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(54) **Apparatus and method for the production of semiconductor material foils.**

(57) A casting device for producing semiconductor material foil includes a casting frame and a substrate band. The casting frame is arranged for holding a molten semiconductor material and includes sidewalls of which an exit sidewall is located at an output position for the semiconductor material foil. The exit side wall is provided with an exit slit. The casting device further includes a force exerting means to exert at the location of the exit slit an external force on the molten semiconductor material to enlarge an outer pressure on the molten material.

Apparatus and method for the production of semiconductor material foils

The invention relates to an apparatus for the production of crystalline semiconductor foils which is arranged for drawing a semiconductor material foil from a volume of molten fluid semiconductor. Additionally, the present invention relates to a method the production of semiconductor material foils.

Such an apparatus is for example known from international patent application WO 2005/122287, which discloses a casting device for the production of crystalline silicon foils.

The casting device consists of a casting frame into which fluid silicon can be poured. The fluid silicon is poured from a furnace into the casting frame with the aid of a feed device. Below the casting frame there is a substrate band that is set up to pass underneath the casting frame at a specific speed. Because the substrate band is moving, a silicon foil or sheet will be produced on a downstream side of the casting frame. The silicon foil can be cut into wafers which can be used for manufacturing photo-voltaic devices. The substrate band can exist of a plurality of (semi-)linked substrate plates, resulting in the production of separate wafers.

A disadvantage of the prior art casting device is that wafers manufactured in this manner often show a rough top-surface (i.e., a free-crystallizing surface). This rough surface results from the drag-out of a molten silicon film on top of the crystallized foil. During the casting process the silicon foil starts to grow at the moment (a portion of) the substrate band comes in contact with the molten silicon. During its pass underneath the casting frame in contact with the molten silicon, the silicon wafer grows to its desired thickness. At the exit of the casting frame the molten silicon is hold-back by the casting frame exit wall. As the casting frame exit wall can move in vertical direction to accommodate variations in foil thickness a small amount of molten silicon is extracted from the casting frame on top of the solid silicon foil. After leaving the casting frame, this liquid crystallizes during cooling down in a less controlled way, causing a rough wafer surface. In a subsequent step, the rough surface must be removed e.g., by polishing.

It is an object of the present invention to reduce or overcome the disadvantages of the prior art.

The object is achieved according to the invention by a casting device for producing semiconductor material foil, comprising a casting frame and a substrate band, the casting frame being arranged for holding a molten semiconductor material and comprising sidewalls of which an exit sidewall is located at an output position for the semiconductor material foil, the exit side wall being provided with an exit slit, wherein the casting device further comprises a force exerting means to exert at the location of the exit slit an external force on the molten semiconductor material to enlarge an outer pressure on the molten semiconductor material.

Advantageously, the present invention allows to reduce the drag-out of liquid molten semiconductor material, by providing an external force to enlarge the outer pressure and as a consequence reduce the static pressure of the liquid semiconductor material in the casting frame. As a result, the outflow of the liquid semiconductor material at the exit slit is better controlled and the drag-out reduced.

According to an aspect of the invention there is provided a casting device as described above, wherein the force exerting means comprises a gas jet generator for producing a gas jet with relatively high pressure compared to the ambient pressure at the location of the exit slit; the gas jet generator being arranged for directing the gas jet towards the exit slit.

According to an aspect of the invention there is provided a casting device as described above, wherein the gas jet generator comprises an inlet for pressurized gas, a duct and an outlet for producing the gas jet; the inlet being connected to the duct and the duct being connected to the outlet.

According to an aspect of the invention there is provided a casting device as described above, wherein the force exerting means comprises an overpressure device; the overpressure device being arranged at the exit sidewall of the casting device and is adapted for producing at the location of the exit slit an overpressure relative to the outer pressure.

According to an aspect of the invention there is provided a casting device as described above, wherein the overpressure device comprises an inlet for pressurized gas, a pressure leveling chamber, and an overpressure chamber ; the inlet being connected with an entrance of the pressure leveling chamber, an exit of the pressure leveling chamber being in communication with the overpressure chamber, the overpressure chamber being located at the exit slit of the casting frame.

According to a further aspect there is provided a casting device as described above wherein the pressure leveling chamber extends along the width of the exit side wall and is adapted for leveling the pressure of the gas along the width of the exit side wall and the overpressure chamber extends substantially along the full width of the exit slit.

According to a further aspect there is provided a casting device as described above, wherein the pressure leveling chamber is connected to the overpressure chamber over the full width of the side wall so as to create a substantially constant pressure in the overpressure chamber over the full width of the exit slit.

According to a further aspect there is provided a casting device as described above, wherein the overpressure device comprises a second pressure leveling chamber arranged in between the pressure leveling chamber and the overpressure chamber; the pressure leveling chamber being connected to the second pressure leveling chamber and the second pressure leveling chamber being connected to the overpressure chamber.

According to an aspect of the invention there is provided a casting device as described above, comprising a conductive coil as force exerting means, the conductive coil being located around the casting frame and being adapted for conducting a alternating electric current.

According to a further aspect there is provided a casting device as described above, wherein the conductive coil is adapted as force exerting means by inducing currents in the molten semiconductor material for causing an electromagnetic force in the molten semiconductor material.

According to a further aspect there is provided a casting device as described above, wherein the conductive coil and the casting frame are arranged for causing the electromagnetic force to produce an additional pressure at the location of the exit slit to enlarge the outer pressure.

According to a further aspect there is provided a casting device as described above, wherein the conductive coil comprises one or more windings, the windings being oriented in an oblique manner, the windings at the side of the exit side wall being positioned at relative closer distance to the substrate band than the windings at the opposite side wall that are positioned at relative larger distance from the substrate band.

According to an aspect of the invention there is provided a casting device as described above, wherein the alternating electric current is a high frequency current and has a frequency between about 2 kHz and about 50 kHz.

According to a further aspect there is provided a casting device as described above, wherein the conductive coil is additionally adapted for heating of molten semiconductor material by the inducted currents in the molten semiconductor material.

According to an aspect of the invention there is provided a casting device as described above, wherein the casting device further comprises a secondary heating system for heating the semiconductor material.

According to an aspect of the invention there is provided a casting device as described above, wherein the secondary heating system is a system for radiative heating.

According to an aspect of the invention there is provided a casting device as described above, wherein the exit side wall at the exit slit comprises a knife edge end beveled on the inner side of the exit side wall.

According to an aspect of the invention there is provided a casting device as described above, comprising a flow restriction wall, the flow restriction wall being attached to the lower end of the exit side wall proximate to the substrate band; the flow restriction wall being adapted to extend the length of the exit side wall in the moving direction of the substrate band.

According to an aspect of the invention there is provided a method for casting semiconductor foil, comprising: - pouring molten semiconductor material into a casting frame, the casting frame comprising sidewalls of which an exit sidewall is located at an output position for the semiconductor material foil, the exit side wall being arranged with an exit slit;

- setting up a substrate band to pass underneath the casting frame at a specific speed for producing the semiconductor foil on a downstream side of the casting frame,

the method further comprising: -exerting at the location of the exit slit an external force on the molten semiconductor material to enlarge an outer pressure on the molten semiconductor material.

According to an aspect of the invention there is provided a semiconductor material foil, produced by a method as described above.

According to an aspect of the invention there is provided a semiconductor material foil produced by a method and a casting device as described above.

Advantageous embodiments are further defined by the dependent claims.

Below, the invention will be explained with reference to some drawings, which are intended for illustration purposes only and not to limit the scope of protection as defined in the accompanying claims.

Brief description of drawings

Figure 1 shows a cross-section of a casting device from the prior art;

Figure 2 shows a cross-section of a casting device according to a first embodiment of the present invention;

Figure 3 shows a cross-section of a casting device according to a second embodiment of the present invention;

Figure 4 shows a cross-section of a casting device according to a third embodiment of the present invention;

Figure 5 shows a cross-section of a casting device according to an alternative embodiment of the present invention;

Figure 6 shows a cross-section of a casting device according to a fourth embodiment of the present invention.

Description of embodiments

Figure 1 shows a cross-section of a casting device from the prior art.

The casting device 100 comprises a casting frame 2, typically a rectangular frame, into which fluid silicon can be poured. The casting frame 2 is typically a rectangular frame and comprises four sidewalls with a thickness t. The fluid semiconductor material 4 is poured from a furnace 10 holding the molten semiconductor material into the casting frame 2 with the aid of a feed device 6. Below the casting frame 2 there is a substrate band 8 that is set up to pass underneath the casting frame 2 at a specific casting speed U_C. The drive installation 15 required for this is schematically indicated.

The temperature of the substrate band 8 is set such that the molten semiconductor material 4 crystallizes at the surface with the substrate band 8. Because the substrate band 8 is moving, to the right in Figure 1, a foil 16 will be produced on a downstream side of the casting frame 2 at an exit slit 3. The contour c of the solidifying foil on the substrate band under the molten semiconductor material is indicated by dashed line 17. The solidified foil 16 pushes the casting frame 2 slightly upwards on the downstream

side, as a result of which the casting frame tilts slightly and an exit slit is created. A semiconductor material foil is drawn in this way. The method described here may be referred to as RGS (Ribbon Growth on Substrate). A major advantage of RGS technology is that a relatively large amount of foil can be produced per hour.

A disadvantage of the prior art casting device is that wafers manufactured in this manner often show a rough top-surface (i.e., a free-crystallizing surface). This rough surface results from the drag-out of a molten semiconductor material film on top of the crystallized foil. During the casting process the semiconductor material foil starts to grow at the moment (a portion of) the substrate band comes in contact with the liquid semiconductor material. During its pass underneath the casting frame in contact with the molten semiconductor material, the semiconductor material wafer grows to its desired thickness. At the exit slit 3 of the casting frame the molten semiconductor material is hold-back by the casting frame exit sidewall 2b.

The drag-out of the casting device can be described by the following equation:

$$\Phi = \langle U \rangle H = \frac{1}{2} U_C H - \frac{1}{12\eta} \frac{\Delta P}{\Delta x} H^3,$$

where Φ is the flux of semiconductor material from the casting frame, <U> is the observed velocity of the liquid, U_C is the casting speed, H is the height of the slit, η is the viscosity of the liquid, ΔP is the static pressure of the liquid, Δx is length of the exit wall in the moving direction of the substrate band.

Within the casting frame the molten semiconductor material is at a level z above the top surface of the foil. The static pressure ΔP is equal to the pressure difference between the column of liquid silicon (with height z) and the outer pressure at the exit of the casting frame.

To reduce the drag-out, the present invention recognizes a reduction of the static pressure term ΔP by providing a casting device comprising a force exerting means to exert an external force to enlarge the outer pressure.

Figure 2 shows a cross-section of a casting device according to a first embodiment of the present invention.

In this cross-section in the same direction as shown in figure 1, the casting device 1 according to the first embodiment, comprises a gas jet generator 20 as force exerting means. Such a gas jet generator comprises an inlet for pressurized gas, a duct and an outlet 22 for producing a gas jet with relatively high pressure compared to outer or

ambient pressure. The gas jet generator is arranged for generating and directing the gas jet towards the exit slit.

It will be appreciated that outer or ambient pressure, i.e., the pressure outside of the casting frame, relates to the static pressure of the work space in which the casting frame is located. The typical process pressure, the pressure in the casting frame (process chamber) above the molten semiconductor material, is less than atmospheric pressure. In a non-limiting example, the pressure in the casting frame is chosen between 0.1 and 0.9 bar (absolute pressure) and the pressure of the gas jet is chosen between about 2 and about 4 bar (absolute pressure).

Within the gas jet generator, the inlet is connected to the duct and the duct is connected to the outlet.

The outlet 22 of the gas jet generator is shaped in such a way so as to produce a gas jet that substantially extends along the width of the exit slit 3 of the casting frame. In this manner the gas jet is adapted to exert an external pressure along substantially the full width of the exit slit.

The outlet of the gas jet generator 20 is arranged at the exit sidewall 2b of the casting device 2 and is adapted for producing a gas jet directed towards the exit slit 3.

The pressure exerted by the gas jet, provides that molten semiconductor material that is dragged with the foil from the semiconductor material bath in the casting frame is held back.

Additionally, the exit side wall 2b of the casting frame can be shaped to optimize the effect of the gas jet and can comprise a knife edge end beveled on the inner side of the side wall 2b.

It is observed that the gas jet in combination with the knife edge end on the exit side wall 2b, improves reduction of the drag-out even further. As a result, the roughness of the cast semiconductor material foil is reduced.

The gas jet may comprise a gas species which does not react with the semiconductor material. For example, the gas stream may comprise a noble gas like Argon or an inert gas like Nitrogen.

Figure 3 shows a cross-section of a casting device according to a second embodiment of the present invention.

In Figure 3 an alternative embodiment is shown in which the exit side wall 2b of the casting frame comprises a flow restriction wall 2e. The flow restriction wall 2e is

attached to the lower end of the exit side wall proximate to the substrate band 8. The flow restriction wall 2e is substantially parallel to the substrate band and is adapted to extend the length Δx of the exit wall in the moving direction of the substrate band 8. The flow restriction wall is arranged relatively close to the substrate band so as to form a narrow channel towards the exit slit. Due to the small dimension of the channel the flow of molten material during the casting process is reduced in comparison to the speed U_C of the substrate band. Advantageously, the reduction of the flow creates an underpressure which reduces the static pressure ΔP at the exit slit.

Moreover, the gas jet in combination with the flow restriction wall 2e end on the exit side wall 2b is observed to improve a reduction of the drag-out.

Figure 4 shows a cross-section of a casting device according to a third embodiment of the present invention.

In this cross-section in the same direction as shown in figure 1, the casting device 1 according to the third embodiment, comprises an overpressure device 30 as force exerting means and a flow restriction wall 2e.

The overpressure device 30 is arranged at the exit sidewall 2b of the casting device 2 and is adapted for producing at the location of the exit slit an overpressure relative to the outer pressure.

The overpressure device 30 comprises an inlet 31 for pressurized gas, a pressure leveling chamber 32, and an overpressure chamber 33. Within the overpressure device , the inlet is connected with an entrance of the pressure leveling chamber. An exit of the pressure leveling chamber is in communication with the overpressure chamber. The overpressure chamber 33 is located at the exit slit of the casting frame.

The pressure leveling chamber extends along the width of the exit side wall 2b and is adapted for leveling the pressure of the gas along the width of the exit side wall 2b. Similarly, the overpressure chamber extends substantially along the full width of the exit slit. Preferably, the pressure leveling chamber is in communication with the overpressure chamber over the full width of the side wall so as to create a substantially constant pressure in the overpressure chamber over the full width of the exit slit.

Further, the flow restriction wall 2e is attached to the lower end of the exit side wall proximate to the substrate band 8. The flow restriction wall 2e is adapted to extend the length Δx of the exit wall in the moving direction of the substrate band 8.

The pressurized gas may comprise a gas species which does not react with the semiconductor material. For example, the gas stream may comprise a noble gas like Argon or an inert gas like Nitrogen.

Figure 5 shows a cross-section of a casting device according to an alternative embodiment of the present invention.

In this alternative of the third embodiment, the overpressure device 40 comprises the inlet 41 for pressurized gas, a first pressure leveling chamber 42a, a second pressure leveling chamber 42b and the overpressure chamber 43.

Within the overpressure device, the inlet is connected with an entrance of the first pressure leveling chamber. The first pressure leveling chamber is connected to the second pressure leveling chamber. The second pressure leveling chamber is connected with the overpressure chamber. The overpressure chamber is located at the exit slit of the casting frame.

The first pressure leveling chamber extends along the width of the exit side wall 2b and is adapted for leveling the pressure of the gas along the width of the exit side wall 2b. Similarly, the second pressure leveling chamber extends substantially along the full width of the exit slit. Preferably, the first pressure leveling chamber is connected to the second pressure leveling chamber over the full width of the exit side wall.

Figure 6 shows a cross-section of a casting device according to a fourth embodiment of the present invention.

In this cross-section in the same direction as shown in figure 1, the casting device 1 according to the fourth embodiment comprises a conductive coil 50 located around the casting device and is adapted for conducting a high frequency alternating electric current . The conductive coil 50 comprises one or more windings 51 wound around the circumference of the casting device.

The conductive coil 50 is adapted as a force exerting means by inducing currents in the molten semiconductor material which cause an electromagnetic force (Lorentz force) in the molten semiconductor material.

The shape and the thickness of the casting frame wall 2b are designed in a way that the induced electromagnetic currents in the casting frame only partially compensate the alternating magnetic field generated in the conductive coil; the part that is not compensated induces electrical currents in the molten semiconductor material resulting in an electromagnetic force acting on the molten semiconductor material.

The arrangement of the conductive coil and the casting frame is adapted in such a way that at the location of the exit slit the electromagnetic force produces a outer pressure that reduces the static pressure ΔP.

The electromagnetic force can be controlled by the geometry of the coil 51 and of the casting frame 2 in combination with the electrical parameters such as current and frequency.

At the same time, the induced currents in the conductive casting frame and the molten semiconductor material cause heating of the frame and the molten semiconductor material. Advantageously, this allows a better control of the temperature of the molten semiconductor material in the casting frame.

In a further embodiment, the casting device comprises a secondary heating system for additional heating. The secondary heating system is based on heating other than by induced currents, for example by radiative heating.

In figure 5 the windings 51 are oriented in an oblique manner. The windings at the side of the exit side wall 2b are positioned at relative closer distance to the substrate band 8 than the windings at the opposite side wall 2a that are positioned at relative larger distance from the substrate band 8. By the oblique arrangement of the windings the electromagnetic force exerted on the molten semiconductor material at the location of the exit slit is relatively larger than the electromagnetic force exerted on the molten semiconductor material 4 inside the casting frame. As a result, the nett static pressure ΔP at the exit slit is compensated by a pressure originating from the electromagnetic force.

Optionally, the casting device comprises a knife edge end 5 beveled on the inner side of the side wall 2b. The knife edge end on the exit side wall 2b provides a higher transparency for the electromagnetic force and thus a reduced shielding of the molten semiconductor material at the exit slit. The knife edge end 5 allows a locally enhanced coupling between the electromagnetic force and the liquid silicon with a relatively higher electromagnetic force value.

Alternatively, the cast fame according to the fourth embodiment may comprise a flow restriction wall 2e which is attached to the lower end of the exit side wall proximate to the substrate band 8. The flow restriction wall 2e is adapted to extend the length Δx of the exit wall in the moving direction of the substrate band 8. The thickness of the flow

restriction wall is adapted to allow induction of electrical currents in the molten semiconductor material resulting in an electromagnetic force acting on the melt.

It is noted that in the prior art the casting frame is arranged for tilting of the exit side wall, the exit slit is created by a slight tilt of the casting frame caused by the solidified foil being cast. In the embodiments described here, the casting frame may be arranged for tilting to enable the temporary creation of an exit slit during casting by the tilt of the casting frame during the casting process or the casting frame is arranged with a permanent exit slit that may be tooled into the exit side wall.

Other alternatives and equivalent embodiments of the present invention are conceivable within the idea of the invention, as will be clear to the person skilled in the art. The idea of the invention is limited only by the appended claims.

Conclusies

1. Gietinrichting voor het vervaardigen van folie van halfgeleidermateriaal, omvattend een gietframe en een substraatband, waarbij het gietframe is ingericht voor het bevatten van gesmolten halfgeleidermateriaal en zijwanden omvat waarvan een uitgangszijwand is geplaatst aan een uitvoerpositie voor de folie van halfgeleidermateriaal, waarbij de uitgangszijwand is voorzien van een uitgangssleuf, waarbij de gietinrichting voorts middelen voor het uitoefenen van een kracht omvat om op de plaats van de uitgangssleuf een uitwendige kracht uit te oefenen op het gesmolten halfgeleider materiaal om een uitwendige druk op het gesmolten halfgeleider materiaal te vergroten.

2. Gietinrichting volgens conclusie 1, waarbij de middelen voor het uitoefenen van een kracht een gas-jet generator omvatten voor het produceren van een gas-jet met relatief hoge druk in vergelijking met de omgevingsdruk bij de plaats van de uitgangssleuf, waarbij de gas-jet generator is ingericht voor het richten van de gas-jet naar de uitgangssleuf.

3. Gietinrichting volgens conclusie 2, waarbij de gas-jet generator een inlaat voor gas dat onder druk staat, een kanaal en een uitlaat voor het produceren van de gas-jet omvat; waarbij de inlaat verbonden is met het kanaal en het kanaal is verbonden met de uitlaat.

4. Gietinrichting volgens conclusie 1, waarbij de middelen voor het uitoefenen van een kracht een overdrukinrichting omvatten, waarbij de overdrukinrichting is geplaatst bij de uitgangszijwand van de gietinrichting en is ingericht voor het produceren van een overdruk ten opzichte van de uitwendige druk bij de plaats van de uitgangssleuf.

5. Gietinrichting volgens conclusie 4, waarbij de overdrukinrichting een inlaat voor gas dat onder druk staat, een drukvereveningskamer en een overdrukkamer omvat; waarbij de inlaat is verbinding staat met een ingang van de drukvereveningskamer, een uitgang van de drukvereveningskamer in verbinding staat met de overdrukkamer, waarbij de overdrukkamer geplaatst is bij de uitgangssleuf van het gietframe.

6. Gietinrichting volgens conclusie 5, waarbij de drukvereveningskamer zich uitstrekt langs de breedte van de uitgangszijwand en is ingericht voor het verevenen van de druk van het gas langs de breedte van de uitgangszijwand en waarbij de overdrukkamer zich hoofdzakelijk uitstrekt langs de volle breedte van de uitgangssleuf.

7. Gietinrichting volgens conclusie 6, waarbij de drukvereveningskamer is verbonden met de overdrukkamer over de volle breedte van de uitgangszijwand teneinde een hoofdzakelijke constante druk te creëren in de overdrukkamer over de volle breedte van de uitgangssleuf.

8. Gietinrichting volgens conclusie 5, waarbij de overdruk inrichting een tweede drukvereveningskamer omvat die geplaatst is tussen de drukvereveningskamer en de overdrukkamer; waarbij de drukvereveningskamer verbonden is met de tweede drukvereveningskamer en de tweede drukvereveningskamer verbonden is met de overdrukkamer.

9. Gietinrichting volgens conclusie 1, omvattend een geleidende spoel als middelen voor het uitoefenen van een kracht, waarbij de geleidende spoel is geplaatst rond het gietframe en is ingericht voor het geleiden van elektrische wisselstroom.

10. Gietinrichting volgens conclusie 9, waarbij de geleidende spoel is ingericht als middelen voor het uitoefenen van een kracht door het induceren van stromen in het gesmolten hafgeleider materiaal om een elektromagnetische kracht te doen ontstaan in het gesmolten halfgeleidermateriaal.

11. Gietinrichting volgens conclusie 10, waarbij de geleidende spoel en het gietframe zijn ingericht om de elektromagnetische kracht een additionele druk te produceren bij de plaats van de uitgangssleuf om de uitwendige druk te vergroten.

12. Gietinrichting volgens conclusie 10, waarbij de geleidende spoel één of meer windingen omvat, waarbij de windingen scheef zijn gericht, waarbij de windingen aan de zijde van de uitgangssleuf op een relatief kleinere afstand zijn geplaatst ten opzichte

van de substraat band dan de windingen aan de tegenoverliggende zijde die gepositioneerd op een relatief grotere afstand vanaf de substraat band.

13. Gietinrichting volgens één van de conclusies 9 – 12, waarbij de elektrische wisselstroom hoogfrequent is en een frequentie heeft tussen ongeveer 2 kHz en ongeveer 50 kHz.

14. Gietinrichting volgens conclusie 10, waarbij de geleidende spoel daarnaast is ingericht voor het verhitten van gesmolten halfgeleidermateriaal door de geïnduceerde stromen in het gesmolten halfgeleidermateriaal.

15. Gietinrichting volgens conclusie 14, waarbij de gietinrichting voorts een secundair verhittingssysteem omvat voor het verhitten van het halfgeleidermateriaal.

16. Gietinrichting volgens conclusie 15, waarbij het secundaire verhittingssysteem een systeem voor verhitting door middel van straling is.

17. Gietinrichting volgens één van de voorgaande conclusies, waarbij de uitgangszijwand aan de uitgangssleuf een meskant omvat welke is afgeschuind aan de binnenzijde van de uitgangszijwand.

18. Gietinrichting volgens één van de voorgaande conclusies 1 – 16, omvattend een stromingsbeperkingswand, waarbij de stromingsbeperkingswand verbonden is aan een onderzijde van de uitgangszijwand aan de zijde van de substraatband, en waarbij de stromingsbeperkingswand is ingericht om de lengte van de uitgangszijwand in de bewegingsrichting van de substraatband uit te breiden.

19. Werkwijze voor het gieten van folie van halfgeleidermateriaal, omvattend
- uitgieten van gesmolten halfgeleidermateriaal in een gietframe, waarbij het gietframe zijwanden omvat, waarvan een uitgangszijwand is geplaatst bij een uitvoerpositie voor het folie van halfgeleidermateriaal, waarbij de uitgangszijwand is ingericht met een uitgangssleuf;
- instellen van een substraat band voor onder het gietframe te passeren op een

specifieke snelheid voor het produceren van de halfgeleider folie op een stroomafwaartse zijde van het gietframe,

waarbij de werkwijze omvat:

- uitoefenen bij de plaats van de uitgangssleuf van een uitwendige kracht op het gesmolten halfgeleidermateriaal om de uitwendige druk op het gesmolten halfgeleidermateriaal te vergroten.

20. Folie van halfgeleidermateriaal, vervaardigd door een werkwijze volgens conclusie 19.

21. Folie van halfgeleidermateriaal, vervaardigd door een werkwijze volgens conclusie 19 en een gietinrichting volgens één van de conclusies 1 – 18.

Fig 1 Prior Art

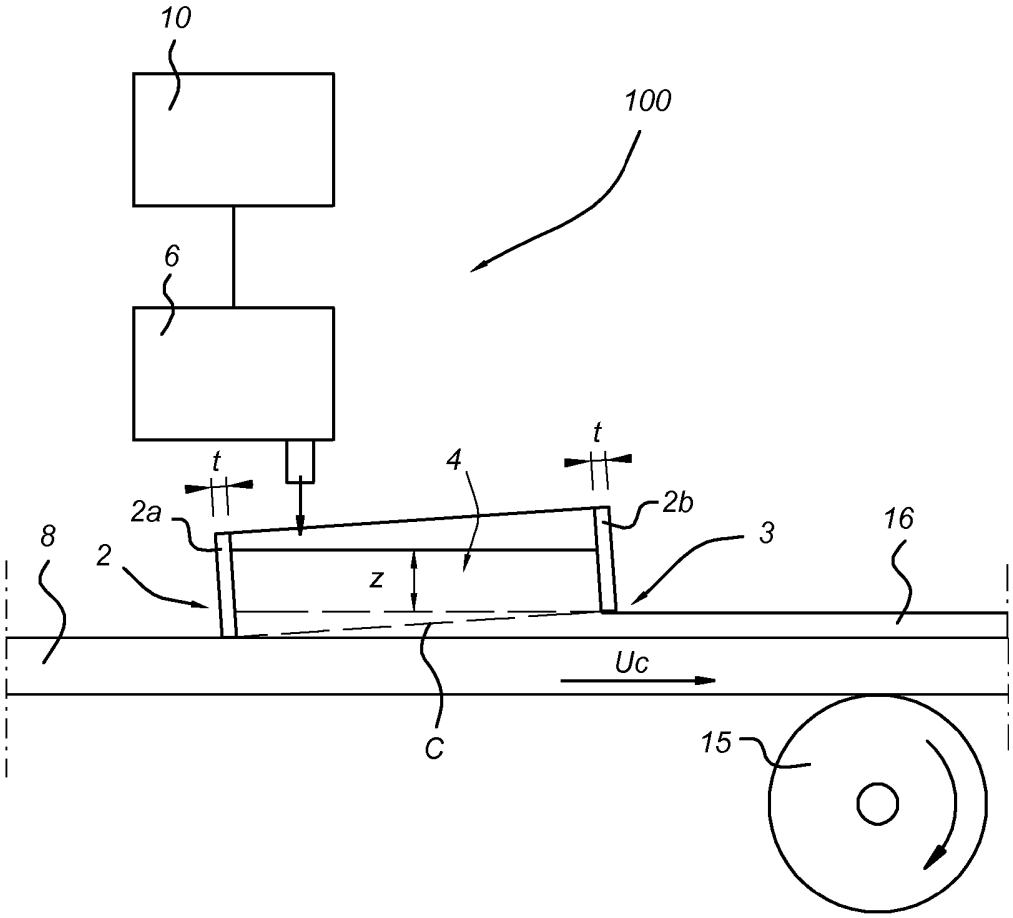


Fig 2

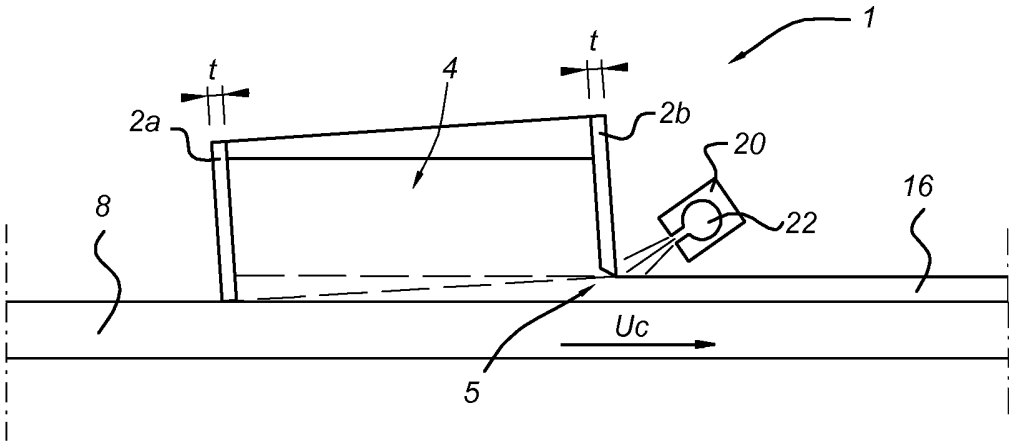


Fig 3

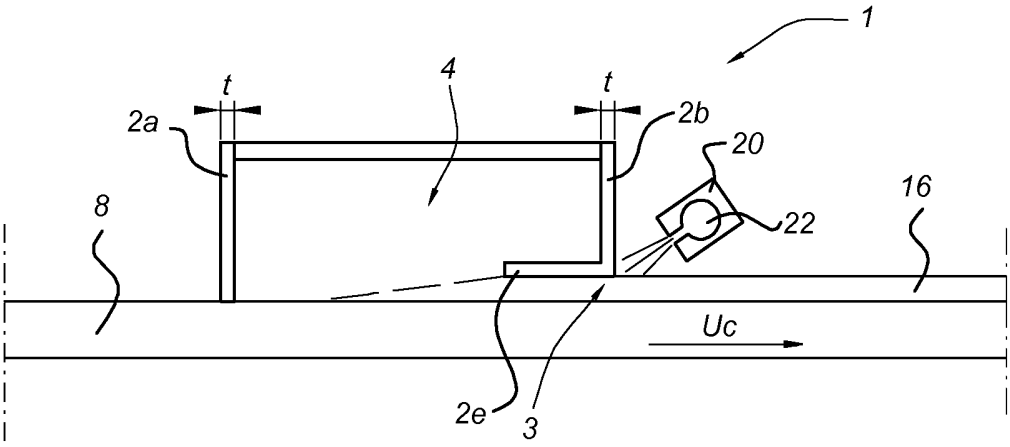


Fig 4

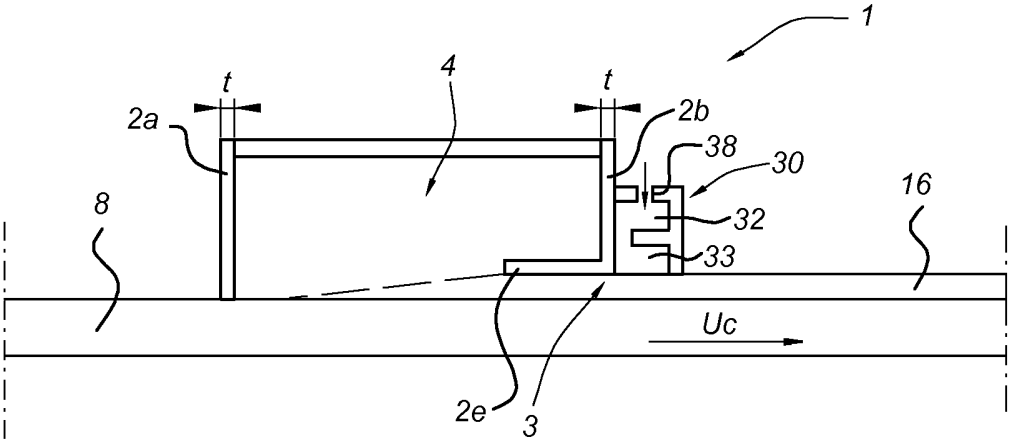


Fig 5

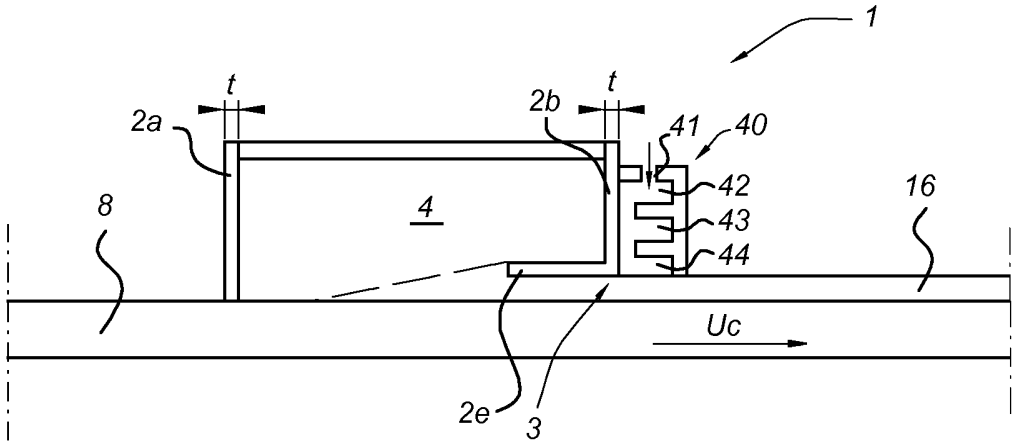
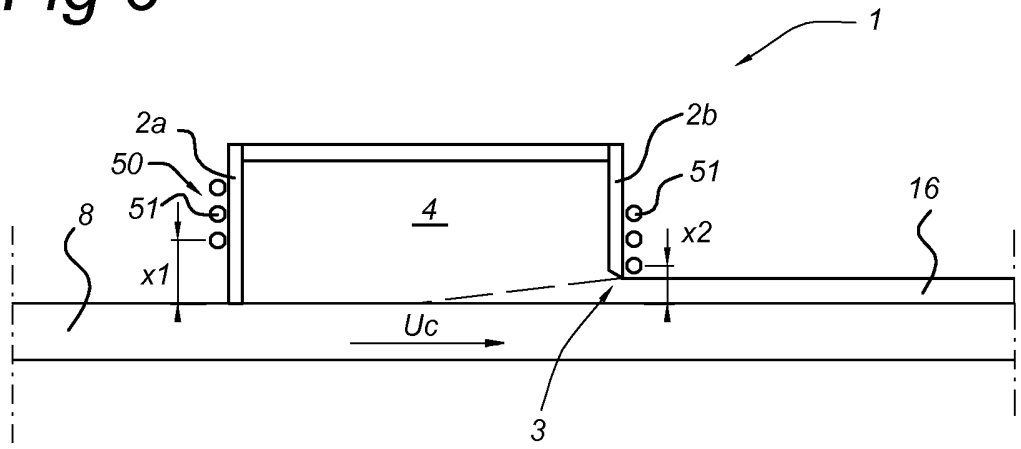


Fig 6



SAMENWERKINGSVERDRAG (PCT)

RAPPORT BETREFFENDE NIEUWHEIDSONDERZOEK VAN INTERNATIONAAL TYPE

IDENTIFICATIE VAN DE NATIONALE AANVRAGE	KENMERK VAN DE AANVRAGER OF VAN DE GEMACHTIGDE
	P6029074NL
Nederlands aanvraag nr. **2004209**	Indieningsdatum **08-02-2010**
	Ingeroepen voorrangsdatum
Aanvrager (Naam) **RGS Development B.V.**	
Datum van het verzoek voor een onderzoek van internationaal type **17-04-2010**	Door de Instantie voor Internationaal Onderzoek aan het verzoek voor een onderzoek van internationaal type toegekend nr. **SN 54002**

I. CLASSIFICATIE VAN HET ONDERWERP (bij toepassing van verschillende classificaties, alle classificatiesymbolen opgeven)

Volgens de internationale classificatie (IPC)

C30B28/10 **C30B15/00** **C30B29/06**

II. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimumdocumentatie

Classificatiesysteem	Classificatiesymbolen
IPC 8	**C30B** **H01L**

Onderzochte andere documentatie dan de minimum documentatie, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

III. ☐ **GEEN ONDERZOEK MOGELIJK VOOR BEPAALDE CONCLUSIES** (opmerkingen op aanvullingsblad)

IV. ☐ **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 2004209

A. CLASSIFICATIE VAN HET ONDERWERP
INV. C30B28/10 C30B15/00 C30B29/06
ADD.

Volgens de Internationale Classificatie van octrooien (IPC) of zowel volgens de nationale classificatie als volgens de IPC.

B. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte miminum documentatie (classificatie gevolgd door classificatiesymbolen)
C30B H01L

Onderzochte andere documentatie dan de mimimum documentatie, voor dergelijke documenten, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

Tijdens het onderzoek geraadpleegde elektronische gegevensbestanden (naam van de gegevensbestanden en, waar uitvoerbaar, gebruikte trefwoorden)
EPO-Internal

C. VAN BELANG GEACHTE DOCUMENTEN

Categorie °	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
X	DE 100 47 929 A1 (BAYER AG [DE]) 11 april 2002 (2002-04-11) * alinea [0044] - alinea [0051] * -----	1,9-11, 13-15, 19-21
X	WO 2005/104244 A1 (STICHTING ENERGIE [NL]; SCHOENECKER AXEL GEORG [NL]; STEINBACH KARL IN) 3 november 2005 (2005-11-03)	20,21
A	* bladzijde 1, regel 14 - regel 16; conclusies 1-11 * -----	1,19
A,D	WO 2005/122287 A1 (STICHTING ENERGIE [NL]; SCHOENECKER AXEL GEORG [NL]) 22 december 2005 (2005-12-22) in de aanvraag genoemd * conclusie 6 * -----	1
	-/--	

[X] Verdere documenten worden vermeld in het vervolg van vak C.

[X] Leden van dezelfde octrooifamilie zijn vermeld in een bijlage

° Speciale categorieën van aangehaalde documenten

"A" niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft

"D" in de octrooiaanvrage vermeld

"E" eerdere octrooi(aanvrage), gepubliceerd op of na de indieningsdatum, waarin dezelfde uitvinding wordt beschreven

"L" om andere redenen vermelde literatuur

"O" niet-schriftelijke stand van de techniek

"P" tussen de voorrangsdatum en de indieningsdatum gepubliceerde literatuur

"T" na de indieningsdatum of de voorrangsdatum gepubliceerde literatuur die niet bezwarend is voor de octrooiaanvrage, maar wordt vermeld ter verheldering van de theorie of het principe dat ten grondslag ligt aan de uitvinding

"X" de conclusie wordt als niet nieuw of niet inventief beschouwd ten opzichte van deze literatuur

"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

"&" lid van dezelfde octrooifamilie of overeenkomstige octrooipublicatie

Datum waarop het onderzoek naar de stand van de techniek van internationaal type werd voltooid	Verzenddatum van het rapport van het onderzoek naar de stand van de techniek van internationaal type
20 mei 2010	

Naam en adres van de instantie	De bevoegde ambtenaar
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Cook, Steven

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Formulier PCT/ISA/201 (tweede blad) (Januari 2004)

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 2004209

C.(Vervolg). VAN BELANG GEACHTE DOCUMENTEN

Categorie °	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
A	KOCH W ET AL: "PREPARATION, CHARACTERISATION AND CELL PROCESSING OF BAYER RGS SILICON FOILS (RIBBON GROWTH ON SUBSTRATE)" 2ND WORLD CONFERENCE ON PHOTOVOLTAIC SOLAR ENERGY CONVERSION. / 15TH EUROPEAN PV SOLAR ENERGY CONFERENCE. / 27TH US IEEE PHOTOVOLTAICS SPECIALISTS CONFERENCE. / 10TH ASIA/PACIFIC PV SCIENCE AND ENGINEERING CONFERENCE. VIENNA, AUSTRIA, JULY 6 - 10, 19, 6 juli 1998 (1998-07-06), bladzijden 1254-1259, XP001137936 ISBN: 978-92-828-5419-8 * bladzijde 1256; figuur 6 *	1,19
A	LANGE H ET AL: "RIBBON GROWTH ON SUBSTRATE (RGS) - A NEW APPROACH TO HIGH SPEED GROWTH OF SILICON RIBBONS FOR PHOTOVOLTAICS" JOURNAL OF CRYSTAL GROWTH, ELSEVIER, AMSTERDAM, NL LNKD-DOI:10.1016/0022-0248(90)90317-E, deel 104, nr. 1, 1 juli 1990 (1990-07-01), bladzijden 108-112, XP000138032 ISSN: 0022-0248 * bladzijde 109; figuur 2 *	1,19

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 2004209

In het rapport genoemd octrooigeschrift	Datum van publicatie	Overeenkomend(e) geschrift(en)		Datum van publicatie
DE 10047929	A1 11-04-2002	NL	1019030 C2	27-03-2006
		NL	1019030 A1	28-03-2002
WO 2005104244	A1 03-11-2005	AU	2005236766 A1	03-11-2005
		BR	PI0510265 A	30-10-2007
		EP	1743385 A1	17-01-2007
		ES	2317229 T3	16-04-2009
		JP	2007534600 T	29-11-2007
		KR	20070004994 A	09-01-2007
		NL	1026043 C2	27-10-2005
		US	2009044925 A1	19-02-2009
WO 2005122287	A1 22-12-2005	AU	2005253501 A1	22-12-2005
		BR	PI0511961 A	22-01-2008
		EP	1754264 A1	21-02-2007
		JP	2008503101 T	31-01-2008
		NL	1026377 C2	14-12-2005
		US	2009014840 A1	15-01-2009

OCTROOICENTRUM NEDERLAND

WRITTEN OPINION

File No.	Filing date *(day/month/year)*	Priority date *(day/month/year)*	Application No.
SN54002	08.02.2010		NL2004209

International Patent Classification (IPC)
INV. C30B28/10 C30B15/00 C30B29/06

Applicant
RGS Development 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
	Cook, Steven

Application number

WRITTEN OPINION

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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	2-8, 12, 16-18
	No:	Claims	1, 9-11, 13-15, 19-21
Inventive step	Yes:	Claims	2-8, 12, 14, 15, 17, 18
	No:	Claims	1, 9-11, 13, 16, 19-21
Industrial applicability	Yes:	Claims	1-21
	No:	Claims	

2. Citations and explanations

see separate sheet

Application number

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Box No. VII Certain defects in the application

see separate sheet

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:

D1 *DE 100 47 929 A1 (BAYER AG [DE]) 11 april 2002 (2002-04-11)*

D2 *WO 2005/104244 A1 (STICHTING ENERGIE [NL]; SCHOENECKER AXEL GEORG [NL]; STEINBACH KARL IN) 3 november 2005 (2005-11-03)*

Clarity

The subject-matter of independent product claims 20 and 21 is not clear because it fails to define the claimed product in terms of product features allowing a comparision with products of the prior art. See also item VIII below.

Novelty

The present application does not meet the criteria of patentability, because the subject-matter of claims 1, 9-11,13-15,19-21 is not new.

D1 discloses [see paragraphs [0044]-[0046], [0051] and figure 2b a casting apparatus for preparing a foil/ribbon of semiconducting material. The casting frame of D1 has all the features of the casting frame of the present claim 1 and is surrounded by an induction coil operating at an AC frequency of between 1 and 30 kHz. The effect of this coil is to heat the melt and also to apply an electromotive force on the silicon melt. This electromotive pressure will also occur at the exit slot of the casting frame denoted by the reference numeral (8) in the figure of 2b and will be additional to any pressure differences caused by hdrostatic pressure differences. D1 also teaches using a secondary heating means (see paragraph [0051]). For these reasons the subject-matter of claims 1,9-11,13-15 defining the apparatus and the subject-matter of claim 19 defining the method of operation is not novel with respect to the teachings of D1. Insofar as the product of claims 20 and 21 contains no special distinguishing features, it is also considered to lack novelty with respect to the foil produced by the apparatus and method of D1.

Inventive step

Insoafar as the claims already mentioned lack novelty, they also lack an inventive step.

Applicant has addressed the problem of surface roughening of foil produced by the "drag-out" effect in the RGS technique. Applicant has solved the problem by providing means to exert an external force at the exit point of the molten semiconducting

material. Alternative means to achieve this are a gas-jet generator, an overpressure generator and a conducting coil to generate an electromagnetic force (EMF). The latter alternative is to be found in D1 but is not taught in the way decribed in present claim 12, i.e. arranged assymetrically so that the EMF will apply an extra pressure just outside the exit gap of the casting frame. Reducing the drag-out effect to improve surface smoothness in the way proposed in the present application is not suggested in D1 and cannot obviously be derived from the known prior art. An inventive step can thus be acknowledged in the claims 2-8, 12, 17 and 18. Concerning the subject-matter of claim 16, an additional heating means in the form of an irradiation means is considered obvious and in any case does not contribute to solving the stated problem.

Industrial applicability

Relating to the production of semiconducting foils/ribbons for photovoltaic applications, the subject-matter of claims 1-21 is considered industrially applicable.

Re Item VII

Relevant backround art provided by the teachings of D1 and D2 should be mentioned in the description.

Re Item VIII

The claims lack clarity. In claim 1 it is not clear where the extra external force is applied in relation to the exit slot of the casting frame. Reference numerals used in the figures would help to improve the clarity of the claims.

Independent claims 20 and 21 concern a product (foil of semiconductor material) but provide no other product features. The product is thus not clearly defined and semiconductor foil products of the prior art (e.g. from D1 or D2) are considered prejudicial to the novelty of these claims.