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73 Octrooihouder(s):

**ATLAS TECHNOLOGIES HOLDING B.V.
te Helmond**

72 Uitvinder(s):

**Hendrik Slingerland te Venlo
Durandus Dijken te Eindhoven**

74 Gemachtigde:

Geen

54 **Crystalline semiconductor chip that can be curved in two directions**

57 The invention relates to a method for producing a chip that can be curved in two direction, the chip showing a periphery, the method comprising a step of providing a chip, the method characterized in that the method comprises a step of making through-slots (6, 7, 8, 9) in the chip. By dividing the chip (such as a photovoltaic cell or a logic chip) in number of connected flaps, a chip is formed with a high degree of flexibility that can be used using a small number of electrical connections.

Crystalline semiconductor chip that can be curved in two directions

Technical field of the invention.

[0001] The invention relates to a method for producing a crystalline semiconductor chip
5 that can be curved in two direction, the chip showing a periphery, the method comprising
a step of providing a chip

Acknowledgement.

[0002] The project leading to this application has received funding from the European
10 Union's Horizon 2020 research and innovation program under grant agreement No.
848620.

Background of the invention.

[0003] In the context of this invention the phrase 'chip' includes 'solar cell', also known as
15 'photovoltaic cell' or 'PV cell'. These phrases are used interchangeable.

[0004] Thin chips, such as certain types of crystalline silicon solar cells, can be curved.
Curving the chip enables the chip to be attached to a curved transparent cover, as shown
in, for example, US patent application US2019/0181283A1 to Toyota, further referred to
as Toyota [-1-]. Toyota [-1-] describes how a sandwich of a flat back plate, a sealant
20 (encapsulant), strings of interconnected solar cells, and finally another sealant
(encapsulant) are heated and pressed together by a curved jig and a similarly curved
transparent cover plate. The result is a curved solar panel comprising the transparent
cover and bonded to that encapsulated solar cells.

[0005] A solar cell is mostly rectangular (although other forms such as hexagonal or
25 octagonal are known). To achieve a high flexibility (to achieve small radius of curvature)
such a cell has a thickness of, for example, 80 μm . Although a smaller thickness would
increase the flexibility, this results in an increase of transparency of the solar cell and thus
a reduced efficiency.

[0006] Another example of curved chips is described in, for example, "Ultra-thin chips for
30 high-performance flexible electronics", Gupta, S *et al.* . npj Flex Electron **2**, 8 (2018).
<https://doi.org/10.1038/s41528-018-0021-5>, further referred to as Gupta [-2-].

[0007] It is noted that bending a chip in only one direction results in much lower
mechanical stress than when bending locally a chip in two directions. Therefore, a solar
cell (a chip) can be bended, (flexed) in only one direction only, or, more accurate, it may
35 not show local bending in two directions as happens in a saddle point or a dome, as

otherwise the resultant stress may exceed the fracture limit, resulting in fracture of the chip.

[0008] It is further noted that a flexible chip must not be confused with a MEMS chip, in which a small (surface) part of a chip can be flexed with respect to the flat (non-flexible)

5 bulk of the chip.

[0009] As known to the skilled artisan a solution for this problem is to divide the chip into a multitude of smaller chips, in which each chip can be seen as flat or curved in one direction, with a negligible curvature in another direction. A disadvantage of using a large number of solar cells or flexible chips is that the amount of interconnection raises as well.

10 Also, the positioning of the cells involves the positioning of a large number of cells or flexible chips. This results in more expensive and error prone solar panels or flexible electronic circuit.

Summary of the invention.

15 [0010] The invention intends to provide flexible chips with a larger surface area, more specifically solar cells to be used in conjunction with double curved (3D curved) transparent covers.

[0011] To that end the method according to the invention is **characterized in that** the method comprises a step of making through-slots in the chip.

20 [0012] By making through-slots in the chip, the chip is divided in several connected 'flaps'. Each of these flaps can flex (bend) independent from others, When the chip is a solar cell with one side being the anode and the other side the cathode, each flap can bend while anode side and the cathode side stay interconnected. When the chip is an electronic chip interconnection lines (wires) between the flaps stay available for
25 interconnection. The through-slots thus enable the chip to be bend or flex in two directions, while interconnection between the flaps stay possible.

[0013] It is noted that when forming such a through-slot, a small area bordering the through slot will become inactive. However, as known to the skilled artisan, this is also the case when several separate chips are bordering each other, as any border (several
30 microns to tens of microns) of a chip becomes unavailable for electronic processes due to the high number of recombination sites and crystal imperfections occurring there.

[0014] In an embodiment of the method according to the invention while forming the through-slots, material is removed from the chip.

35 [0015] When forming the through-slots, for example by laser cutting, typically material is removed (ablated or cut-out). This can equally well happen using other machining techniques, such as water jet cutting, or chemical techniques such as (anisotropic)

etching. In the latter case it may be well combined with wafer techniques in which also the metallization etc. is formed.

5 [0016] In a further embodiment of the method according to the invention, as a result of the removal of material, in curved condition no parts of the chip overlaps with another part.

[0017] By modifying (cutting away) the area of the chip such, that in curved condition no parts of the chip touch each other or overlap each other, the thickness of the curved chip is identical to the non-curved chip. Also, no shorts between anode and cathode will occur.
10

[0018] In another embodiment of the method according to the invention at least one of the through-slots is completely surrounded by the periphery of the chip.

[0019] Here the through-slot is completely within the periphery of the chip. Forming, for example, two perpendicular through-slots intersecting each other, four flaps are formed that are held together at the edges. In the case of a solar cell the edges can be used to
15 contact neighboring cells using, for example, finger electrodes.

[0020] In a preferred embodiment of the method according to the invention at least one of the through-slots intersects the periphery of the chip.

20 [0021] This results in several flap held together at, for example, the center. In the case of a solar cell the anode and the cathode can be contacted using, for example, a back-contact foil contacting electrodes in the center, a method of interconnecting cells known to the skilled artisan.

25 [0022] In another embodiment of the method according to the invention the chip is a solar cell.

[0023] Especially solar cells (also known as photovoltaic cells) are typically large chips (tens of square centimeters). When such large chips are used in solar vehicles or building integrated photovoltaic systems (BIPS), there is often a desire to curve them in two
30 directions (for efficiency or esthetic reasons). As an example the solar panel of a solar car such as the Lightyear 1, sold by Atlas Technologies, Helmond, the Netherlands, is curved in two directions. Such curved large cells benefit from this invention as it enables the use of much larger cells using less interconnections.

35 **Brief description of the drawings.**

[0024] The invention is now elucidated using figures, in which identical reference signs indicate corresponding features. To that end:

Figure 1A schematically shows a chip with four through-slots from the periphery inwards,

Figure 1B schematically shows a chip with a multitude of through-slots,

5 Figure 1C schematically shows a chip with four through-slots from the center outwards,

Figure 1D schematically shows a chip with a through-slot in the form of a spiral,

Figure 1E schematically shows a chip with fractal-like through-slots. and

Figure 2 schematically shows a detail of the end of a through-slot.

10 **Detailed description of the invention.**

[0025] Figure 1A schematically shows a chip with four through-slots from the periphery inwards.

[0026] Here a chip is formed in which four flaps 1, 2, 3 and 4 are connected by a common center 5. Each of the flaps can now show curvature around its individually axis.

15 The requirement that for a whole chip curvature may only occur in one direction is now that curvature for each flap may occur in one direction, but that the curvature of different flaps may occur in different directions. For a solar cell the centerpart is the most convenient place to position electrodes (anode, cathode) upon, as it shows the smallest average distance from any of the parts of the chip, and thus the lowest resistivity. For an
20 electronic chip the centerpart is the part where all interconnections between circuitry on the flaps must pass, but the electrodes where the 'bumps' are connected to the lead frame

[0027] Figure 1B schematically shows a chip with a multitude of through-slots.

25 [0028] A chip with a multitude of through-slots in a form resembling a fish-bone structure offer a large degree of freedom, as this implies a multitude flaps, each with its own curvature.

[0029] Figure 1C schematically shows a chip with four through-slots from the center
30 outwards,

[0030] Instead of four flaps connected by a common center, here four flaps are shown with a common periphery

[0031] Figure 1D schematically shows a chip with a through-slot in the form of a spiral.

35 [0032] The through-slot need not be a straight line, but can also be a curved or a angular line, depending on the requirements.

[0033] Figure 1E schematically shows a chip with fractal-like through-slots.

[0034] Here the through-slots are formed in a fractal like pattern, dividing the chip in a multitude of flaps, offering high flexibility of the chip.

5 [0035] Figure 2 schematically shows a detail of the end of a through-slot.

[0036] At the end of the through-slot where it ends in the chip, mechanical stresses concentrate, possibly leading to fracture etc. To avoid this, said end is best formed such, that no sharp edges occur, but for example ending as a small circular hole, as shown in this figure 2 and figure 1A.

10

Cited non-patent literature.

[-2-] "Ultra-thin chips for high-performance flexible electronics", Gupta, S *et al.* . npj Flex Electron **2**, 8 (2018). <https://doi.org/10.1038/s41528-018-0021-5>.

Conclusies.

1. Werkwijze voor het produceren van chips die in twee richtingen kunnen worden gebogen, waarbij de chips een periferie vertonen, waarbij de werkwijze een stap omvat van het verschaffen van chips, waarbij de werkwijze wordt gekenmerkt doordat de werkwijze een stap omvat van het maken van doorgaande gleuven (6, 7, 8, 9) in de chips.
5
2. Werkwijze volgens conclusie 1, waarbij tijdens de stap van het maken van doorgaande gleuven materiaal van de chip wordt verwijderd.
10
3. Werkwijze volgens conclusie 2, waarbij als gevolg van het verwijderen van materiaal in gebogen toestand geen delen van de chip overlappen met een ander deel.
4. Werkwijze volgens één der voorgaande conclusies, waarbij ten minste één van de doorgaande gleuven volledig is omgeven door de omtrek van de chip.
15
5. Werkwijze volgens één der voorgaande conclusies, waarbij ten minste één van de doorgaande gleuven de omtrek van de chip kruist.
- 20 6. Werkwijze volgens een van de voorgaande conclusies, waarbij de chip een fotonvoltaïsche cell is.

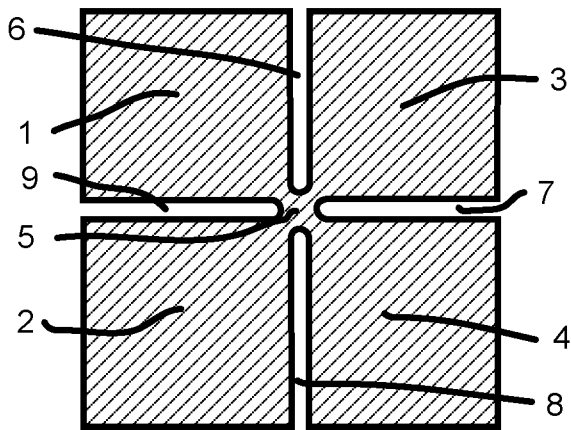


FIG. 1A

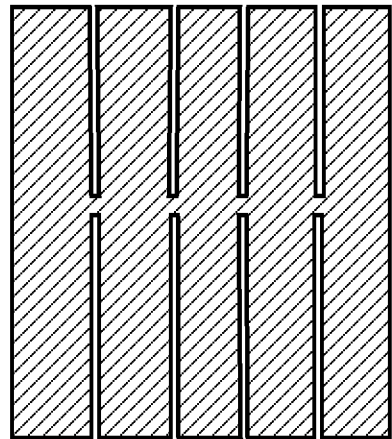


FIG. 1B

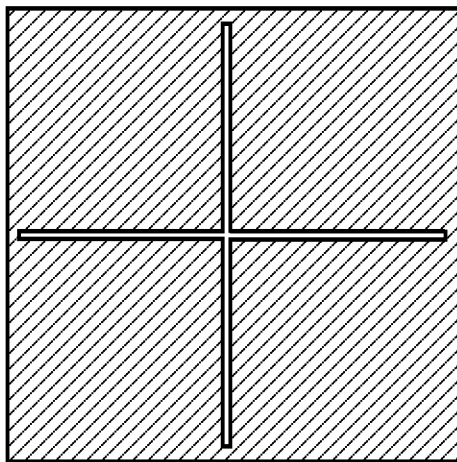


FIG. 1C

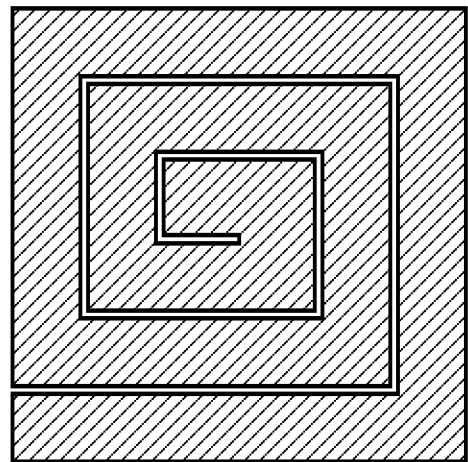


FIG. 1D

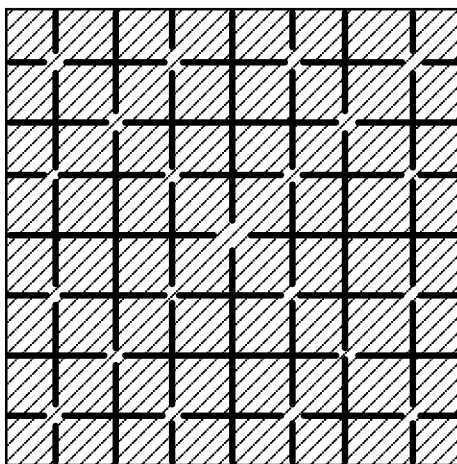


FIG. 1E

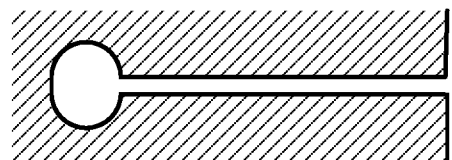


FIG. 2

SAMENWERKINGSVERDRAG (PCT)

RAPPORT BETREFFENDE NIEUWHEIDSONDERZOEK VAN INTERNATIONAAL TYPE

IDENTIFICATIE VAN DE NATIONALE AANVRAGE	KENMERK VAN DE AANVRAGER OF VAN DE GEMACHTIGDE PAT2020-002NL
Nederlands aanvraag nr. 2024940	Indieningsdatum 19-02-2020
	Ingeroepen voorrangdatum
Aanvrager (Naam) ATLAS TECHNOLOGIES HOLDING B.V.	
Datum van het verzoek voor een onderzoek van internationaal type 11-04-2020	Door de Instantie voor Internationaal Onderzoek aan het verzoek voor een onderzoek van internationaal type toegekend nr. SN75975
I. CLASSIFICATIE VAN HET ONDERWERP (bij toepassing van verschillende classificaties, alle classificatiesymbolen opgeven)	
Volgens de internationale classificatie (IPC) Zie onderzoeksrapport	
II. ONDERZOCHE GEBIEDEN VAN DE TECHNIEK	
Onderzochte minimumdocumentatie	
Classificatiesysteem	Classificatiesymbolen
IPC	Zie onderzoeksrapport
Onderzochte andere documentatie dan de minimum documentatie, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen	
III. <input type="checkbox"/>	GEEN ONDERZOEK MOGELIJK VOOR BEPAALDE CONCLUSIES (opmerkingen op aanvullingsblad)
IV. <input type="checkbox"/>	GEBREK AAN EENHEID VAN UITVINDING (opmerkingen op aanvullingsblad)

**ONDERZOEKSRAPPORT BETREFFENDE HET
RESULTAAT VAN HET ONDERZOEK NAAR DE STAND
VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE**

Nummer van het verzoek om een onderzoek naar
de stand van de techniek

NL 2024940

<p>A. CLASSIFICATIE VAN HET ONDERWERP INV. H01L31/0352 H01L31/042 ADD.</p>		
<p>Volgens de Internationale Classificatie van octrooien (IPC) of zowel volgens de nationale classificatie als volgens de IPC.</p>		
<p>B. ONDERZOCHETE GEBIEDEN VAN DE TECHNIEK</p>		
<p>Onderzochte minimum documentatie (classificatie gevolgd door classificatiesymbolen) H01L</p>		
<p>Onderzochte andere documentatie dan de minimum documentatie, voor dergelijke documenten, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen</p>		
<p>Tijdens het onderzoek geraadpleegde elektronische gegevensbestanden (naam van de gegevensbestanden en, waar uitvoerbaar, gebruikte trefwoorden) EPO-Internal, WPI Data</p>		
<p>C. VAN BELANG GEACHTE DOCUMENTEN</p>		
Categorie °	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
X	US 2014/283898 A1 (PILAT ERIC [FR] ET AL) 25 september 2014 (2014-09-25) * het gehele document *	1-4,6
X	WO 2018/042416 A1 (ROSENFELD HILLEL [IL]; ALONSO GUTIERREZ JUAN CARLOS [CN]) 8 maart 2018 (2018-03-08) * bladzijde 3; figuren 4,5 *	1-3,5,6
X	WO 2012/154211 A1 (NAT UNIV TSING HUA; FAN LONG-SHENG) 15 november 2012 (2012-11-15) * alineas [0037] - [0041]; figuren 3A-3C *	1
<p><input type="checkbox"/> Verdere documenten worden vermeld in het vervolg van vak C. <input checked="" type="checkbox"/> Leden van dezelfde octrooifamilie zijn vermeld in een bijlage</p>		
<p>° Speciale categorieën van aangehaalde documenten</p> <p>"A" niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft</p> <p>"D" in de octrooiaanvraag vermeld</p> <p>"E" eerdere octrooi(aanvraag), gepubliceerd op of na de indieningsdatum, waarin dezelfde uitvinding wordt beschreven</p> <p>"L" om andere redenen vermelde literatuur</p> <p>"O" niet-schriftelijke stand van de techniek</p> <p>"P" tussen de voorrangsdatum en de indieningsdatum gepubliceerde literatuur</p>		<p>"T" na de indieningsdatum of de voorrangsdatum gepubliceerde literatuur die niet bezwarend is voor de octrooiaanvraag, maar wordt vermeld ter verheldering van de theorie of het principe dat ten grondslag ligt aan de uitvinding</p> <p>"X" de conclusie wordt als niet nieuw of niet inventief beschouwd ten opzichte van deze literatuur</p> <p>"Y" de conclusie wordt als niet inventief beschouwd ten opzichte van de combinatie van deze literatuur met andere geciteerde literatuur van dezelfde categorie, waarbij de combinatie voor de vakman voor de hand liggend wordt geacht</p> <p>"&" lid van dezelfde octrooifamilie of overeenkomstige octrooipublicatie</p>
<p>Datum waarop het onderzoek naar de stand van de techniek van internationaal type werd voltooid</p> <p>29 oktober 2020</p>		<p>Verzenddatum van het rapport van het onderzoek naar de stand van de techniek van internationaal type</p>
<p>Naam en adres van de instantie</p> <p>European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016</p>		<p>De bevoegde ambtenaar</p> <p>Persat, Nathalie</p>

**ONDERZOEKSRAPPORT BETREFFENDE HET
RESULTAAT VAN HET ONDERZOEK NAAR DE STAND
VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE**

Informatie over leden van dezelfde octrooifamilie

Nummer van het verzoek om een onderzoek naar
de stand van de techniek

NL 2024940

In het rapport genoemd octrooigeschrift	Datum van publicatie	Overeenkomend(e) geschrift(en)	Datum van publicatie	
US 2014283898	A1	25-09-2014	CN 103918176 A	09-07-2014
			EP 2751844 A2	09-07-2014
			FR 2979752 A1	08-03-2013
			JP 2014532293 A	04-12-2014
			KR 20140080489 A	30-06-2014
			US 2014283898 A1	25-09-2014
			WO 2013030342 A2	07-03-2013

WO 2018042416	A1	08-03-2018	IL 247556 A	30-05-2019
			WO 2018042416 A1	08-03-2018

WO 2012154211	A1	15-11-2012	AU 2011367826 A1	19-12-2013
			AU 2016200484 A1	18-02-2016
			EP 2705536 A1	12-03-2014
			JP 5907633 B2	26-04-2016
			JP 6307543 B2	04-04-2018
			JP 6541194 B2	10-07-2019
			JP 2014527279 A	09-10-2014
			JP 2016178296 A	06-10-2016
			JP 2018098512 A	21-06-2018
			KR 20140074870 A	18-06-2014
			KR 20170095411 A	22-08-2017
			WO 2012154211 A1	15-11-2012

WRITTEN OPINION

File No. SN75975	Filing date (<i>day/month/year</i>) 19.02.2020	Priority date (<i>day/month/year</i>)	Application No. NL2024940
International Patent Classification (IPC) INV. H01L31/0352 H01L31/042			
Applicant ATLAS TECHNOLOGIES HOLDING B.V.			

This opinion contains indications relating to the following items:

- Box No. I Basis of the opinion
- Box No. II Priority
- Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- Box No. IV Lack of unity of invention
- Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- Box No. VI Certain documents cited
- Box No. VII Certain defects in the application
- Box No. VIII Certain observations on the application

	Examiner Persat, Nathalie
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WRITTEN OPINION**Box No. I Basis of this opinion**

1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.
2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the application and necessary to the claimed invention, this opinion has been established on the basis of:
 - a. type of material:
 - a sequence listing
 - table(s) related to the sequence listing
 - b. format of material:
 - on paper
 - in electronic form
 - c. time of filing/furnishing:
 - contained in the application as filed.
 - filed together with the application in electronic form.
 - furnished subsequently for the purposes of search.
3. In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
4. Additional comments:

Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty	Yes: Claims	
	No: Claims	1-6
Inventive step	Yes: Claims	
	No: Claims	1-6
Industrial applicability	Yes: Claims	1-6
	No: Claims	

2. Citations and explanations

see separate sheet

WRITTEN OPINION

Application number
NL2024940

Box No. VIII Certain observations on the application

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1 Reference is made to the following documents:

D1 US 2014/283898 A1 (PILAT ERIC [FR] ET AL) 25 september 2014 (2014-09-25)

D2 WO 2018/042416 A1 (ROSENFELD HILLEL [IL]; ALONSO GUTIERREZ JUAN CARLOS [CN]) 8 maart 2018 (2018-03-08)

D3 WO 2012/154211 A1 (NAT UNIV TSING HUA; FAN LONG-SHENG) 15 november 2012 (2012-11-15)

2 The present application does not meet the criteria of patentability, because the subject-matter of claim 1 is not new.

D1 discloses (Figs. 2-6, [0031]-[0038]):

Werkwijze voor het produceren van chips die in twee richtingen kunnen worden gebogen ([0034] "the network of notches 17 is calculated beforehand using techniques of the type used in origami, in order to obtain whatever three-dimensional shape is desired"; par. [0037] "this principle may also be used more generally to cover any non-planar surface, such as the surface of an automotive vehicle for example, with photovoltaic devices"), waarbij de chips een periferie vertonen, waarbij de werkwijze een stap omvat van het verschaffen van chips (par. [0031] "This process first comprises the manufacture of a silicon-based photovoltaic cell 12"), waarbij de werkwijze een stap omvat van het maken van doorgaande gleuven in de chips (par. [0034] "a step of producing notches 17, extending through all or part of the thickness of the photovoltaic cells 12"; "As a variant, all or some of the notches may even extend through part of the thickness of the flexible substrate").

3 The present application does not meet the criteria of patentability, because the subject-matter of claim 1 is not new.

D2 discloses (Figs. 4-5, page 3):

Werkwijze voor het produceren van chips die in twee richtingen kunnen worden gebogen (Fig. 5), waarbij de chips (10) een periferie vertonen, waarbij de werkwijze een stap omvat van het verschaffen van chips (10), waarbij de werkwijze een stap omvat van het maken van doorgaande gleuven (52A, 52B;

- Empty area 52A includes line cuts 54A and 54B both extending from a point 56A; empty area 52B includes line cuts 54C and 54D both extending from a point 56B) in de chips ("the cutting of Fig. 4 cuts each of solar cells").
- 4 The present application does not meet the criteria of patentability, because the subject-matter of claim 1 is not new.
- D3 discloses (Figs. 3A-3C, par. [0037]-[0041]):
- Werkwijze voor het produceren van chips die in twee richtingen kunnen worden gebogen (Fig. 3B), waarbij de chips een periferie vertonen (Fig. 3A), waarbij de werkwijze een stap omvat van het verschaffen van chips (Fig. 3A), waarbij de werkwijze een stap omvat van het maken van doorgaande gleuven (301, 303) in de chips.
- 5 Dependent claims 2-6 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of novelty, see documents D1 and D2.
- D1 discloses "tijdens de stap van het maken van doorgaande gleuven materiaal van de chip wordt verwijderd" (par. [0034] "The notches are produced by any process, such as by laser etching.").
- D1 discloses "als gevolg van het verwijderen van materiaal in gebogen toestand geen delen van de chip overlappen met een ander deel" (Fig. 6). Reference is also made to D2, Fig. 5
- D1 discloses "ten minste één van de doorgaande gleuven volledig is omgeven door de omtrek van de chip" (Fig. 6).
- D2 discloses "ten minste één van de doorgaande gleuven de omtrek van de chip kruist" (Fig. 4).
- In each of D1 and D2, the chip is a photovoltaic cell.

Re Item VIII

Certain observations on the application

Claims 1-5 are not supported by the description, as their scope is broader than justified by the description and drawings. Claims 1-4 concern any type of chips. The description however merely refers to a solar cell as a chip, not to any chip.