(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
19 May 2016 (19.05.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/077587 A3

(51) International Patent Classification:
H01L 21/04 (2006.01) *H01L 31/102* (2006.01)

(21) International Application Number:
PCT/US2015/060385

(22) International Filing Date:
12 November 2015 (12.11.2015)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/078,818 12 November 2014 (12.11.2014) US
62/166,617 26 May 2015 (26.05.2015) US

(71) Applicant: **PRESIDENT AND FELLOWS OF HARVARD COLLEGE** [US/US]; 17 Quincy Street, Cambridge, Massachusetts 02138 (US).

(72) Inventors: **MAZUR, Eric**; 57 Lowell Road, Concord, Massachusetts 01742 (US). **FRANTA, Benjamin**; 1010 First Street, NW, Elkader, Iowa 52043 (US). **AZIZ, Michael, J.**; 53 Silver Hill Road, Concord, Massachusetts 01742 (US). **PASTOR, David**; 63 Inman Street Apt. #1, Cambridge, Massachusetts 02139 (US).

(74) Agent: **MOLLAAGHABABA, Reza**; Pepper Hamilton LLP, High Street Tower, 19th Floor, 125 High Street, Boston, Massachusetts 02110-2736 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(88) Date of publication of the international search report:
21 July 2016

(54) Title: CREATION OF HYPERDOPED SEMICONDUCTORS WITH CONCURRENT HIGH CRYSTALLINITY AND HIGH SUB-BANDGAP ABSORPTANCE USING NANOSECOND LASER ANNEALING

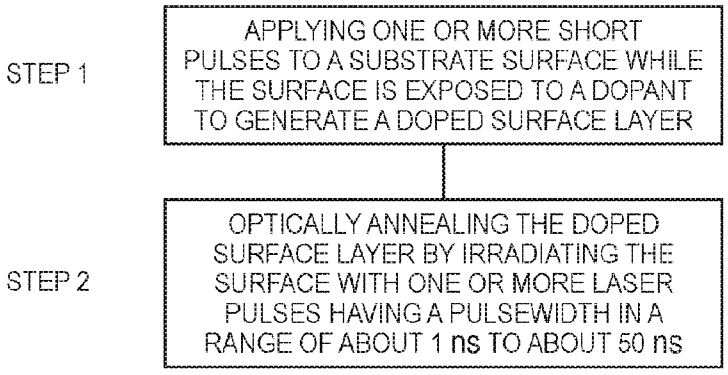

FIG. 1

(57) Abstract: In one aspect, a method of processing a semiconductor substrate is disclosed, which comprises incorporating at least one dopant in a semiconductor substrate so as to generate a doped polyphase surface layer on a light-trapping surface, and optically annealing the surface layer via exposure to a plurality of laser pulses having a pulsewidth in a range of about 1 nanosecond to about 50 nanoseconds so as to enhance crystallinity of said doped surface layer while maintaining high above-bandgap, and in many embodiments sub-bandgap optical absorptance.

WO 2016/077587 A3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 15/60385

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H01L 21/04; H01L 31/102 (2016.01)
CPC - H01L 21/263; H01L 21/324; H01L 31/103; H01L 27/14603; H01L 27/14609
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8): H01L 21/04; H01L 31/102 (2016.01)
CPC: H01L 21/263; H01L 21/324; H01L 31/103; H01L 27/14603; H01L 27/14609

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC: 257/463; 257/461; 257/E31.13; 438/164; 438/166; 438/514; 438/798

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Google Scholar, Google Patents, PatBase
Keywords used: semiconductor, doping, doped, dopant, polyphase, laser, optical, anneal, pulse width, enhance, improve, increase, crystallinity, recrystallization, nanosecond, amorphous

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2003/0045074 A1 (Seibel et al.) 06 March 2003 (06.03.2003); entire document, but especially: para [0010], para [0011], para [0032], para [0044], para [0046]	1; 6; 8-9; 17; 24-27 --- 2-5; 7; 10-16; 18-23
Y	US 2012/0024364 A1 (Carey, III et al.) 02 February 2012 (02.02.2012); entire document, but especially: para [0012], para [0013], para [0015], para [0016], para [0022], para [0023], para [0047], para [0048], para [0053], para [0054], para [0066], para [0081], fig. 5, fig. 6	2-5; 7; 10-13; 18-23
Y	US 5,858,473 A (Yamazaki et al.) 12 January 1999 (12.01.1999); entire document, but especially: col 1 lines 10-12, col 1 lines 40-46, col 1 lines 66-67, col 2 lines 1-3, col 4 lines 55-66, col 5 lines 12-13	14-16
A	Peercy et al. "Explosive crystallization in amorphous Si initiated by long pulse width laser irradiation", Applied Physics Letters, Vol 52 Issue 3 (18 January 1988): pages 203-205; entire document	1-27
A	US 2013/0168826 A1 (Vineis) 04 July 2013 (04.07.2013); entire document, but especially: para [0002]	2
A	US 2003/0040130 A1 (Mayur et al.) 27 February 2003 (27.02.2003); entire document	1-27
A	US 2007/0241086 A1 (Arao et al.) 18 October 2007 (18.10.2007); entire document	1-27

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 March 2016 (29.03.2016)	20 JUN 2016

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 15/60385

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
---See Supplemental Box----

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-27

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 15/60385

Lack of Unity Invention

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I: Claims 1-27 directed to a method of processing a semiconductor substrate, comprising incorporating at least one dopant in a semiconductor substrate so as to generate a doped polyphase surface layer.

Group II: Claims 28-45 directed to a method of processing a semiconductor substrate, comprising generating a doped surface layer and thermally annealing said doped surface layer by exposing the substrate to an elevated temperature.

Group III: Claims 46a, 46b, 47-50 directed to semiconductor substrate comprising a substantially crystalline doped surface layer wherein said doped surface layer forms a diode junction with underlying portion of the substrate.

Group IV: Claims 51-55 directed to a method of processing a substrate, comprising applying a plurality of texturing laser pulses to a substrate surface so as to form a polyphase surface layer exhibiting a plurality of surface textures.

The inventions listed as Groups IV do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons.

SPECIAL TECHNICAL FEATURES

The invention of Group I includes the special technical feature of generating a doped polyphase surface layer, not required by the claims of Groups II, III, or IV.

The invention of Group II includes the special technical feature of thermally annealing a doped surface layer, not required by the claims of Groups I, III, or IV.

The invention of Group III includes the special technical feature of forming a diode junction, not required by the claims of Groups I, II, or III.

The invention of Group IV includes the special technical feature of a polyphase surface layer exhibiting a plurality of surface textures, not required by the claims of Groups I, II, or III.

The invention of Groups I, II, and III include the special technical feature of a semi-conductor substrate comprising a doped surface layer, not required by the claims of Group IV.

The invention of Groups I, II, and IV include the special technical feature of optically annealing a surface layer, not required by the claims of Croup III.

COMMON TECHNICAL FEATURES

Groups I, II, and III share the common technical feature of a doped surface layer and a semi-conductor substrate. However, this shared technical feature does not represent a contribution over prior art as being anticipated by US 2003/0045074 A1 to Seibel et al. (hereinafter Seibel), which discloses of a semi-conductor substrate comprising a doped surface layer (para [0010]: "...a method of forming a doped polycrystalline silicon gate in a Metal Oxide Semiconductor (MOS) device...")

Groups I, II, and IV share the common technical feature of optically annealing a surface layer using a plurality of laser pulses having a pulsewidth of 1 to 50 nanoseconds. However, this shared technical feature does not represent a contribution over prior art as being anticipated by Seibel, which discloses of optically annealing a surface layer using a plurality of lasers (para [0041]: "...a laser beam 230 irradiates the top surface 202 of the amorphous silicon (a-Si) 200... Between pulses of the laser beam 230, the molten layer 220 is allowed to cool to room temperature and crystallize..."; para [0044]: "Laser beam 230 is a pulsed radiation generated by a Neodymium YAG laser and has... a pulse width of 16 nanoseconds...")

Groups II, III, and IV share the common technical feature of a surface comprising a plurality of surface textures. However, this shared technical feature does not represent a contribution over prior art as being anticipated by US 2012/0024364 A1 to Carey, III et al. (hereinafter Carey), which discloses of a substrate comprising a plurality of surface textures (para [0053]: "This sulfur-rich layer exhibits an undulating surface morphology (topography) with micron-sized surface height variations. Such a textured surface obtained by irradiating a silicon surface...").

Groups II and III share the common technical feature of a doped surface layer having a thickness in the range of about 10 nanometers to about 1 micrometer. However, this shared technical feature does not represent a contribution over prior art as being anticipated by Seibel, who discloses of a doped surface layer having a thickness in the range of about 10 nanometers to about 1 micrometer (para [0010]: "...forming a doped polycrystalline silicon gate..."; para [0037]: "In one example, the gate 112 has a height of approximately 200 nanometers").

Groups II and III share the common technical feature of a doped surface layer having a plurality of light-trapping surface textures. However, this shared technical feature does not represent a contribution over prior art as being anticipated by Carey, which discloses of a doped surface layer having a plurality of light-trapping surface textures (para [0053]: "The irradiation of the silicon surface with the laser pulses in the presence of SF6... can cause formation of a sulfur-rich layer... sulfur-rich layer exhibits an undulating surface morphology (topography) with micron-sized surface height variations... textured surface obtained by irradiating a silicon surface..."; it is well known in the art that surface textures have light-trapping properties, see US 2013/0168826 A1 to Vineis, para [0002]: "Surface texturing can also improve light trapping within the material...").

---Continued in Extra Sheet---

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 15/60385

Lack of Unity Invention Continued

Groups I and IV share the common technical feature of a optically annealing a polyphase surface layer, via exposure to a plurality of laser pulses having a pulsewidth in a range of about 1 nanosecond to about 50 nanoseconds so as to enhance crystallinity of said doped surface layer. However, this shared technical feature does not represent a contribution over prior art as being anticipated by Seibel, which discloses of optically annealing a polyphase surface layer via exposure to a plurality of laser pulses having a pulsewidth in a range of about 1 nanosecond to about 50 nanoseconds so as to enhance crystallinity of said doped surface layer (para [0010]: "...a crystalline silicon substrate... an amorphous layer on top..."; see instant specification [0070]: "The term 'polyphase'... refers to a material... having distinct physical and/or chemical characteristics... For example, when the substrate is a silicon substrate (e.g., a crystalline silicon substrate prior to formation of the polyphase layer), the polyphase layer can include amorphous silicon..."; para [0010]: "The radiation beam heats the top surface layer of the amorphous silicon and causes melting and explosive recrystallization (XRC) of the amorphous silicon layer "; para [0032]: "Laser beam 230 is a pulsed radiation generated by a Neodymium YAG laser and has... a temporal width of 16 nanoseconds... XRC is well known in the art and is described... in a published paper 'Explosive Crystallization in Amorphous Si Initiated by Long Pulse Width Laser Irradiation', P.S. Peercy..."; para [0044]: "Laser beam 230... a pulse width of 16 nanoseconds").

As the common technical features were known in the art at the time of the invention, these cannot be considered special technical feature that would otherwise unify the groups.

Therefore, Groups I-IV lack unity under PCT Rule 13 because they do not share a same or corresponding special technical feature.

Certain observations on the international application:

Note 1: There is an unnumbered claim in the international application, the last two lines of claim 46 state: "The semiconductor substrate of claim 44, where said surface layer exhibits an absorptance greater than about 50% for at least one sub-bandgap wavelength". This has been interpreted as a typo, and that this claim is a dependent claim on 44 and is missing a claim number and is not part of claim 46. In the interest of completing the international search, claim 46 will be considered as two separate claims, with claim 46a stated as " A semiconductor substrate, comprising: a substantially crystalline doped surface layer having a dopant concentration in a range of about 0.01 to about 1.5 atom percent and a thickness in a range of about 10 nanometers to about 1 micrometer, said doped surface layer having a plurality of light-trapping surface textures, wherein said doped surface layer forms a diode junction with underlying portion of the substrate" and claim 46.b stated as: "The semiconductor substrate of claim 44, where said surface layer exhibits an absorptance greater than about 50% for at least one sub-bandgap wavelength."

Note 2: The following are observations and interpretations have been made in order to complete the international search, since the claims as written were very unclear and confusing.

Claim 3 states "... wherein said optically annealing step..." and has an improper dependency on claim 2 which depends on claim 1, since claim 2 does not disclose of said optically annealing step. Therefore, this claim has been interpreted to be dependent on claim 1, which does disclose of said optically annealing step.

Claim 7 states "... wherein said optically annealed doped surface layer..." and has an improper dependency on claim 3 which depends on claim 1, since claim 3 does not disclose of said optically annealed doped surface layer. Therefore, this claim has been interpreted to be dependent on claim 1, which does disclose of said optically annealed doped surface layer.

Claim 12 states "...wherein said semiconductor substrate..." and has an improper dependency on claim 8 which depends on claim 1, since claim 8 does not disclose of said semiconductor substrate. Therefore, this claim has been interpreted to be dependent on claim 1, which does disclose of said semiconductor substrate.

Claim 15 states "...wherein said thermal annealing step..." and has an improper dependency on claim 7 which depends on claim 1, since claim 7 does not disclose of a thermal annealing step. Therefore, this claim has been interpreted to be dependent on claim 14, which further discloses of the method of claim 1, further comprising a thermal annealing step.

Claim 19 states "...wherein said dopant..." and has an improper dependency on claim 16 which depends on claim 1, since claim 16 does not disclose of said dopant. Therefore, this claim has been interpreted to be dependent on claim 1, which does disclose of said dopant.

Claim 20 states "....wherein said laser pulses employed in the incorporating step..." and has an improper dependency on claim 16 which depends on claim 1, since claim 16 does not disclose of said incorporating step and claim 1 discloses of a range of nanoseconds, which is significantly larger than femtoseconds or picoseconds. Therefore, this claim has been interpreted to be dependent on claim 18, which does disclose of said incorporating step and additionally discloses of a range of femtoseconds to picoseconds.

Claim 21 states "...wherein said step of exposing said substrate..." and has an improper dependency on claim 16 which depends on claim 1, since none of these steps disclose of said step of exposing the substrate. Therefore, this claim has been interpreted to be dependent on claim 18, which further discloses of the incorporating step of method of claim 1, further comprising the step of exposing the substrate.

Claim 22 states "...wherein said step of exposing said substrate..." and has an improper dependency on claim 16 which depends on claim 1, since none of these steps disclose of said step of exposing the substrate. Therefore, this claim has been interpreted to be dependent on claim 18, which further discloses of the incorporating step of method of claim 1, further comprising the step of exposing the substrate.

Claim 26 states "...wherein the implanting step..." and has an improper dependency on claim 19 which depends on claim 1, since neither claim 19 nor claim 1 disclose of an implanting step. Therefore, this claim has been interpreted to be dependent on claim 25, which further discloses of the method of claim 1, further comprising an implanting step.

---Continued in Supplemental Box---

Continuation of Observations on the International Application

Claim 27 states "...wherein the dopant ion beam..." and has an improper dependency on claim 21 which depends on claim 18 which depends on claim 1, since none of those claims disclose of an ion beam. Therefore, this claim has been interpreted to be dependent on claim 26, which further discloses of the method of claim 1, further comprising an ion beam.

Claim 30 states "...wherein said thermal annealing step..." and has an improper dependency on claim 26 which depends on claim 25 which depends on claim 1, since none of those claims disclose of a thermal annealing step. Therefore, this claim has been interpreted to be dependent on claim 28, which discloses of a thermal annealing step.

Claim 31 states "...wherein said thermal annealing step..." and has an improper dependency on claim 27 which depends on claim 26 which depends on claim 25 which depends on claim 1, since none of claims disclose of a thermal annealing step. Therefore, this claim has been interpreted to be dependent on claim 28, which discloses of a thermal annealing step.

Claim 32 states "...wherein said optical annealing step..." and has an improper dependency on claim 31 which depends on claim 28, since claim 31 does not disclose of an optical annealing step. Therefore, this claim has been interpreted to be dependent on claim 28, which does disclose of said optical annealing step.

Claim 34 states "...wherein said semiconductor substrate..." and has an improper dependency on claim 30 which depends on claim 28, since claim 30 does not disclose of said semiconductor substrate. Therefore, this claim has been interpreted to be dependent on claim 28, which does disclose of said semiconductor substrate.

Claim 35 states "...wherein said elevated temperature..." and has an improper dependency on claim 26 which depends on claim 25 which depends on claim 1, since none of the claims 1 disclose of said elevated temperature. Therefore, this claim has been interpreted to be dependent on claim 28, which does disclose of said elevated temperature.

Claim 36 states "...wherein said optical annealing laser pulses..." and has an improper dependency on claim 26 which depends on claim 25 which depends on claim 1, since neither claim 26 nor 25 disclose of said optical annealing laser pulses. Therefore, this claim has been interpreted to be dependent on claim 28, which does disclose of said optical annealing laser pulses.

Claim 37 states "...wherein said optical annealing laser pulses..." and has an improper dependency on claim 26 which depends on claim 25 which depends on claim 1, since neither claim 26 nor 25 disclose of said optical annealing laser pulses. Therefore, this claim has been interpreted to be dependent on claim 28, which does disclose of said optical annealing laser pulses and not on claim 1 since claim 16, which is dependent on claim 1, already discloses of this claim.

Claim 38 states "...wherein said incorporating step..." and has an improper dependency on claim 26 which depends on claim 25 which depends on claim 1, since neither claim 26 nor 25 disclose of said incorporating step. Therefore, this claim has been interpreted to be dependent on claim 28, which does disclose of said optical annealing laser pulses, and not on claim 1 since claim 18, which is dependent on claim 1, already discloses of this claim (i.e. claim 38 now reads "The method of claim 28, wherein said generating step comprises...").

Claim 39 states "...wherein said step of exposing..." and has an improper dependency on claim 35 depends which depends on claim 28, since claim does not disclose of said exposing step. Therefore, this claim has been interpreted to be dependent on claim 38, which does disclose of said exposing step.

Claim 40 states "...wherein said step of exposing..." and has an improper dependency on claim 35 depends on claim 28, since claim 35 does not disclose of said exposing step. Therefore, this claim has been interpreted to be dependent on claim 38, which does disclose of said exposing step.

Claim 41 states"...wherein said incorporating step..." and has an improper dependency on claim 26 which depends on claim 25 which depends on claim 1, since neither claim 26 nor 25 disclose of said incorporating step. Therefore, this claim has been interpreted to be dependent on claim 28, which does disclose of said optical annealing laser pulses, and not on claim 1 since claim 25, which is dependent on claim 1, already discloses of this claim (i.e. claim 41 now reads "The method of claim 28, wherein said generating step comprises...").

Claim 42 states "...wherein said implanting step..." and has an improper dependency on claim 26 which depends on claim 25 depends on claim 1, since none of the claims disclose of said implanting step. Therefore, this claim has been interpreted to be dependent on claim 41, which does disclose of said implanting step.

Claim 43 states "...wherein said dopant ion beam..." and has an improper dependency on claim 39 which depends on claim 38 depends on claim 28, since none of the claims disclose of said dopant ion beam. Therefore, this claim has been interpreted to be dependent on claim 42, which does disclose of said dopant ion beam.

Claim 44 states "...wherein said doped surface layer generated by said incorporating step... said thermal and optical annealing steps..." and has an improper dependency on claim 26 which depends on claim 25 depends on claim 1, since none of the claims disclose of said incorporating step or a thermal annealing step. Therefore, this claim has been interpreted to be dependent on claim 28, which does disclose of said incorporating step and thermal annealing step, (i.e. claim 44 now reads "The method of claim 28, wherein said doped surface layer generated by said generating step...").

Claim 45 states "...said doped surface layer..." and has an improper dependency on claim 35 which depends on claim 28, since claim 35 does not disclose of said doped surface layer. Therefore, this claim has been interpreted to be dependent on claim 28, which does disclose of said doped surface layer.

---Continued in Supplemental Box---

Continuation of Observations on the International Application

Claim 46b states "...semiconductor substrate of claim 44..." and has an improper dependency on claim 44 which depends on claim 28, since claim 44 does not disclose of a semiconductor substrate. Therefore, this claim has been interpreted to be dependent on claim 46a, which does disclose of said semiconductor substrate.

Claim 47 states "...semiconductor substrate of claim 46..." and has been interpreted to be dependent on claim 46a.

Claim 48 states "...semiconductor substrate of claim 44..." and has an improper dependency on claim 44 which depends on claim 28, since claim 44 does not disclose of a semiconductor substrate. Therefore, this claim has been interpreted to be dependent on claim 46a, which does disclose of said semiconductor substrate.

Claim 49 states "...semiconductor substrate of claim 46..." and has been interpreted to be dependent on claim 46a.

Claim 50 states "...semiconductor substrate of claim 44..." and has an improper dependency on claim 44 which depends on claim 28, since claim 44 does not disclose of a semiconductor substrate. Therefore, this claim has been interpreted to be dependent on claim 46a, which does disclose of said semiconductor substrate.

Claim 52 states "...said surface textures of the optically annealed surface layer..." and has an improper dependency on claim 50 which depends on claim 46a, since neither claim 46a nor claim 50 disclose of optical annealing. Therefore, this claim has been interpreted to be dependent on claim 51, which does disclose of surface textures on an optically annealed surface layer.

Claim 53 states "...said plurality of texturing laser pulses..." and has an improper dependency on claim 50 which depends on claim 46a, since neither claim 46a nor claim 50 disclose of texturing laser pulses. Therefore, this claim has been interpreted to be dependent on claim 51, which does disclose of texturing laser pulses.

Claim 54 states "...wherein said substrate comprises a semiconductor..." is unclear and confusing since it is dependent on claim 50 which depends on claim 46a, claim 46 discloses that the substrate is a semiconductor. Therefore, this claim has been interpreted to be dependent on claim 51, which does not specifically disclose what the substrate comprises.

Claim 55 states "...wherein the semiconductor substrate..." and has an improper dependency on claim 53 which depends on claim 51, since neither claim 53 nor claim 51 disclose of semiconductor substrate. Therefore, this claim has been interpreted to be dependent on claim 54, which does disclose of a semiconductor substrate.