005

Case Number: T 1004/03 - 3.4.02

Application Number: 99112564.2

Publication Number: 0969519

IPC: H01L 31/0236

Language of the proceedings: EN

Title of invention:
Solar cell having depressions in the substrate and production process therefor

Patentee:
SHARP KABUSHIKI KAISHA

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 56

Keyword:
"Inventive step - yes"

Decisions cited:
-

Catchword:
-

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Beschwerdekammern | Boards of Appeal | Chambres de recours

Case Number: T 1004/03 - 3.4.02

D E C I S I O N
of the Technical Board of Appeal 3.4.02
of 23 September 2005

Appellant: SHARP KABUSHIKI KAISHA
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Osaka 545-8522 (JP)

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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 13 May 2003 refusing European application No. 99112564.2 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: A. Klein
Members: A. Maaswinkel
J. Willems

Summary of Facts and Submissions

I. The appellant lodged an appeal, received on 4 July 2003, against the decision of the examining division, dispatched on 13 May 2003, refusing the European patent application 99112564.2. The fee for the appeal was paid on 4 July 2003 and the statement setting out the grounds of appeal was received on 12 September 2003.

II. The examining division objected that the application did not meet the requirements of Article 52(1) and 56 EPC because the subject matter of claim 1 of both the main and auxiliary requests then on file did not involve an inventive step in view of the disclosure in document D3 and trial and error experiments.

III. During the examining proceedings *inter alia* the following documents had been cited:

D1: US-A-4 135 950

D3: Washio H et al: "Development of High Efficiency Thin Silicon Space Solar Cells", Proceedings of the Photovoltaic Specialists Conference, New York, USA, IEEE, vol. Conf. 23, 10 May 1993, pages 1347 - 1351.

D4: Patent Abstracts of Japan, vol. 016, no.097 (E-1176), 10 March 1992 & JP-A-03 276682.

IV. After a telephone consultation with the rapporteur the appellant filed with a letter dated 8 July 2005 amended documents. The appellant requested that the decision

under appeal be set aside and a patent be granted on the basis of the following documents:

Claims: 1 to 7 as filed with the letter of 1 February 2002;
8 as filed with the letter of 8 July 2005;

Description: pages 1 to 11 and 14 to 30 as originally filed;
pages 12, 12a and 13 filed with the letter of 8 July 2005;

Drawings: sheets 1/9 to 9/9 (Figures 1 to 9) as originally filed.

V. The wording of independent claim 1 reads as follows:

"A solar cell comprising a crystalline substrate having projections and depressions formed on either side or both sides of the substrate, wherein a substrate thickness lies within a range extending from 40 μm to 110 μm, and a projection-depression depth is 25 μm or more".

The wording of independent claim 8 reads as follows:

"A process for producing a solar cell comprising the step of etching a substrate using a mask comprising a frame having a width of 2 μm or more to 4 μm or less and quadrangular patterns formed at a pitch of 35 μm or more on the mask, thereby to form projections and depressions with a depth of 25 μm or more on either side or both sides of the substrate, wherein a substrate

thickness lies within a range extending from 40 µm to 110 µm".

Claims 2 to 7 are dependent claims.

VI. The appellant's arguments may be summarised as follows:

Amended claim 1 includes the combined features of original claims 1 and 7. Claim 8 is based on the features of claim 9 wherein the substrate of the produced cell has a thickness within the range defined in claim 7 as originally filed. The description has been adapted to the present claims, acknowledging the prior art cited during the examining procedure. Therefore the amendments should be admissible under Article 123(2) EPC.

In its decision the examining division had stated that the "objective" problem to be solved when starting from document D3 would be to provide a solar cell with a texture to reduce the reflection loss of light. The appellant does not agree with this point of view. Although changing the projection-depression depth also has an effect on the reflection losses this does not imply that the problem to be solved would be to reduce the reflection losses of the incident light. Instead, the problem to be solved by the present invention was to optimise the parameters of a solar cell, namely to find a compromise in a way that both high mechanical strength and high radiation resistance is realized. This object is disclosed on page 12, lines 11 to 16 of the original application and is solved by the concrete range of progression-depression depth values defined in independent claims 1 and 8.

Starting from a 100 µm thick substrate disclosed in D3 the skilled person would have many possibilities to solve the problem of providing a high mechanical strength and high radiation resistance. Amongst others he could modify the following parameters, alone or in combination: the substrate thickness, the material composition of the cell, the form of the texture structure and the projection-depression depth. Document D3 does not give the skilled person any hint which of the above parameters should be modified for solving the above problem. In fact, it is very likely that the skilled person would just vary (reduce) the substrate thickness of the 100 µm solar cell since it is known that reducing the substrate thickness also improves the radiation resistance (*see page 11, lines 6 to 8 of the patent application*). This, however, would prevent the skilled person from experimenting with the parameter of the projection-depression depth. As to the value of this depth of the cell disclosed in D3, the appellant does not agree with the opinion of the examining division in point 1.1 of the Reasons for the decision that "*since D3 does not give any indication as to the value of the projection-depression depth... the skilled person is faced with the problem of determining the value of the projection-depression depth*". Document D3 is a publication from the present applicants and discloses the prior art acknowledged in the context of Figure 9(e) of the patent application. In this discussion it is stated on page 5, lines 8 to 10 that in the prior art the projection-depression depth is "*about 5 µm to about 15 µm*". To corroborate this the appellants include a declaration of Mr K. Nakamura, one of the inventors of the present patent application, who

joined the group of scientists which published document D3 just one year after its publication and who is therefore familiar with the contents of this document. According to Mr Nakamura, the texture structures of the solar cells disclosed in D3 are very shallow, as is also visible from the solar cell structures shown in Figure 1 of D3.

Starting from the disclosure in document D3, the skilled person would not have found an incentive in the prior art to arrive at the invention, since there is no disclosure that an increase of the progression-depression depth almost does not deteriorate the mechanical stability of the cell, nor that such an increase at the same time is beneficial to the radiation resistance. In particular although document D1 addresses radiation hardening of a solar cell and discloses a cell with projection-depression depth of 190 μm, this cell has a different electrode structure than the solar cell disclosed in D3. The structure in D1 has an electrode provided on each projection. If the depression depth is shallow, the percentage of electrode area in the whole cell is increased, thereby decreasing the photoelectric conversion efficiency, which is the reason why in the cell of D1 a deep depression depth is needed. Therefore D1 and the present invention differ in purpose of the projection-depression depth. Furthermore, because of the different electrode structures in D3 and D1, there is no obvious reason to combine the teachings of these documents. Document D4 is a document of the present applicant and discloses a solar cell for ground, not space, use. Therefore it is not concerned with cosmic rays or radiation resistance at all. Furthermore the substrate

is considerably thick, i.e. 200 µm. This document does not teach that an increase of the projection-depression depth does almost not affect the mechanical stability of the solar cell, and that such an increase would be advantageous for increasing the radiation resistance. It is therefore not obvious that the person skilled in the art would arrive at the substrate thickness range and the projection-depression depth range as defined by apparatus claim 1 and process claim 8 when starting from a solar cell as described in D3. Since the solar cell and its production defined in respective claims 1 and 8 shows a remarkable improvement over the prior art solar cells as disclosed in D3 the subject-matter of these claims therefore involves an inventive step.

Reasons for the Decision

1. The appeal is admissible.

2. *Amendments (Article 123(2) EPC)*

The board is satisfied that the amendments in the claims are fairly supported by the original application documents referred to by the appellant. The adaptation of the description is equally admissible.

3. *Patentability*

3.1 Novelty

3.1.1 Document D3 discloses a solar cell comprising a crystalline substrate (*silicon*) having projections and depressions (*normal or inverted pyramid, V-groove, see*

Figure 1) formed on its surface. The substrate thicknesses of the cells are 100 µm or 200 µm. Document D3 does not disclose values for the projection-depression depth. The solar cell defined in claim 1 differs from the disclosure in D3 by the feature that the projection-depression depth is 25 µm or more. This similarly applies to the process defined in claim 8.

3.1.2 Document D1 discloses a solar cell having a crystalline (*silicon*) substrate having projections at its surface. The total substrate thicknesses are 380 µm (*320+60 µm*) or 240 µm (*190+50 µm*), see column 2, line 56 to column 3, line 17. This differs from the cells defined in claims 1 and 8, which have a substrate thickness in the range extending between 40 µm to 110 µm.

3.1.3 Document D4 discloses a polycrystalline semiconductor solar cell having projections and depressions at both surfaces of the substrate. In the Patent Abstract no values for the substrate thickness or depth of the projections/depressions are disclosed. According to the appellant (*who is also the proprietor of this patent*) the substrate thickness is approximately 200 µm.

3.1.4 Therefore the subject-matter of claims 1 and 8 is novel.

3.2 Inventive step

3.2.1 The board agrees with the examining division and the appellant that document D3 discloses the closest prior art. The solar cell defined in claim 1 differs in the feature that the projection-depression depth is 25 µm or more.

3.2.2 In the decision under appeal it was stated that the objective problem addressed by this difference should be seen in providing a solar cell leading to a reduced reflection. The examining division referred to page 1347, left hand column, last five lines of document D3, where this problem was disclosed.

3.2.3 According to the appellant the problem to be solved by the invention was to optimise parameters of a solar cell in a way that both high mechanical strength and high radiation resistance is realized.

3.2.4 The board does not concur with the examining division's view that, starting from the disclosure in document D3, the technical problem lays in the reduction of the reflection. It is true that in the passage of the Section "Introduction" in document D3, referred to in the decision, the aim of "*improving photo-currents by reducing the reflection loss of light*" is mentioned. However, already in this Section, and more detailed in the following Section "Solar Cell Structure" this problem of reducing the reflection is approached by introducing non-reflective-surface (NRS) structures on the substrate, see also the three structures with projections and depressions in Figure 1. Neither in document D3, nor in any of the other available documents, could a disclosure be found linking the depth of the projections/depressions to reduction of the reflection. Therefore this definition of the technical problem does not appear sound for the problem and solution approach.

3.2.5 Starting from the solar cell disclosed in D3, which relates to the same type of cell (*for space*

applications) and with the same object (*aiming at high efficiency and discussing the problem of radiation effects*) as in the patent application the technical problem should rather be seen in a further improvement of this cell. It should therefore be analysed whether the skilled person *would* have considered modifying the cell structure known from document D3 to the parameters defined in claim 1 and its production defined in claim 8, either considering the teaching of D3 alone and on the basis of ordinary practical skill (or "*trial and error experiments*" as stated in the decision under appeal) or by an obvious combination of further prior art documents.

3.2.6 Considering the disclosure of document D3 alone it is noted that this document does not restrict the substrate thickness to 100 µm, but apparently considers substrates of thickness 200 µm as a viable alternative. In particular in Table 2, and page 1349, left hand column, end of first paragraph it is disclosed that the 200 µm thick cells attained the highest efficiency of 18.3%. Furthermore the optimising process in document D3 focuses on the type of the solar cell structure (*Figure 1*) and on the base resistivity of the wafers (*2 or 10Ωcm*). Further items for research and development are mentioned on page 1347, right hand column (*thermal processing; front and rear surface passivation; improving the back surface reflector structure*). Therefore the argument that the skilled person, when considering the teaching of document D3 alone, *would* select a solar cell with substrate thickness of 100 µm and try to optimise the projection-depression depth of the texture, thereby automatically arriving at the cell defined in claim 1, is not persuasive, the less so

because the depth of the texture or its variation is not discussed at all in document D3. Rather, if considering the disclosure in D3 in its entirety this document does not give any clue why the skilled person would have put emphasis in optimising/maximising the projection-depression depth of the texture. It would appear that in these prior art cells, the texture depressions where "shallow" as asserted by Mr Nakamura ("*10-15% of the substrate thickness*") which would also appear in global agreement with the structures shown in Figure 1 of D3.

3.2.7 Document D1 discloses a solar cell for space applications and discusses possibilities for radiation hardening of the cells. Since both the application area and this problem are also the subject of document D3, the skilled person might contemplate whether the teaching of document D1 would be useful when trying to further optimise the solar cell known from D3.

3.2.8 A combination of the teachings of these documents would, however, not be straightforward, since, as indicated by the appellant, the electrode structure in the solar cell disclosed in D1 is different from the one in document D3. Therefore it would *a priori* not be clear, whether, and if so, in which way the skilled person would combine these designs. Furthermore the minimum value for thickness of the cell in D1 (*240 µm*) is already larger than the maximum value of the cell disclosed in D3 (*200 µm*). Therefore, if the skilled person would combine these teachings at all (*in spite of the different electrode structures*), it would appear more obvious to start from a 200 µm thick cell which would be nearer to the range of thicknesses disclosed

in D1. In any case, such a combination would not result in the range of cell thicknesses and projection-depression depth defined in claim 1 and its production method defined in claim 8.

3.2.9 It is added that the examining division also was of the opinion that "none of the documents D1, D2, D4 can be combined in a reasonable way with D3 to obtain such a value". Finally it is noted that the publication date of document D1 was 14 years before the publication date of D3, and 19 years before the priority date of the patent application. In the rapidly developing field of research of solar cells this must be considered as a very long time period, which could be seen as a further indication for the presence of an inventive step.

3.2.10 Document D4 discloses a solar cell for terrestrial use and is not related to the problem of cosmic rays. The skilled person would therefore not consider combining this document for an optimisation of the cell of document D3 for reducing the effect of cosmic rays. Furthermore, as pointed out by Mr Nakamura, the cell thickness of this cell is 200 µm, therefore even a mosaic-wise combination of the teaching of D4 with that of D3 would not result in the claimed subject-matter.

3.3 Claims 2 to 7 are dependent of independent claim 1 and therefore they also define patentable subject-matter.

4. For the above reasons, the board finds that the appellant's request meets the requirements of the EPC and that a patent can be granted on the basis thereof.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the department of first instance with the order to grant a patent on the basis of the following documents:

Claims: 1 to 7 as filed with the letter of 1 February 2002;
8 as filed with the letter of 8 July 2005;

Description: pages 1 to 11 and 14 to 30 as originally filed;
pages 12, 12a and 13 filed with the letter of 8 July 2005;

Drawings: sheets 1/9 to 9/9 (Figures 1 to 9) as originally filed.

The Registrar: The Chairman:

P. Martorana A. Klein