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Case Number: T 0168/15 - 3.4.03

Application Number: 11006399.7

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Title of invention:
Solar cell

Applicant:
LG Electronics Inc.

Headword:

Relevant legal provisions:
EPC Art. 56, 97(2), 111(1)
RPBA Art. 13(1)

Keyword:
Inventive step - main request and auxiliary requests 1 and 2 - (no)
Late-filed auxiliary request 3 - admitted (no)

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Catchword:

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Case Number: T 0168/15 - 3.4.03

D E C I S I O N
of Technical Board of Appeal 3.4.03
of 11 December 2019

Appellant: (Applicant)	LG Electronics Inc. 20, Yeouido-dong Yeongdeungpo-gu Seoul 150-721 (KR)
Representative:	Frenkel, Matthias Alexander Wuesthoff & Wuesthoff Patentanwälte PartG mbB Schweigerstrasse 2 81541 München (DE)
Decision under appeal:	**Decision of the Examining Division of the European Patent Office posted on 28 August 2014 refusing European patent application No. 11006399.7 pursuant to Article 97(2) EPC.**

Composition of the Board:

Chairman	G. Eliasson
Members:	T. M. Häusser
	G. Decker

Summary of Facts and Submissions

I. The appeal concerns the decision of the examining division refusing the European patent application No. 11 006 399 for lack of inventive step (Articles 52(1) and 56 EPC).

II. Reference is made to the following documents:

D1: DE 42 17 428 A1,

D16: DE 10 2007 054 384 A1,

D19: *Handbook of Photovoltaic Science and Engineering*, edited by A. Luque and S. Hegedus, 2003, John Wiley & Sons, pages 255-306.

III. At the oral proceedings before the board the appellant requested that the decision under appeal be set aside and that a patent be granted on the basis of the claims of the main request or, auxiliarily, of one of the auxiliary requests 1 to 3, all requests filed with the letter dated 7 November 2019.

IV. The wording of respective claim 1 of the main request and auxiliary requests 1 to 3 is as follows (board's labelling "(a)", "(a)'", "(b1)", "(b2)", ... , "(i)"):

Main request:

"1. A bifacial solar cell comprising:
(a) a substrate (110) of n-type;
(b1) an emitter layer (120) positioned at a front surface of the substrate (110), the emitter layer (120) being p-type and including a first doped region (121), which is lightly doped with impurities of the p-type, and a second doped region (123), which is more heavily

doped than the first doped region with impurities of the p-type;

a plurality of first electrodes (150) connected to the second doped region (123) of the emitter layer (120);

(c1) a first protective layer (130) positioned on a front surface of the emitter layer (120) where the plurality of first electrodes (150) is not positioned,

(c2) the first protective layer (130) formed of aluminum oxide, AlO_x , having negative fixed charges of the same conductive type as the n-type configured to reduce a surface recombination velocity;

a first anti-reflection layer (140) positioned on the first protective layer (130) and formed of a material having positive fixed charges of the same conductive type as the p-type;

a plurality of back surface field layers (160) locally positioned at a back surface of the substrate (110), the plurality of back surface field layers (160) being an n-type region that is more heavily doped than the substrate (110) with impurities of the same conductive type as the substrate (110);

a plurality of second electrodes (190), each second electrode being connected to a back surface field layer (160) of the plurality of back surface field layers (160);

(d1) a second protective layer (170) positioned on the back surface of the substrate (110) where the plurality of second electrodes (190) is not positioned,

(d2) the second protective layer (170) formed of aluminum oxide, AlO_x ; and

(e) a second anti-reflection layer (180) positioned on a back surface of the second protective layer (170) and formed of a material having positive fixed charges of the same conductive type as the p-type,

(f) wherein each back surface field layer of the plurality of back surface field layers overlaps with a second electrode of the plurality of second electrodes."

Auxiliary request 1:

Claim 1 of the first auxiliary request differs from claim 1 of the main request in that features (a), (b1), (e), and (f) are replaced by the following features (a)', (b1)', (e)', and (g)-(i), respectively:

(a)' "a substrate (110) of a first conductive type, the first conductive type being n-type;"

(b1)' "an emitter layer (120) positioned at a front surface of the substrate (110), the emitter layer (120) being of a second conductive type, the second conductive type being p-type and wherein the emitter layer includes a first doped region (121), which is lightly doped with impurities of the second conductive type, and a second doped region (123), which is more heavily doped than the first doped region with impurities of the second conductive type;"

(e)' "a second anti-reflection layer (180) positioned on a back surface of the second protective layer (170) and formed of a material having positive fixed charges of the same conductive type as the second conductivity type,"

(g) "wherein a width (W3) of each back surface field layer of the plurality of back surface field layers is equal to a width (W2) of a respective second electrode of the plurality of second electrodes,"

(h) "wherein each of the first protective layer and the second protective layer has a refractive index of about 1.55 to 1.7 and a thickness of about 5 nm to 30 nm, and"

(i) "wherein each of the first anti-reflection layer and the second anti-reflection layer has a refractive index of about 1.9 to 2.3 and a thickness of about 50 nm to 100 nm."

Auxiliary request 2:

"1. A method for manufacturing a bifacial solar cell comprising:

forming a substrate (110) of n-type;

forming an emitter layer (120) comprising forming a first doped region (121) using an ion implantation method to lightly inject impurities of p-type on an entire front surface of the substrate (110), and forming a second doped region (123) using the ion implantation method to inject impurities of the p-type into the front surface of the substrate (110) more heavily than for the first doped region (121);

forming a plurality of back surface field layers (160) using the ion implantation method to inject impurities of the n-type into local positions at a back surface of the substrate (110), so that the local positions are more heavily doped than the substrate (110) with impurities of the same conductive type as the substrate (110);

forming a first protective layer (130) and a second protective layer (170) by depositing aluminum oxide, AlO_x, on a front surface of the emitter layer (120) and on the back surface of the substrate (110), respectively;

forming a first anti-reflection layer (140) and a second anti-reflection layer (180) by depositing a material having positive fixed charges of the same conductive type as the p-type on the first protective layer (130) and on a back surface of the second protective layer (170), respectively;

printing a first conductive paste (151) on a front surface of the first anti-reflection layer (140) with a first electrode pattern, wherein the first conductive paste (151) is obtained by mixing a mixture, Ag:Al, of silver, Ag, and aluminum, Al, with a glass frit containing an etching component;

printing a second conductive paste (191) on the back surface of the second anti-reflection layer (180) with a second electrode pattern, wherein the second conductive paste (191) is obtained by mixing silver, Ag, with a glass frit containing an etching component;

performing a firing process on the first conductive paste (151) and the second conductive paste (191),

wherein, in the firing process, the material of the first and second protective layers (130, 170) and the material of the first and second anti-reflection layers (140, 180) are etched by the etching component contained in the glass frit and a plurality of first electrodes (150) connected to the second doped region (123) of the emitter layer (120) are formed and a plurality of second electrodes (190) is formed, each second electrode being connected to a back surface field layer (160) of the plurality of back surface field layers (160)."

Auxiliary request 3:

Claim 1 of auxiliary request 3 differs from claim 1 of the main request in that the following feature (b2) is appended to feature (b1):

(b2) "wherein a thickness of the second doped region (123) is larger than a thickness of the first doped region (121)"

V. The appellant argued essentially as follows:

(a) Main request, auxiliary requests 1 and 2 - inventive step

The appellant submitted that the subject-matter of respective claim 1 of the main request and auxiliary requests 1 and 2 involved an inventive step, in particular over document D1 in combination with document D16.

(b) Auxiliary request 3 - admission

The appellant was of the opinion that the amendments effected in relation to claim 1 of auxiliary request 3 were based on Figures 2 and 4 of the application as filed and related to subject-matter which was not disclosed in document D1. This request should be admitted into the proceedings.

Reasons for the Decision

1. Main request - inventive step

1.1 Closest state of the art

In the decision under appeal the examining division considered document D1 the closest state of the art (see point 4.1 of the Reasons). The appellant also argued inventive step taking document D1 as the starting point.

Indeed, document D1 discloses - as detailed below - subject-matter that is conceived for the same purpose as the claimed invention, namely for providing a bi-facial solar cell, and has the most relevant technical features in common with it. Document D1 is therefore regarded as the closest state of the art.

1.2 Distinguishing features

1.2.1 Document D1 discloses (see column 3, line 38 - column 4, line 2; column 4, lines 19-23; Figures 1-3) a bi-facial solar cell structure with a p- or n-type silicon substrate 1 comprising on its upper side an n^+-layer 2 with a more highly doped n^{++}-region 3 adjacent to the contact area 6. Similarly, on its lower side the substrate 1 comprises a p^+-layer 7 with a more highly doped p^{++}-region 8 adjacent to the contact area 11. Passivation oxide layers 4 and 9 with respective anti-reflection layers 5 and 10, made of silicon nitride, are attached to the n^+-layer 2 and p^+-layer 7, respectively. The embodiment of Figure 3 is a further development of the prior art structure of Figures 1 and 2 which show that the structure is to be repeated horizontally.

1.2.2 The examining division held that the subject-matter of claim 1 of the former main request differed from the solar cell of document D1 in comprising features (c2) and (d2) (see point 4.2 of the Reasons). This was not contested by the appellant.

Indeed, document D1 discloses, using the wording of claim 1 of the main request, a bifacial solar cell comprising:

a substrate (1) of n-type;

an emitter layer (p^+-layer 7 with a more highly doped p^{++}-region 8) positioned at a front surface of the substrate (1), the emitter layer being p-type and including a first doped region (p^+-layer 7), which is lightly doped with impurities of the p-type, and a second doped region (p^{++}-region 8), which is more heavily doped than the first doped region with impurities of the p-type;

a plurality of first electrodes (contact areas 11) connected to the second doped region (p^{++}-region 8) of the emitter layer;

a first protective layer (passivation oxide layer 9) positioned on a front surface of the emitter layer where the plurality of first electrodes is not positioned (see Figure 3, references 9 and 11),

a first anti-reflection layer (10) positioned on the first protective layer (passivation oxide layer 9) and formed of a material having positive fixed charges of the same conductive type as the p-type (layer 10 being made of silicon nitride as in the claimed device, see claims 4 and 5 of the main request);

a plurality of back surface field layers (n^{++}-regions 3) locally positioned at a back surface of the substrate (1), the plurality of back surface field layers (n^{++}-regions 3) being an n-type region that is more heavily doped than the substrate (1) with impurities of the same conductive type as the substrate (1);

a plurality of second electrodes (contact areas 6), each second electrode being connected to a back surface field layer of the plurality of back surface field layers (n^{++}-regions 3);

a second protective layer (passivation oxide layer 4) positioned on the back surface of the substrate (1) where the plurality of second electrodes is not positioned (see Figure 3, references 4 and 6), and

a second anti-reflection layer (5) positioned on a back surface of the second protective layer (passivation oxide layer 4) and formed of a material having positive fixed charges of the same conductive type as the p-type (layer 5 being made of silicon nitride),

wherein each back surface field layer of the plurality of back surface field layers (n^{++}-regions 3) overlaps with a second electrode of the plurality of second electrodes (contact areas 6) (see Figure 3, references 3 and 6).

The subject-matter of claim 1 of the main request differs therefore from the device of document D1 in comprising features (c2) and (d2).

1.3 Objective technical problem

1.3.1 The appellant argued that the distinguishing features had the effect of reducing a surface recombination velocity and that the technical problem was therefore to improve the efficiency and reliability of the solar cell.

1.3.2 However, the board notes that it is explicitly stated in the description of the application (see paragraph [0028]) that when a layer is referred to as being "on" another element, it can either be directly on the other element or intervening elements may be present. Accordingly it is foreseen in the application that a silicon oxide layer may be provided at interfaces between the first protective layer and the substrate and between the second protective layer and the substrate (see paragraph [0081] of the description of the application). Hence, features (c1) and (d1) of claim 1 of the main request have to be understood such that intervening layers may well be present between the substrate and

the first and second protective layers, respectively. The claimed first and second protective layer are therefore not considered to have the alleged technical effect of reducing the recombination velocity at the surface of the substrate.

On the other hand, in document D1 it is merely disclosed that the passivation oxide layers 4 and 9 are fabricated by thermal oxidation without specifying any details as to their composition (see D1, sentence bridging columns 3 and 4).

In view of the above the objective technical problem is considered to be the implementation of the passivation layers.

1.4 Obviousness

1.4.1 In the decision under appeal the examining division held that claim 1 of the former main request did not involve an inventive step in view of document D1 in combination with document D16 (see point 4.3 of the Reasons).

1.4.2 The appellant was of the opinion that document D16 did not relate to a bifacial solar cell and would not have been considered by the skilled person for solving the posed technical problem. Furthermore, even if the document was taken into account it would not lead the skilled person to the claimed invention as it only disclosed that the aluminum oxide layer was provided on one side of the substrate.

1.4.3 Document D16 relates to a solar cell comprising a silicon substrate and passivating layers, in particular with a first dielectric layer comprising aluminum oxide

and a second dielectric anti-reflection layer comprising silicon nitride (see D16, paragraphs [0001], [0011], and [0026]; claims 1 and 3).

Document D16 resides in the same technical field as the claimed invention, namely the field of solar cells, and discloses details concerning the disclosed passivation layers. The skilled person would therefore consider document D16 when attempting to solve the posed technical problem.

Furthermore, document D16 discloses the crucial piece of information, namely that a passivation layer may be made of aluminum oxide, and would thus lead the skilled person to consider implementing the passivation layers of document D1 using this material. The fact that document D16 does not relate to bifacial solar cells or that it does not disclose passivation layers on both sides of the substrate is not relevant in this respect since these attributes are already known from the closest state of the art document D1.

In view of document D16 the skilled person would therefore implement the passivation layers of document D1 as aluminum oxide layers thereby arriving at the claimed subject-matter without exercising any inventive skills.

Hence, the subject-matter of claim 1 of the main request does not involve an inventive step (Articles 52(1) and 56 EPC).

2. Auxiliary request 1 - inventive step

2.1 Distinguishing features / objective technical problem

2.1.1 Claim 1 of auxiliary request 1 differs from claim 1 of the main request - apart from a slight rewording in features (a)', (b1)', and (e)' - in that feature (f) is replaced by features (g)-(i).

The examining division considered feature (g) and the claimed refractive index of the first and second anti-reflection layers (part of feature (i)) to be disclosed in document D1 (see point 5.1 of the Reasons of the decision).

2.1.2 The board agrees with the examining division's assessment. Indeed, feature (g) follows from the corresponding manufacturing steps e) and f) described in document D1 (see column 3, lines 15-22) and is also shown in Figure 3 of D1 (see references 3 and 6). Moreover, the anti-reflection layers 5 and 10 of the device of D1 are made of the same material, namely silicon nitride (see D1, column 4, lines 19-23), as the claimed device (see claims 3 and 4 of the main request). Hence, the fact that the refractive index of the first and second anti-reflection layers are in the claimed range (part of feature (i)), which reflects standard values of typical silicon nitride compositions under normal working conditions for solar cells, is considered implicitly disclosed in document D1.

Furthermore, the claimed thickness of the first and second protective layers (part of feature (h)) is also disclosed in document D1 (see column 4, lines 48-55).

The subject-matter of claim 1 of auxiliary request 1 differs therefore from the device of the closest state of the art document D1 in comprising features (c2) and (d2), the first and second protective layers having the claimed refractive index (part of feature (h)) and the

first and second anti-reflection layers having the claimed thickness (part of feature (i)).

In view of these differences the objective technical problem is considered to be the implementation of the passivation and anti-reflection layers.

2.2 Obviousness

Under point 1. above it was shown that it would be obvious for the skilled person to implement the passivation layers of document D1 as aluminum oxide layers. In the board's opinion the skilled person would in particular consider such specific compositions having a refractive index within the claimed range, which provides merely standard values of typical aluminum oxides under normal working conditions.

Moreover, in document D1 the anti-reflection layers are described to be "several 100 Å" thick (see column 4, lines 19-23), i. e. several tens of nanometers. The board considers that it would be obvious for the skilled person and represents merely an arbitrary choice among various possibilities to select the actual thickness of the anti-reflection layers to have a value within the claimed range (50 nm to 100 nm) when implementing the anti-reflection layers.

In view of the above the subject-matter of claim 1 of auxiliary request 1 does not involve an inventive step (Articles 52(1) and 56 EPC).

3. Auxiliary request 2 - inventive step

3.1 Distinguishing features / objective technical problem

3.1.1 Claim 1 of auxiliary request 2 relates to a method of manufacturing the bifacial solar cell of claim 1 of the main request by means of

- ion implantation for forming the emitter layer and the back surface field layers,
- deposition of the protective and anti-reflection layers and
- printing conductive pastes on the anti-reflection layers followed by a firing process for forming the plurality of first and second electrodes.

3.1.2 Document D1 discloses that the anti-reflection layers are manufactured using a deposition method, namely vapour deposition (see D1, claim 10). On the other hand, the passivation layers are manufactured using thermal oxidation and the n^+-layer 2 with the more highly doped n^{++}-region 3 and the p^+-layer 7 with the more highly doped p^{++}-region 8 are fabricated using a diffusion method. Moreover, the contacts 6 and 11 are fabricated using screen printing techniques (see D1, column 3, lines 1-22; column 3, line 64 - column 4, line 7; column 4, line 68 - column 5, line 2; claims 1 and 6).

Hence, the claimed method differs from the method of the closest state of the art document D1 in that the resulting bifacial solar cell comprises protective layers formed of aluminum oxide and in that ion implantation is used for forming the emitter layer and the back surface field layers, a deposition method is used for forming the passivation layers, and printing and firing processes are used for making the plurality of first and second electrodes.

3.1.3 The appellant argued that the claimed manufacturing method was fast, easy and highly efficient.

The objective technical problem is therefore to implement the passivation layers by using a fast, easy and highly efficient manufacturing method.

3.2 Obviousness

3.3 The skilled person constantly endeavours to improve the processes of manufacturing solar cells, in particular in relation to their speed, efficiency and ease of use.

Moreover, ion implantation methods for generating desired doping levels in the substrate, deposition methods for producing various layers, and methods of fabricating electrodes by means of printing a conductive paste comprising a glass frit with an etching component followed by a firing process are standard and well-known in the relevant technical field of solar cells (see, for example, section 7.4.2 of document D19). The skilled person is also aware of the advantages and disadvantages of the different manufacturing techniques and will use those methods which provide the desired advantages. It is therefore obvious for the skilled person to adapt the manufacturing processes of document D1 and use these other known techniques in order to fabricate the solar cell with the structure as claimed in claim 1 of the main request (shown to be obvious under point 1. above).

Hence, the subject-matter of claim 1 of auxiliary request 2 also lacks inventive step (Articles 52(1) and 56 EPC).

4. Auxiliary request 3 - admission

4.1 Auxiliary request 3 was filed about one month before the date of the oral proceedings before the board. The request constitutes therefore an amendment to the appellant's case after it has filed its grounds of appeal and may be admitted into the proceedings and considered at the board's discretion (Article 13(1) RPBA).

4.2 In accordance with established case law, late-filed auxiliary requests are inadmissible if - *prima facie* - they do not overcome the outstanding objections under the EPC or give rise to new objections (see *Case Law of the Boards of Appeal of the EPO*, 9th edition 2019, sections V.A.4.4.2 and 4.5.1).

4.3 Claim 1 of auxiliary request 3 differs from claim 1 of the main request in that feature (b2) relating to the thickness of the second doped region being larger than a thickness of the first doped region is added to the claim.

4.3.1 The appellant was of the opinion that the amendment was based on Figures 2 and 4 of the application as filed.

In paragraph [0062] of the description of the application it is stated that the region 123 of the emitter layer 120 is more heavily doped than the region 121 of that layer 120. However, even though in Figures 2 and 4 the region 123 is shown thicker than region 121, this may well be merely a means of highlighting that specific part of the emitter layer 120 in these schematic Figures without reflecting the relative thicknesses of the regions 121 and 123 of the emitter layer 120.

Hence, *prima facie*, auxiliary request 3 gives rise to a new objection under Article 123(2) EPC concerning added subject-matter.

4.3.2 Moreover, the appellant has not stated which technical problem was addressed by the subject-matter of the added feature, nor is this evident to the board.

Therefore, auxiliary request 3 does not, *prima facie*, overcome the objection concerning lack of inventive step.

4.4 In view of the above auxiliary request 3 is not admitted into the proceedings (Article 13(1) RPBA).

5. Conclusion

Since the subject-matter claimed according to the main request and auxiliary requests 1 and 2 does not involve an inventive step and auxiliary request 3 is not admitted into the proceedings, the examining division's decision refusing the application is confirmed. Consequently the appeal has to be dismissed (Articles 97(2) and 111(1) EPC).

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

S. Sánchez Chiquero G. Eliasson

Decision electronically authenticated