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Datasheet for the decision of 23 August 2007

Case Number: T 0965/05 - 3.4.03

Application Number: 99118281.7

Publication Number: 1020931

IPC: H01L 31/075

Language of the proceedings: EN

Title of invention:
Amorphous silicon solar cell

Applicant:
MITSUBISHI HEAVY INDUSTRIES, LTD.

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 56

Keyword:
"Inventive step (no)"

Decisions cited:
-

Catchword:
-

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Beschwerdekammern | Boards of Appeal | Chambres de recours

Case Number: T 0965/05 - 3.4.03

D E C I S I O N
of the Technical Board of Appeal 3.4.03
of 23 August 2007

Appellant: MITSUBISHI HEAVY INDUSTRIES, LTD.
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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 14 February 2005 refusing European application No. 99118281.7 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: R. G. O'Connell
Members: R. Bekkering
T. Bokor

Summary of Facts and Submissions

I. This is an appeal against the refusal of application 99 118 281 for lack of inventive step having regard to

D1: US-A-5 736 431

D2: Y. Hishikawa et al.: "Effects of the i-layer properties and impurity on the performance of a-Si solar cells", Solar Energy Materials and Solar Cells, Elsevier Science Publishers, Amsterdam, NL, vol. 34, no. 1 - 04, 1 September 1994, pages 303 to 312, and

D4: US-A-4 839 701

II. At oral proceedings before the board the appellant applicant requested that the decision under appeal be set aside and a patent granted on the basis of the refused claims.

III. Claim 1 reads as follows:

"*1. An amorphous silicon solar cell comprising a transparent substrate (11), a transparent electrode (12) formed on said transparent substrate (11), a power-generating film (16) formed on said transparent electrode (12), and a back-side electrode (17) formed on said power-generating film (16), characterized in that said power-generating film (16) is formed by sequentially stacking p-type/i-type/n-type hydrogenated amorphous silicon layers (13, 14, 15), a defect density in said i-type hydrogenated amorphous silicon layer (14) is less than* 10^{15} *defects/cc, and*

a thickness of said i-type hydrogenated amorphous silicon layer (14) is not more than 300 nm."

Independent claim 2, the only other claim, differs from claim 1 in that the power-generating film is formed "*by sequentially stacking n-type/i-type/p-type hydrogenated amorphous silicon layers (13, 14, 15)*".

Reasons for the Decision

1. The appeal is admissible.

2. The sole issue is inventive step. In the following the board approves and largely adopts the reasoning of the examining division in the decision under appeal while taking into account the arguments adduced by the applicant on appeal.

2.1 Document D1 discloses a conventional amorphous silicon solar cell representing the closest prior art (column 1, line 11 to column 5, line 6; figures 1 and 3).

In particular, document D1 discloses an amorphous silicon solar cell comprising:
a substrate (101),
a reflective electrode (102) formed on the substrate,
a power-generating film (16) formed on the reflective electrode (12), and a back-side electrode (104) formed on the power-generating film, wherein
the power-generating film is formed by sequentially stacking p-type/i-type/n-type hydrogenated amorphous silicon layers, and

the i-type layer has a preferred thickness of 30 to 60 nm (column 2, line 25).

The solar cell of independent claim 2 differs therefrom in that:
- it comprises a transparent electrode on a transparent substrate, and
- the defect density in the i-type layer is less than 10^{15} defects/cc.

2.2 The first of the above identified differences allows for illumination of the solar cell from the opposite face, through its substrate. The second difference improves the photovoltaic conversion efficiency of the solar cell.

As these effects are unrelated, it is appropriate to assess inventive step based on separate problems derivable from the respective effects.

2.3 Following this approach the first problem to be solved relative to D1 is that of rendering the solar cell suitable for illumination from the substrate face.

It is notorious and undisputed that illumination through the substrate represents an alternative to illumination from the opposite face. Moreover, it would be obvious to the skilled person to allow illumination from the substrate face by making both the substrate and the overlying electrode transparent. In fact, document D1 generally suggests alternative arrangements to this extent (column 1, lines 12 to 25).

2.4 The second problem to be solved relative to D1 is that of improving the photovoltaic conversion efficiency of the solar cell.

It is notorious and undisputed that defects in the intrinsic hydrogenated amorphous silicon layer of the solar cell act as recombination sites and hence reduce the cell's conversion efficiency. It follows that the skilled person would realise that a decrease in the defect density of about 10^{15} /cm^3 disclosed in document D1 (column 3, lines 31 to 33 and table 2) to less than 10^{15} defects/ cm^3 as claimed, is bound *ceteris paribus* to increase the conversion efficiency of the solar cell.

A hydrogenated amorphous silicon layer for use in *inter alia* solar cells having a decreased defect density of down to 4.10^{14} cm^{-3} eV^{-1} is known from document D4 (see column 3, lines 1 to 11; column 1, lines 16 to 20). Given the known deleterious effect of semiconductor material defects, the skilled person would consider using this low defect density a-Si:H for the intrinsic layer of the solar cell of document D1 in order to improve its conversion efficiency, thereby arriving at an i-type hydrogenated amorphous silicon layer having a defect density of less than 10^{15} defects/cc as per claim 2.

2.5 As far as the assessment relating to the defect density is concerned the appellant in substance argued that there was no teaching in the cited documents that the defect density should be reduced and that it was taking an overly simplistic view to argue that a skilled person would always, as a matter of principle, seek to reduce the defect density.

By way of analogy the appellant argued that when fuelling a plane, the skilled person would not always completely fill the fuel tanks as a matter of principle, but rather balance the amount of fuel against other factors such as the weight added to the plane.

In the present case, however, the appellant has not instanced any factor that would have prevented the skilled person from at least considering a reduction of the defect density of the intrinsic layer.

2.5.1 As regards D1, the appellant argued that although the two samples shown in Table 1 had different conversion efficiencies, the defect density was stated not to have so large a difference (column 4, lines 30 to 34), from which the skilled person would have concluded that the defect density did not matter.

On the boards' reading of D1 the difference in the initial conversion efficiency of the two samples in Table I of D1 is rather caused by the difference in temperature at which the i-type layer is formed (D1 column 4, lines 13 to 15). On the other hand, it is known that the conversion efficiency is degraded by light irradiation which causes a deterioration of the a-Si:H i-type layer. It is also known that the deterioration of the a-Si:H i-type layer is caused by an increase in the defect density in the layer. Specifically, the initial defect density of about 10^{15} per cm^3 is increased to about 5.10^{16} or more due to light deterioration (D1 column 3, lines 11 to 33 and figure 3). Based hereon, the skilled person would not only be aware that defect density matters and that any

increase is detrimental, but would also be led to consider starting with a lower initial defect density.

2.5.2 Regarding D4, the appellant submitted that this document failed to disclose any consequence of using the low defect density film in solar cells. Moreover, table 2 showed that no improvement was obtained at lower defect densities.

On the board's reading of D4, the low defect density a-Si:H film is intended to overcome problems encountered in conventional films used inter alia in solar cells (see column 1, lines 44 to 48). Specific advantages when used in solar cells are not addressed in D4, but the advantage of a low defect density is obvious from both D1 and D2, as discussed above. Document D4 in this respect confirms the viability of the use of such low defect density layers in solar cells. As to table 2, the data provided do not show any clear correlation and, moreover, the relevance of the parameter "*saturation charge acceptance*" to the solar cells claimed in the present application is not evident.

2.5.3 Furthermore, the appellant argued that document D2 disclosed that the defect density N_d was dependent on the optical band gap and that, therefore, the skilled person would not reduce the defect density. According to document D2 the optimum thickness for a 1.56 eV i-type layer was 800 nm and, hence, much more than the upper limit of 300 nm claimed.

On the board's reading of D2 figure 5 shows *inter alia* the solar cell efficiency as a function of the i-type layer thickness. Two samples are considered with

bandgaps E_{opt} of 1.56 and 1.65 eV, respectively. The sample with a bandgap of 1.65 eV has an optimum thickness of about 200 nm, which falls within the claimed thicknesses. The application is silent about any preference regarding the width of the bandgap. Furthermore, according to document D2, "*this result also indicates that the conversion efficiency is readily improved if N_d is successfully reduced while conserving E_{opt}*" (see sentence bridging pages 307 and 308).

2.5.4 Finally, the appellant argued that the higher production costs would have dissuaded the skilled person from reducing the defect density.

While admitting that evidence in a particular case might lead to a different conclusion, the board does not assent to the general proposition that cost implies technical prejudice. In the present case there is no evidence to suggest any such prejudice.

2.6 For the above reasons the subject-matter of claim 2 is not considered to involve an inventive step within the meaning of Article 56 EPC.

2.7 Claim 1 differs from claim 2 only in that it specifies an p-i-n stacking sequence rather than n-i-p - an alternative which is disclosed in D1 at column 2, line 30.

Hence claim 1 is also not considered to involve an inventive step.

Order

For these reasons it is decided that:

The appeal is dismissed.

Registrar | Chair

G. Nachtigall | R. G. O'Connell