IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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INVENTOR(S):	David Foord, et al.	§	ART UNIT:	1756
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TITLE: ION IMPLANTATION TO ALTER ETCH RATE

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Commissioner for Patents
PO Box 1450
Alexandria, VA 22313-1450

AMENDMENTS AND RESPONSE PURSUANT TO REQUEST FOR CONTINUED EXAMINATION

Dear Sir:

In response to the Final Office Action dated October 19, 2017, Applicant respectfully requests the following amendments in the above-identified application. The changes made are shown by underlining the added text and striking through the deleted text in bold.

Amendments to the Claims begin on page 2 of this paper.

Remarks/Arguments begin on page 6 of this paper.

Technical arguments are provided in Sections III-V (pages 9-17).

The purpose of this "Response" is to convince a patent examiner that the "claimed invention" is patenably distinguishable over the material processing methods described in certain publications ("references") that predate the filing of the patent application. These publications are cited in rejections against Applicant's "claims" as part of an "Office Action" issued by the Examiner. To overcome the Office Action, the Response includes claim amendments and rebuttal arguments that Applicant's attorney believes will be effective in distinguishing the claims over the subject matter of the publications.

AMENDMENTS TO THE CLAIMS

This listing of claims will replace all prior versions and listings of claims in the application.

Listing of Claims

1. (Currently Amended) A method for preparing a thin, reinforced lamellar structure using a charged particle beam system, comprising:

~~partly~~ forming a lamella from a sample material;

applying to the lamella a hardening material in a pattern corresponding to a reinforcing structure by directing a focused beam of ions ~~toward~~ onto a face of the lamella to implant ions into the ~~lamella~~ face according to the pattern; and

thinning the lamella by milling, wherein a region of the lamella corresponding to the reinforcing structure is milled at a slower rate than a region of the lamella without the hardening material, leaving the reinforcing structure where the hardening material was applied to mechanically strengthen the lamella.

2. (Cancelled)

3. (Currently Amended) The method of claim 1 in which: ~~the rate of milling of the region of the lamella with the hardening material is 20% less than the rate of milling of the region of the lamella without the hardening material.~~

the focused beam of ions is a first beam;

thinning the lamella comprises milling the lamella with a second beam; and

the second beam mills a region of the lamella implanted with ions at a rate that is at least 20% lower than a rate at which the second beam mills a region of the lamella not implanted with ions.

4. (Previously Presented) The method of claim 1 in which directing a focused ion beam toward the lamella to implant ions includes directing Be^+, Ga^+, Xe^+, Ar^+, O^+, In^+, Si^+, Kr^+, or Bi^+ ions.

5. (Previously Presented) The method of claim 4 in which directing a focused ion beam toward the lamella to implant ions includes directing a beam of beryllium ions towards the lamella.

6. (Previously Presented) The method of claim 1 in which directing a focused ion beam toward the lamella to implant ions into the lamella includes providing an ion dose of between 0.1-1.0 nC/μm^2.

7. (Original) The method of claim 1 in which applying a hardening material and milling the lamella are performed by a single focusing column in the charged particle beam system.

8. (Original) The method of claim 7 in which the single focusing column comprises of a liquid metal alloy source or a plasma ion source and a mass filter to select the ions.

9. (Previously Presented) The method of claim 1 in which the lamella has a final thickness of less than 20 nm.

10-16. (Cancelled)

17. (Withdrawn – Previously Presented) A method for preparing a microscopic structure, comprising:

directing a focused beam of ions in a pattern corresponding to a reinforcing structure toward a work piece to implant atoms into a surface of the work piece and thereby to form as hardening material the reinforcing structure within the work piece; and

etching a portion of the work piece, the etched portion including at least a portion of the pattern corresponding to the reinforcing structure, the implanted atoms reducing an etch rate of the pattern to form a protruding region in the form of the pattern.

18. (Withdrawn) The method of claim 17 in which etching the work piece includes milling the work piece using a focused ion beam or a focused electron beam.

19. (Withdrawn) The method of claim 18 in which etching the work piece includes exposing the work piece to a precursor gas that decomposes in a presence of a charged particle beam.

20. (Withdrawn) The method of claim 17 in which etching the work piece includes exposing the work piece to an etchant that will etch the work piece without requiring a presence of a charged particle beam.

21. (Withdrawn) The method of claim 17 in which etching the work piece includes directing an ion beam having a spot size greater than 500 nm onto the work piece.

22. (Withdrawn) The method of claim 17 in which directing a focused beam of ions in a pattern toward a work piece to implant atoms into a surface of the work piece includes directing Be^+, Ga^+, Xe^+, Ar^+, O^+, In^+, Si^+, Kr^+, or Bi^+ ions.

23. (Currently Amended) The method of claim 1, wherein thinning the lamella by milling comprises: ~~the lamella is by directing a focused ion beam toward a lamella surface.~~

milling the lamella with a focused ion beam comprising ions different than the ions implanted into the lamella; or

milling the lamella with a focused ion beam having a beam energy different than the focused beam of ions used for implanting ions into the lamella.

24. (Cancelled)

25. (Previously Presented) The method of claim 1 wherein applying to the lamella a hardening material by directing a focused beam of ions toward the lamella to implant ions into the lamella comprises applying a hardening material without beam-induced deposition.

26. (Previously Presented) The method of claim 1 wherein applying to the lamella a hardening material in a pattern corresponding to a reinforcing structure by directing a focused beam of ions toward the lamella to implant ions into the lamella comprises implanting ions into an implanted area and wherein thinning the lamella by milling comprises milling a milled area and wherein the

milled area is larger than the implanted area.

27. (Previously Presented) The method of claim 1 wherein the reinforcing structure reduces bending of the lamella.

28. (New) A method, comprising:

forming a lamella from a bulk sample;

directing a first focused ion beam into a face of the lamella such that ions are implanted into the face in a pattern, the ions implanted being of a species that hardens the material of the lamella where implanted; and

thinning the lamella using a second focused ion beam, wherein the second focused ion beam thins a region of the lamella implanted with the ions at a slower rate than a region of the lamella not implanted with the ions, thereby exposing a raised structure that corresponds to the pattern and mechanically reinforces the lamella.

29. (New) The method of claim 28, further comprising observing a feature in the lamella using a transmission electron microscope.

REMARKS/ARGUMENTS

Claims 1, 3 and 23 are amended. Claims 2 and 24 are cancelled. Claims 10-16 were previously cancelled. Claims 17-22 were previously withdrawn from consideration. Claims 28-29 are added. Claims 23-27 were previously added. Thus, claims 1, 3-9, 17-23 and 25-29 are pending, and claims 1, 3-9, 23 and 25-29 are under consideration.

I. Examiner Interview

Applicant thanks the Examiner for courtesies rendered during the December 19, 2017 interview conducted by telephone between Examiner Ibrahime Abraham and Applicant's representative, John Hillert. The substance of the interview is summarized as follows:

- Applicant's representative and the Examiner discussed whether and to what extent the Sievila reference (full citation, *infra*) discloses using gallium ion implantation to form masks for dry etching processes.
- Applicant's representative and the Examiner discussed whether it would have been obvious to modify the process of Mayer reference (full citation, *infra*) to include a gallium ion implantation step when the Abstract of Mayer describes gallium ion implantation as a contaminant.
- No agreement was reached regarding the pending rejections.
- No exhibits were shown and no demonstrations conducted.

II. Claim Amendments

Applicant respectfully submits that the claim amendments do not introduce new matter and are supported by Applicant's originally filed disclosure. Examples of support in the originally filed application for the claim amendments are provided as follows.

Amendments to Claims 1 and 3

Support for the amendments to **claim 1** replacing the word "toward" with "onto a face of," and replacing the fourth instance of "lamella" with "face according to the pattern" may be found in the application as originally filed, for example, at least at FIG. 2 and ¶ [0028] ("FIG. 2 shows a cross section milled though the region of FIG. 1 using a focused ion beam. The ion beam was *directed normal to the surface* and normal to the Be implant lines."); ¶ [0035] ("In step 1004, the hardening material is applied <u>*to the lamella*</u> *in a pattern corresponding to the desired reinforcing structure*.").

The amendment to **claim 1** deleting the word "partly" is made to clarify antecedent basis for instances of the term "lamella." The expressions "partly form," "partly formed" and "partly forming," are used in the originally-filed application to refer to a lamella formed from a bulk sample material that has not yet been thinned to its final thickness. *Cf.*, Application at ¶ [0002] (1st sentence), ¶ [0033] (2nd sentence) and FIG. 10 (blocks 1002 and 1004). Applicant submits that deleting "partly" does not change the scope of claim 1 or introduce new matter, as claim 1 recites subsequent thinning of the lamella.

Support for the amendments to **claim 3** may be found, for example, at least at:

- ¶ [0037] ("A preferred hardening material, when applied, preferably produces an etch rate at least 10% less, more preferably 20% less, and most preferably 30% less than the etch rate of the work piece material without the implant.");
- ¶ [0022] ("In accordance with some embodiments of the invention, a material is provided to harden a region of a work piece before etching. The region with the added material etches at a slower rate than the surrounding region without the added material, leaving structures defined by the added material."); and
- ¶ [0024] ("The ions are typically implanted in a first region, and then a second region, preferably a superset of the first region, is etched, for example, such as by being processed using a second beam, such as an ion beam, an electron beam, or a laser beam, or other process, such as chemical etching.").

Cancellation of Claims 2 and 24; Amendment to Claim 23

In order to avoid introducing excess claim fees with the introduction of new claims 28-29, claims 2 and 24 are cancelled, and claim 23 is amended to incorporate the subject matter of cancelled claim 24.

New Claim 28

Examples of support in the originally filed application for new claim 28 are provided in Table I below.

TABLE I – Examples of Support for New Claim 28	
Feature	**Support**
"forming a lamella from a bulk sample"	¶ **[0002]** ("A thin TEM sample cut from a bulk sample material is known as a "lamella.""); ¶ **[0047]** (" . . . a method for preparing a thin, reinforced lamellar structure using a charged particle beam systems comprises partly forming a lamella from a sample material")
"directing a first focused ion beam into a face of the lamella such that ions are implanted into the face in a pattern, the ions implanted being of a species that hardens the material of the lamella where implanted"	¶ **[0009]** ("In accordance with some embodiments of the invention, *a hardening material is implanted* into regions of the lamella to strengthen the lamella"); ¶ **[0022]** ("The region with the added material etches at a slower rate than the surrounding region without the added material, leaving structures defined by the added material. *The material can be added, for example, by ion implantation*, which allows for the precise definition of structures having dimensions in the nanometer range."); **FIG. 2** and ¶ **[0028]** ("FIG. 2 shows a cross section milled though the region of FIG. 1 using a focused ion beam. The ion beam was *directed normal to the surface and normal to the Be implant lines*."); ¶ **[0035]** ("In step 1004, the hardening material is applied *to the lamella in a pattern corresponding to the desired reinforcing structure*."); ¶ **[0036]** ("The hardening process is not limited to beryllium ions and other ions can be used to provide a similar effect. For example, Li+, Mg+, and Ca+ may be useful to implant into Si or other materials. Other material that may be useful for implanting to harden a material include Ga+, Xe+, Ar+, O+, In+, Si+, Kr+, and Bi+. Implanting may be useful to harden almost any material . . . "); ¶ **[0046]** ("In some embodiments, the beam-assisted etch rate of portions of the work piece *in which ions have been implanted is reduced, leaving raised areas corresponding to the implanted regions*.")
"thinning the lamella using a second focused ion beam, wherein the second focused ion beam thins a region of the lamella implanted with the ions at a slower rate than a region of the lamella not implanted with the ions, thereby exposing a raised structure that corresponds to the pattern and mechanically reinforces the lamella"	¶ **[0022]** ("The region with the added material etches at a slower rate than the surrounding region without the added material, leaving structures defined by the added material."); ¶ **[0028]** (as quoted, *supra*), and

	¶ **[0032]** ("FIG. 9 shows that surface material is etched away in the milled region 902, but the portion of region 902 that had implanted Be is not milled as deeply as the rest of the region, leaving a raised strip 904 where the Be was implanted."), ¶ **[0039]** ("Based on the examples, and guidance provided above, a skilled person can readily select an ion species, beam energy and dose *to harden a substrate* for a particular application."), **original claim 1** (" . . . milling the lamella, the region of the lamella with the hardening material being milled at a slower rate than the region of the lamella without the hardening material, *leaving at least one <u>raised structure</u> where the hardening material was applied to <u>mechanically strengthen</u> the lamella*)

New Claim 29

New claim 29 is supported, for example, at paragraph [0034] ("FIG. 11 is a diagram showing an arrangement of a hardened area 1102 structurally reinforcing the lamella 1104 without affecting a region of interest 1106 defined around a feature 1108."); paragraph [0035] ("In step 1008, the lamella is viewed on a transmission electron microscope."); and Block 8 of FIG. 10 ("Observe lamella on TEM").

III. <u>Claim Rejections Under 35 U.S.C. § 103</u>

Claims 1-4, 6-9 and 23-27 stand rejected under 35 U.S.C. 103(a) as being unpatentable over TEM sample Preparation and FIB-Induced Damage by Mayer et al., "TEM Sample Preparation and FIB-Induced Damage," *MRS Bulletin*. May 2007; 32:400-407, in view of Sievila et al. "The fabrication of silicon nanostructures by focused-ion-beam implantation and TMAH wet etching," *Nanotechnology*. 2010 (IOPP); 21(14):1-6. Applicant respectfully submits that the rejection should be withdrawn for the following reasons.

A. Mayer and Sievila do not Disclose or Suggest Implanting Ions into a Face of a Lamella

Applicant submits that amended claim 1 is patentable over Mayer and Sievila because the cited references, alone or in combination, fail to disclose or suggest all of the features recited in amended claim 1. Specifically, it is submitted that Mayer and Sievila fail to disclose or suggest the feature of "applying to the lamella a hardening material in a pattern corresponding to a reinforcing structure by *directing a focused beam of ions onto a face of the lamella to implant ions into the face* according to the pattern," which is required by amended claim 1.

In both Mayer and Sievila, a linear mask structure is formed on a bulk material first, and then a lamellar structure is formed underneath the mask structure by etching trenches on both sides of the mask structure. *Cf.*, Mayer at p.401, col.1, ll.23-26 ("The sample material is then mounted on a half-grid and inserted vertically into the FIB chamber. Before cutting, a W or Pt line is usually deposited on the area of interest to protect the top portion of the specimen and to mark the position of the target area. After cutting two deep trenches, the final lamella, if seen from the top, looks like the crossbar in the letter 'H'"), and FIG. 1 (showing the H-bar structure); *See, e.g.,* Sievila at p.2, col.2, ll. 4-7 ("During each etching period the height difference between the implanted regions and the surrounding Si surface increases until the doped layer is totally etched away"), FIG. 8(a) and FIG. 8(a) caption ("The approx.. 50 nm thick and 70 nm wide Ga^+-doped masking layer can be seen on the top of the wall"). In contrast, the reinforcing structure of amended claim 1 is formed *from a lamella* by implanting a region on a face of the lamella and then thinning the lamella. Moreover, whatever portion of the masking structure remains once the Mayer and Sievila processes are finished is located at the edge of the newly etched lamella, not on the face of the lamella, as required by amended claim 1.

Thus, Mayer and Sievila fail to disclose or suggested applying to the lamella a hardening material in a pattern corresponding to a reinforcing structure by directing a focused beam of ions onto a face of the lamella to implant ions into the face according to the pattern. Accordingly, amended claim 1 is nonobvious over the combination of Mayer and Sievila because the cited references do not disclose or suggest all of the claim features recited therein.

B. Mayer Teaches Away from Incorporating the Gallium Ion Implantation of Sievila

In rejecting the claims, the Office Action states that:

> Mayer teaches . . . applying a hardening material in a pattern to the lamella (1"Methods Requiring Pre-Thinning": Line of W or Pt is patterned on partly formed lamella.) . . . . Sievila teaches using a FIB to implant Ga ions into an area of interest . . . . It would have been obvious to one of ordinary skill in the art at the time of the invention to have substituted the hardening/mask process of Mayer, for the hardening/mask process of Sievila, as both are suitable methods of masking/protecting an area to be etched.

Office Action at pp. 3-4, paras. 9-11a.

Applicant submits that the rejection cannot be sustained on the foregoing basis because Mayer teaches away from utilizing ion implantation in TEM lamella preparation, particularly gallium ion implantation. For example, the Abstract of Mayer states:

> One of the most important applications of a focused ion beam (FIB) workstation is preparing samples for transmission electron microscope (TEM) investigation . . . .This article gives an overview of the variety of techniques that have been developed to prepare the final TEM specimen. The strengths of these methods *as well as the problems, such as FIB-induced damage and Ga contamination, are illustrated with examples . . . .*

Id. (emphasis added). As another example, the Introduction section of Mayer concludes by stating:

> *The <u>main disadvantage</u> of FIBs*, however, is caused by the nature of the milling process: the ion collisions initiating sputter removal can also *lead to ion implantation and cause <u>severe damage</u> to the remaining bulk of the material*. As the FIB lamellae method spreads to more advanced TEM techniques, various procedures have been developed to reduce or repair this damage.
>
> In this article, the major specimen preparation techniques are reviewed; *the consequences of FIB-induced damage are discussed, along with strategies to reduce the damage*; and an overview on applications in materials science and in related instrumental fields is presented.

Mayer at p.400, col.3, ll.11-15 (emphasis added). In view of such teachings, persons skilled in the art would have been dissuaded from modifying Mayer to include an ion implantation step, whether it be the gallium ion implantation of Mayer (or an ion implantation step described in another reference). As such, amended claim 1 is nonobvious over the combination of Mayer and Sievila.

The Office Action's assertion that it would have been obvious to replace Mayer's step of depositing "a W or Pt line" with the gallium ion implantation of Sievila is further defective in that it renders the Mayer deposition step unsuitable for its intended purpose, which is to avoid damage to the sample by preventing ion implantation. *Cf.*, *Id.* at p.400, col.3, ll.11-15 (describing damage from ion implantation as the main disadvantage of using FIBs for preparing TEM lamella); and p.401, col.1, ll.23-26 ("Before cutting, a W or Pt line is usually deposited on the area of interest to protect the top portion of the specimen and to mark the position of the target area."). In fact, the proposed modification of Mayer replaces the solution with the stated problem (i.e., deposition of the W or Pt line of Mayer protects the sample from gallium ion implantation, and the Office Action proposes substituting said deposition with a step that implants gallium ions). Persons skilled in the art would not have made the proposed substitution because doing so would result in ions being implanted into lamella being prepared for TEM analysis, which is the opposite outcome that the line deposition step of Mayer is intended to achieve.

Mayer and Sievila also teach away from combination because the effects of ion implantation on the sample believed to impart etch stopping characteristics in Sievila are characterized as sample damage in Mayer. On one hand, Sievila describes amorphization and new phase formation of the sample as possible mechanisms for the etch stop characteristics imparted by gallium ion implantation. Specifically, Sievila states:

> The etch stop mechanism of gallium ion doping of silicon is not truly understood. *The amorphization of Si induced by ion irradiation* and the decrease of free electrons have been proposed to be responsible for the etch stop phenomenon. *Another possible explanation is the formation of non-volatile gallium oxide in the doped surface layer* during the etch process, which has been investigated by means of secondary ion mass spectroscopy (SIMS) and x-ray photoelectron spectroscopy (XPS) for both dry and wet chemical etched samples.

Sievila at p. 2, col. 2, ll. 30-39 (emphasis added; end-note numbering omitted). On the other hand, Mayer teaches that the conversion of portions of the TEM lamella into amorphous layers and Ga-containing phases are regarded as forms of ion implantation-induced damage in TEM lamella preparation processes. Mayer at p. 402, col. 3, ll. 32-38 ("Whereas surface amorphization is the main concern in semiconductor materials, there have been several reports in the literature that FIB milling of fine-grained fcc metals can change the orientation and size of the surface grains and form Ga intermetallic compounds."); and p. 403, col. 1, ll. 16-19 ("One must also be careful that the implantation of Ga into the sample does not result in changes induced by the formation of new Ga-containing phases."). Given these teachings, persons skilled in the art would not have substituted the protective line deposition of Mayer for the gallium implantation of Sievila in order to avoid causing damaging the sample in a way that would interfere with or prevent subsequent analysis of the sample by TEM. As such, Applicant submits that the rejection of claim 1 should be withdrawn because Sievila and Mayer cannot be combined as suggested in the Office Action.

C. Pages 3-5 and Figures 7-8 describe 3D nanostructures formed by ion implantation and wet etching process, not ion implantation and dry etching.

In rejecting claim 1, the Office Action cites pages 3-5 and figures 7-8 of Sievila for the proposition that:

> Sievila teaches that the implanted ions form a mask that can be used for either wet or dry etching. Sievila teaches that an FIB can be used to etch a thin lamella after ion beam implantation. Sievila teaches that the ion implantation and subsequent etching/milling is used in order to form high-resolution features with small dimensions, (pages 1-5, especially pages 3-5 and figures 7-8 which demonstrates lamella formation by ion implantation and etching/cutting with a FIB) .

Office Action at p.4, ll.3-8.

Applicant respectfully submits the rejection of claim 1 should be withdrawn because the above-referenced assertions are inaccurate characterizations of Sievila. The cited portions of Sievila describe forming nanochannels using ion implantation *in conjunction with wet etching*, not "lamella formation by ion implantation and etching/cutting with a FIB," as asserted in the Office Action. *Cf.*, Sievila at pp.3-4, §3.3, ¶1 (describing fabrication of "[n]anochannels separated by very narrow vertical ridges" by implanting single-crystal silicon with gallium and then wet etching the implanted silicon "in 85 °C TMAH solution for 1 min.").

While Sievila may refer to "cutting the *structure* with FIB" (*Id.* at p.4, col.1, ln.4; also captions of FIGS. 4 and 8), the structure referred to is the series of nanochannels formed by wet etching, and the FIB plays the limited role of milling away portions of the nanochannel structure to reveal features and characteristics of the nanochannel structure imparted by Sievila's ion implantation/wet etch technique. *Cf.*, Sievila at Section 3.3, 1st paragraph ("Figure 7 shows 500 nm wide and 600 nm *deep channels*. Figure 7(b) *shows a cross section of the four narrowest walls... obtained by cutting* the structure with FIB."); and Section 3.3, 2nd paragraph ("The anisotropy of the etching and high selectivity of the gallium-implanted mask enables fabrication of very high aspect ratio structures. Figure 8 <u>*shows*</u> *a wall with an aspect ratio of more than 1:30*). The FIB is not used in conjunction with ion implantation to carry out selective etching. This is apparent from the FIB-milled cross-sections shown in FIGS. 7b, 8a and 8b. To form such cross-sections, *it would have been necessary to mill the undoped silicon regions of the Sievila sample* ***from a direction unprotected by the ion-implanted silicon regions***.

D. The Portions of Sievila Discussing Dry Etching do not Suggest the Proposed Incorporation of Gallium Ion Implantation into the TEM Lamella Prep of Mayer.

As discussed in the preceding section, the cited portions of Sievila (i.e., pages 3-5 and FIGS. 7-8) do not disclose the use of ion implantation as an mask/etch stop. Instead, the FIB cutting described in Sievila is used to expose views of nano-channel structures formed by wet-etching a silicon substrate selectively implanted with gallium ions. The only other passage in Sievila that discusses using ion implantation with FIB etching is at page 2, column 2, lines 30-39, which states:

> The etch stop mechanism of gallium ion doping of silicon is not truly understood. The amorphization of Si induced by ion irradiation and the decrease of free electrons have been proposed to be responsible for the etch stop phenomenon. [13] Another possible explanation is the formation of non-volatile gallium oxide in the doped surface layer during the etch process, which has been investigated by means of secondary ion mass spectroscopy (SIMS) and x-ray photoelectron spectroscopy (XPS) **for both *dry* and wet chemical etched samples** [4, 16].

Sievila at p. 2, col. 2, ll. 30-39 (emphasis added; end-note numbering omitted). However, Applicant submits that the above-quoted passage is not useful for establishing *prima facie* obviousness against amended claim 1 because the quoted passage is a summarization of other implantation processes that, for different reasons, do not support the incorporation of gallium ion implantation proposed by the Office Action. The summarized processes are those described in documents [4], [13] and [16], full citations for which can be found at the end of Sievila.

Citation [4], which is enclosed as Appendix A of the present response, is entitled "The fabrication of silicon nanostructures by local gallium implantation and cryogenic deep reactive ion etching." Page 3, column 1, lines 14-17 and 33-34 of Citation [4] describes a mask that is *chemically resistant to cryogenic deep reactive ion etching*: "To determine the mechanism behind the masking effect of the Ga^+ dopant chemical compositions of surfaces of a series of samples were analyzed using x-ray photoelectron spectroscopy (XPS) . . . Both *gallium oxide and gallium fluoride are non-volatile* and could be responsible for the etch stop." (emphasis added). Thus, Citation [4] (Appendix A) would not have suggested the proposed modification of Mayer because the etching in Mayer involves removing material from TEM lamella predominantly by sputtering (a physical mechanism) whereas in Citation [4] ion implantation is used to provide a *chemically resistant* etch stop for a dry *chemical* etching process.

Citation [13] is entitled "Ultrathin channel vertical DG MOSFET fabricated by using ion-bombardment-retarded etching." Citation [13] would not have suggested the proposed modification of Mayer because ion-bombardment-retarded etching is a *wet etching process* where "the ion-implanted region can be used as an etching mask for the subsequent wet chemical etching of silicon in alkaline solution." *See* "Fabrication of Nanostructure Array by Ion-Bombardment-Retarded Etching," which is included as Appendix B in the present response.

Citation [16] is entitled "Etch rate retardation of Ga^{+}-ion beam-irradiated silicon," the Abstract of which is included as Appendix C of this response. Citation [16] would not have suggested the proposed modification because the dry etching process of Citation [16] is "dry *reactive* ion etching" (DRIE), as opposed to the predominantly sputter-based material removal of Mayer, and because the protective mask structure produced by irradiating a silicon substrate with gallium is "almost completely oxidized Ga(Ga_2O_3) layer *free from Si*" rather than a layer of silicon implanted with gallium. Citation [16] at Abstract.

E. Sievila does not teach using ion implantation to form a reinforcing structure.

Claim 1 requires the feature of "applying to the lamella a hardening material in a pattern corresponding to a reinforcing structure by directing a focused beam of ions toward the lamella to implant ions into the lamella . . . thinning the lamella by milling . . . leaving the reinforcing structure where the hardening material was applied to mechanically strengthen the lamella." To account for this feature, the Office Action states:

> Mayer does not explicitly teach that the hardening material is applied by a focused ion beam of ions to implant the ions into the lamella . . .
>
> Sievila teaches using a FIB to implant Ga ions into an area of interest . . . . It would have been obvious to one of ordinary skill in the art at the time of the invention to have substituted the hardening/mask process of Mayer, for the hardening/mask process of Sievila, as both are suitable methods of masking/protecting an area to be etched

Applicant respectfully disagrees that the ion implantation of Sievila corresponds to a process that forms a *mechanically reinforcing* structure comprising implanted ions.

First, whereas claim 1 requires the "reinforcing structure . . . [that] mechanically strengthens the lamella," which is present as part of the lamella after "thinning the lamella," Sievila suggests that the implanted region is *mostly or completely removed* during formation of the high aspect ratio 3D structures. For example, Sievila repeatedly refers to the implanted region as performing the function of a "mask" or an "etch stop," terms that persons skilled in the art would understand as referring to temporary structures used *during* etching, structures that would be partially or completely worn away by the end of the fabrication process. As another example, Sievila states that "[d]uring each etching period the height difference between the implanted regions and the surrounding Si surface increases *until the doped layer is totally etched away.*" Sievila at p.2, col.2,ll.4-7.

Second, Sievila states that "[c]ompared with the direct FIB milling of 3D structures, the described process *only modifies a thin surface layer* so the writing speed is improved by several order of magnitude." Sievila at p.5, col.1, ll.10-13.". Applicant submits that "a thin surface layer" of implanted substrate would not correspond to a reinforcing structure, particularly after being partially or completely removed during etching.

Third, Sievila does not describe any dry etching process in which ion implantation is used to form a mechanically reinforcing structure from a sample material and implanted ions. Citation [16] (Appendix C) may refer to a DRIE process in which "an enhanced Ga oxidation takes place, leading to a thicker GaO_x layer compared to wet chemical treatement." However, as mentioned above, the substrate irradiated in Citation [16] is silicon but the thicker GaO_x layer is "almost completely oxidized Ga(Ga_2O_3) layer *free from Si*," and so Citation [16] does not disclose or suggest a reinforcing structure made from a sample material of a lamella and ions implanted into the sample material, which is implicitly required by amended claim 1.

In view of the foregoing, Applicant submits that the obviousness rejection of claim 1 is deficient in that the proposed modification of Mayer does not disclose the feature of "*applying to the lamella a hardening material in a pattern corresponding to a reinforcing structure by directing a focused beam of ions toward the lamella to implant ions into the lamella . . . thinning the lamella by milling . . . leaving the reinforcing structure where the hardening material was applied to mechanically strengthen the lamella,*" which is required by amended claim 1. Applicant respectfully submits that the rejection of claim 1 should be withdrawn because the rejection fails to account for all of the features recited in claim 1 and therefore fails to establish a *prima facie* case of obviousness with respect to same.

F. Dependent Claims

Claims 3-4, 6-9, 23 and 25-27 depend from amended claim 1 and are patentable over Mayer and Sievila for the reasons as amended claim 1. The rejections of claims 2 and 24 are moot because claims 2 and 24 are cancelled.

IV. Claim Rejections Under 35 U.S.C. § 103

Claim 5 stands rejected under 35 U.S.C. 103(a) as being unpatentable over Mayer in view of Sievila and Kitamura et al. (JP03071632). Applicant respectfully submits that claim 5 is patentable over the combination of Mayer, Sievila and Kitamura because claim 5 depends from amended claim 1 and the Office Action does not rely on Kitamura to make up for the deficiencies of Sievila and Kitamura shown above with respect to amended claim 1.

V. New Claims 28-29

New claim 28 is patentable over Mayer, Sievila and Kitamura for similar reasons as given above for amended claim 1. For example, the cited references fail to disclose the feature of "directing a first focused ion beam into a face of the lamella such that ions are implanted into the face in a pattern," which is required by new claim 28.

New claim 29 depends from claim 28 and is therefore patentable over the cited references for the same reasons as claim 28. The arguments above that Mayer teaches away from incorporating the ion implantation of Sievila into the TEM lamella prep of Mayer are also reasons why persons skilled in the art would not combine the teachings of Mayer and Sievila to arrive at the subject matter of new claim 28, which is directed to a method that includes both a step of "directing a first focused ion beam into a face of the lamella such that ions are implanted into the face in a pattern" (recited in dependent claim 28), and a step of "observing a feature in the lamella using a transmission electron microscope."

VI. Conclusion

It is believed that all of the pending issues have been addressed. However, the absence of a reply to a specific objection, issue or comment does not signify agreement with or concession of the rejection, issue or comment. In addition, because the arguments made above may not be exhaustive, there may be reasons for patentability of any or all pending claims (or other claims) that have not been expressed. Finally, nothing in this reply should be construed as an intent to concede any issue with regard to any claim, except as specifically stated in this reply, and the amendment of any claim does not necessarily signify concession of unpatentability of the claim prior to its amendment.

Applicant submits that all claims in the application are now in condition for allowance, and Applicant respectfully requests that a timely Notice of Allowance be issued in this case.

If the Commissioner determines that any additional fees or extensions are required, Applicant requests that such extensions be granted and any fees be charged to Deposit Account 50-1635.

Respectfully submitted,

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By: /john e hillert/
John E. Hillert
Patent Registration No.: 64,296
Scheinberg & Associates, PC
P.O. Box 164140
Austin, TX 78716-4140
Tel. (512) 637-0800
Fax (512) 306-1963