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Kim et al.

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(45) **Date of Patent:** **Dec. 11, 2007**

(54) **NON-CRITICAL COMPLEMENTARY MASKING METHOD FOR POLY-1 DEFINITION IN FLASH MEMORY DEVICE FABRICATION**

(52) **U.S. Cl.** 438/427; 438/424; 257/E21.545
(58) **Field of Classification Search** 438/424, 438/427, 200; 257/E21.545
See application file for complete search history.

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Primary Examiner—Bradley K. Smith

(57) **ABSTRACT**

A method is disclosed for the definition of the poly-1 layer in a semiconductor wafer. A non-critical mask is used to recess field oxides in the periphery prior to poly-1 deposition by an amount equal to the final poly-1 thickness. A complementary non-critical mask is used to permit CMP of the core to expose the tops of core oxide mesas from the shallow isolation trenches.

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(*) **Notice:** Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 287 days.

(21) **Appl. No.:** **11/099,339**

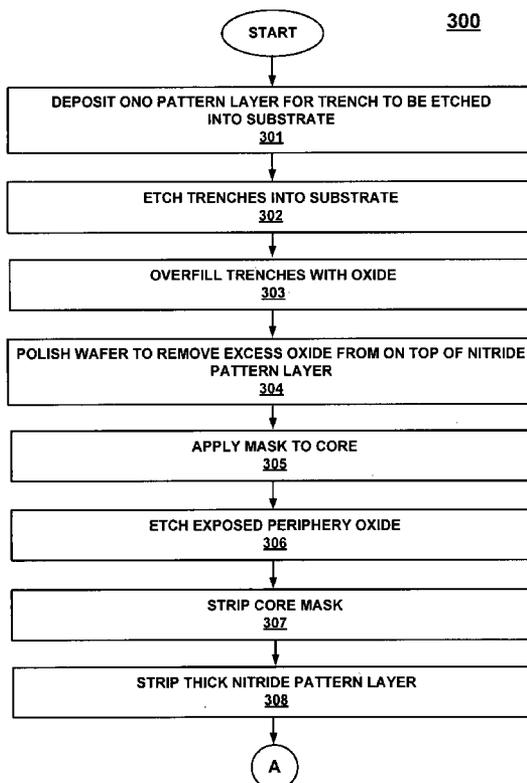
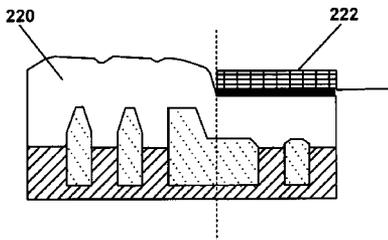
(22) **Filed:** **Apr. 4, 2005**

(65) **Prior Publication Data**

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(51) **Int. Cl.**
H01L 21/76 (2006.01)

10 Claims, 13 Drawing Sheets



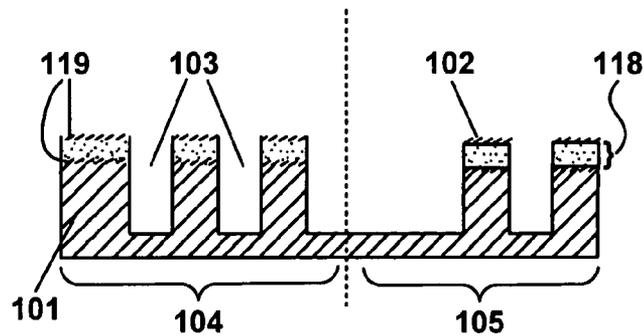


FIG. 1
(Prior Art)

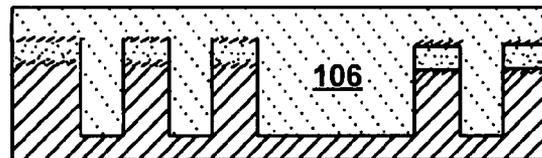


FIG. 2
(Prior Art)

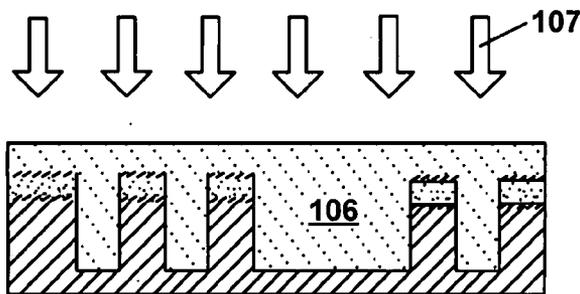


FIG. 3
(Prior Art)

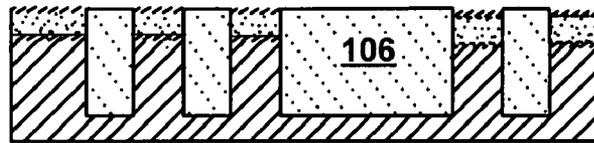


FIG. 4
(Prior Art)

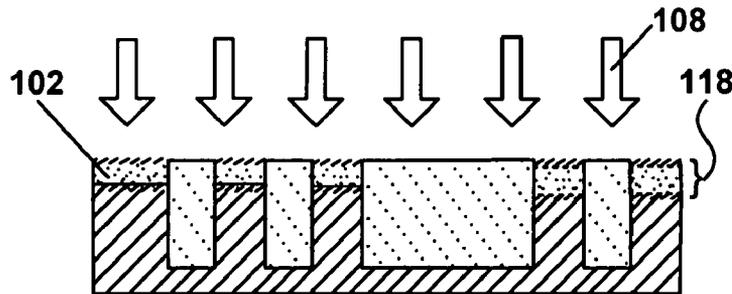


FIG. 5
(Prior Art)

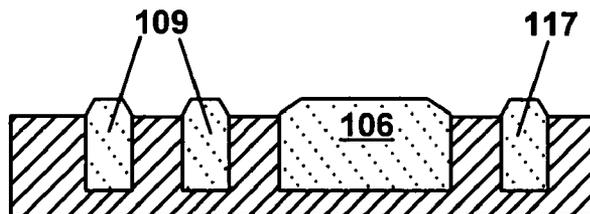


FIG. 6
(Prior Art)

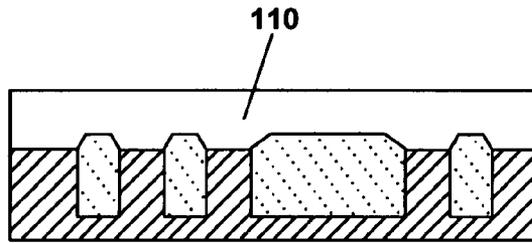


FIG. 7
(Prior Art)

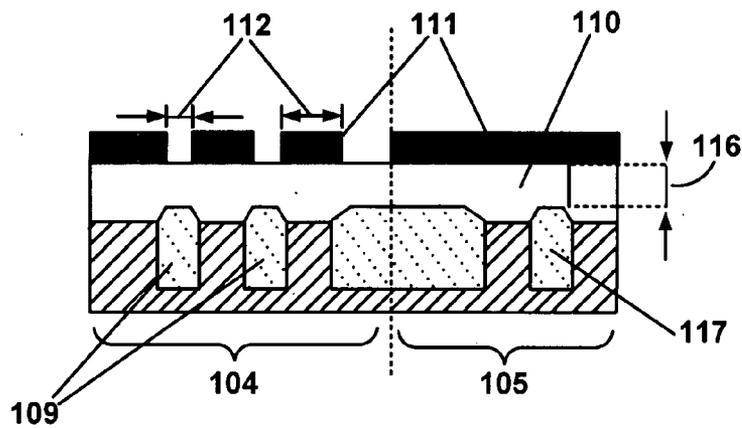


FIG. 8
(Prior Art)

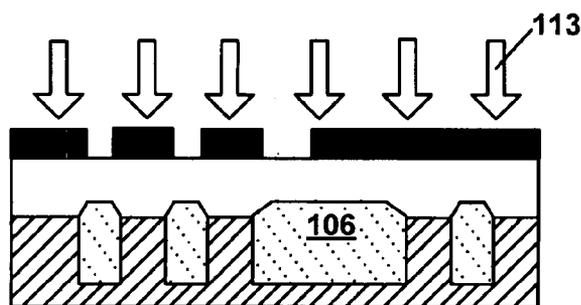


FIG. 9
(Prior Art)

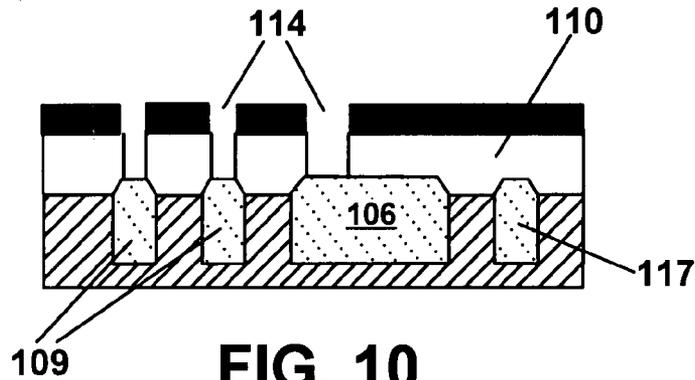


FIG. 10
(Prior Art)

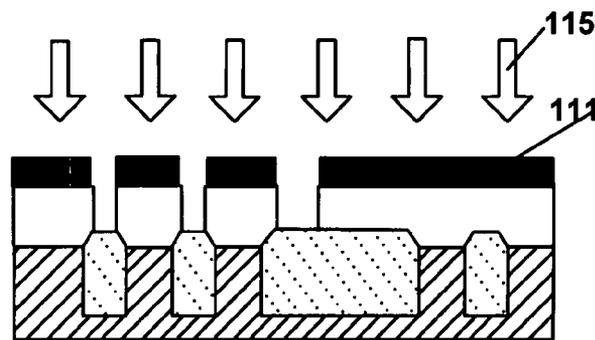


FIG. 11
(Prior Art)

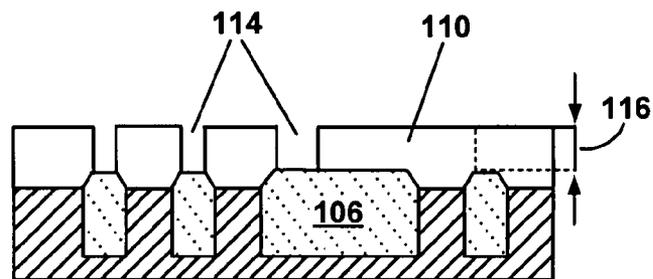


FIG. 12
(Prior Art)

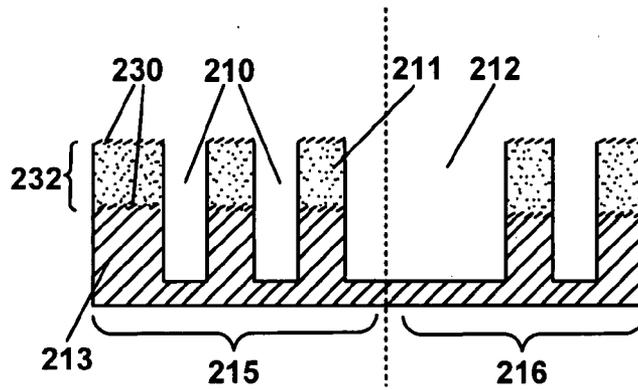


FIG. 13

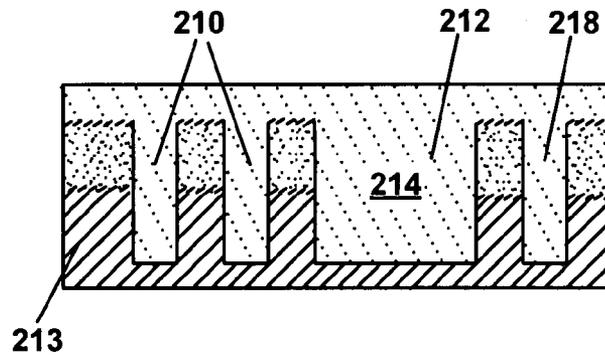


FIG. 14

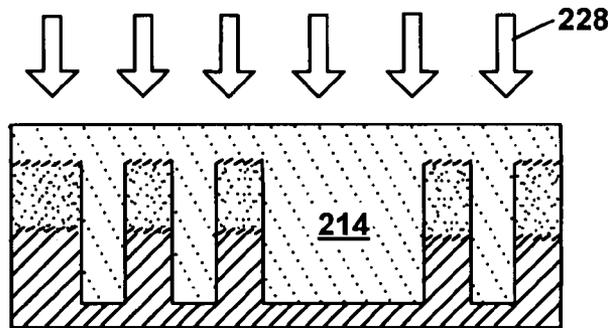


FIG. 15

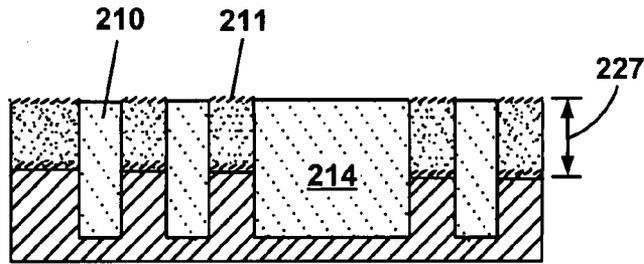


FIG. 16

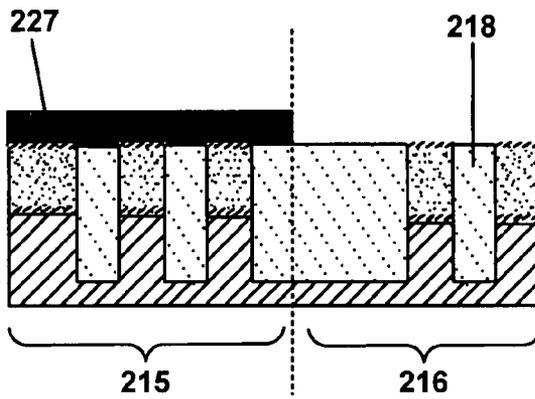


FIG. 17

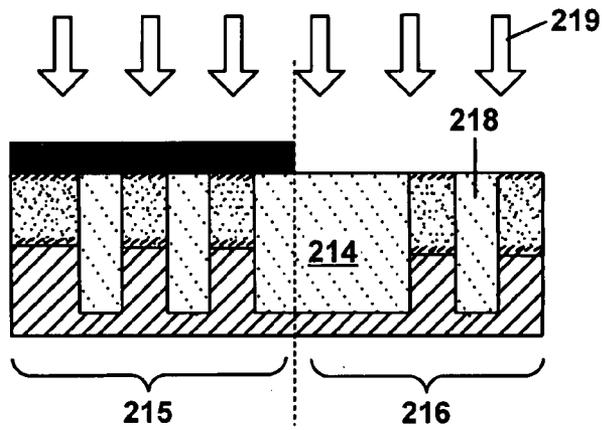


FIG. 18

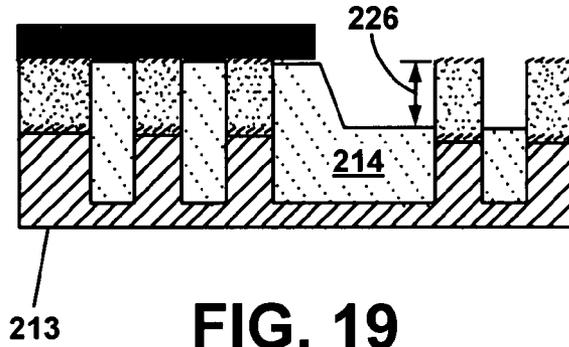


FIG. 19

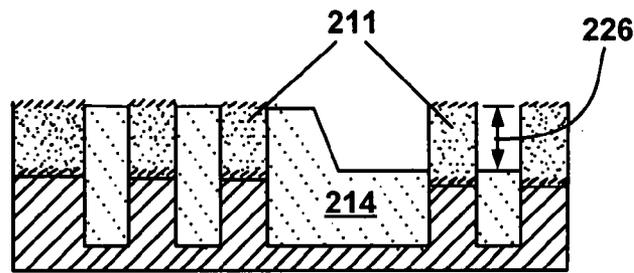


FIG. 20

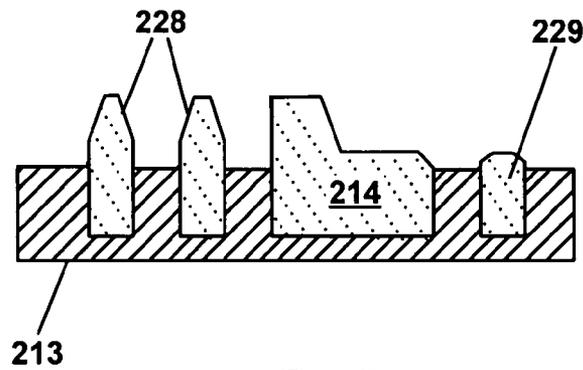


FIG. 21

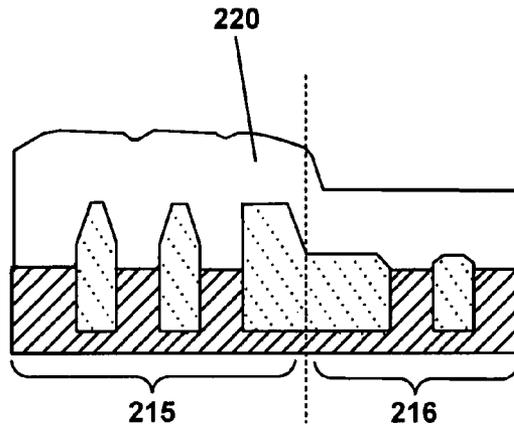


FIG. 22

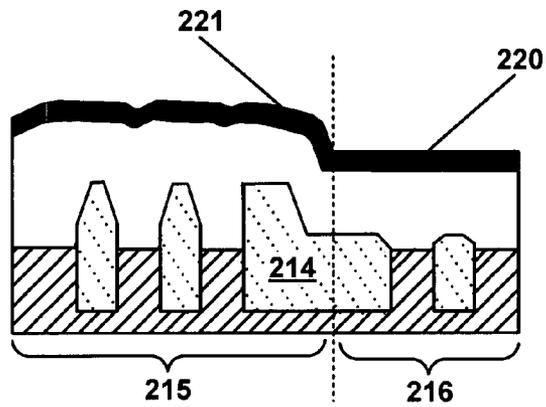


FIG. 23

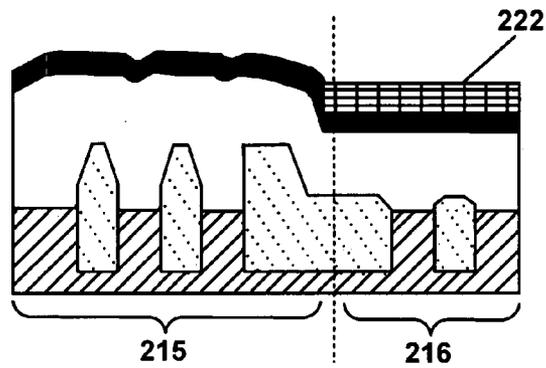


FIG. 24

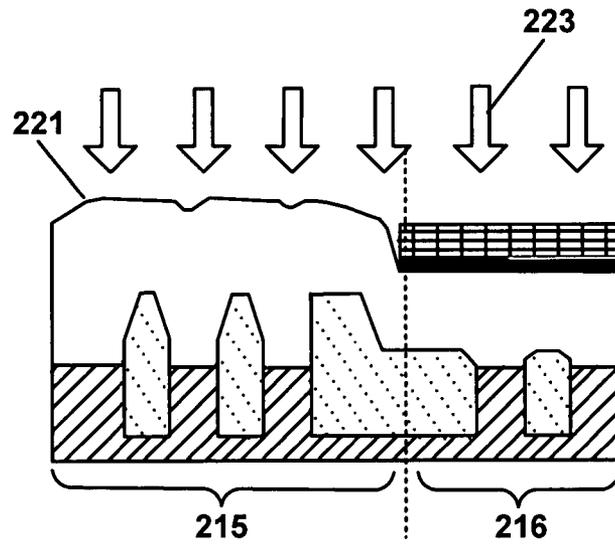


FIG. 25

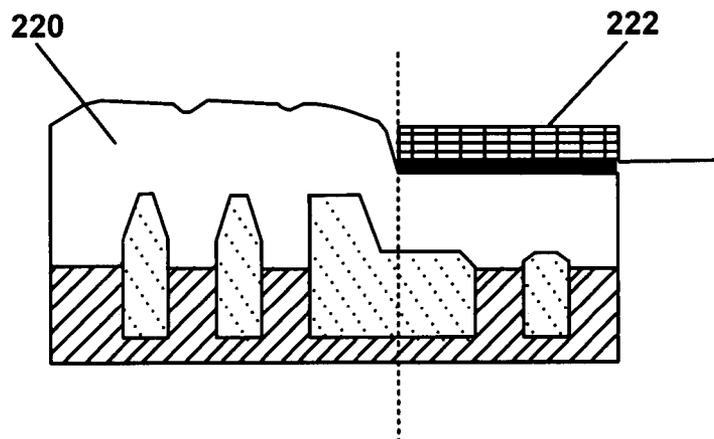


FIG. 26

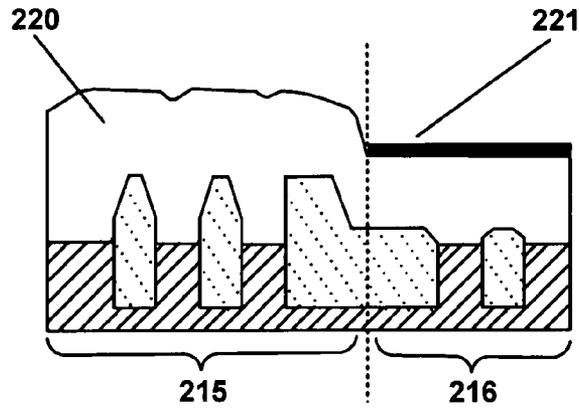


FIG. 27

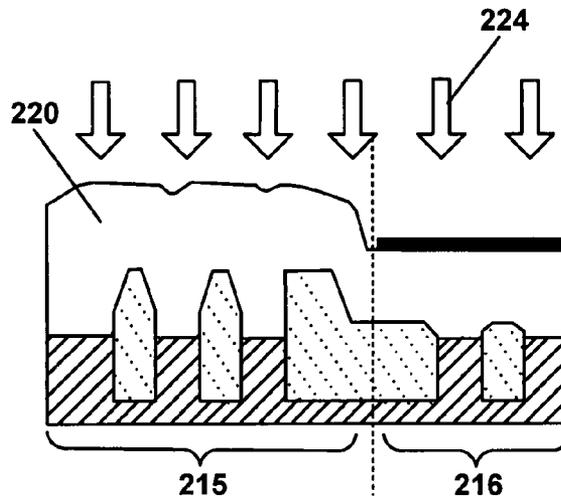


FIG. 28

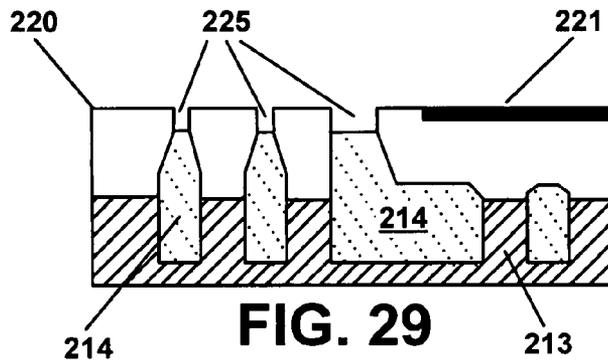


FIG. 29

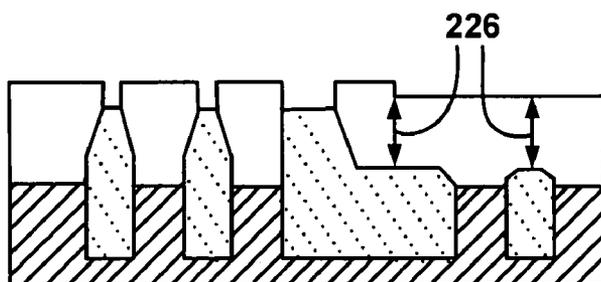


FIG. 30

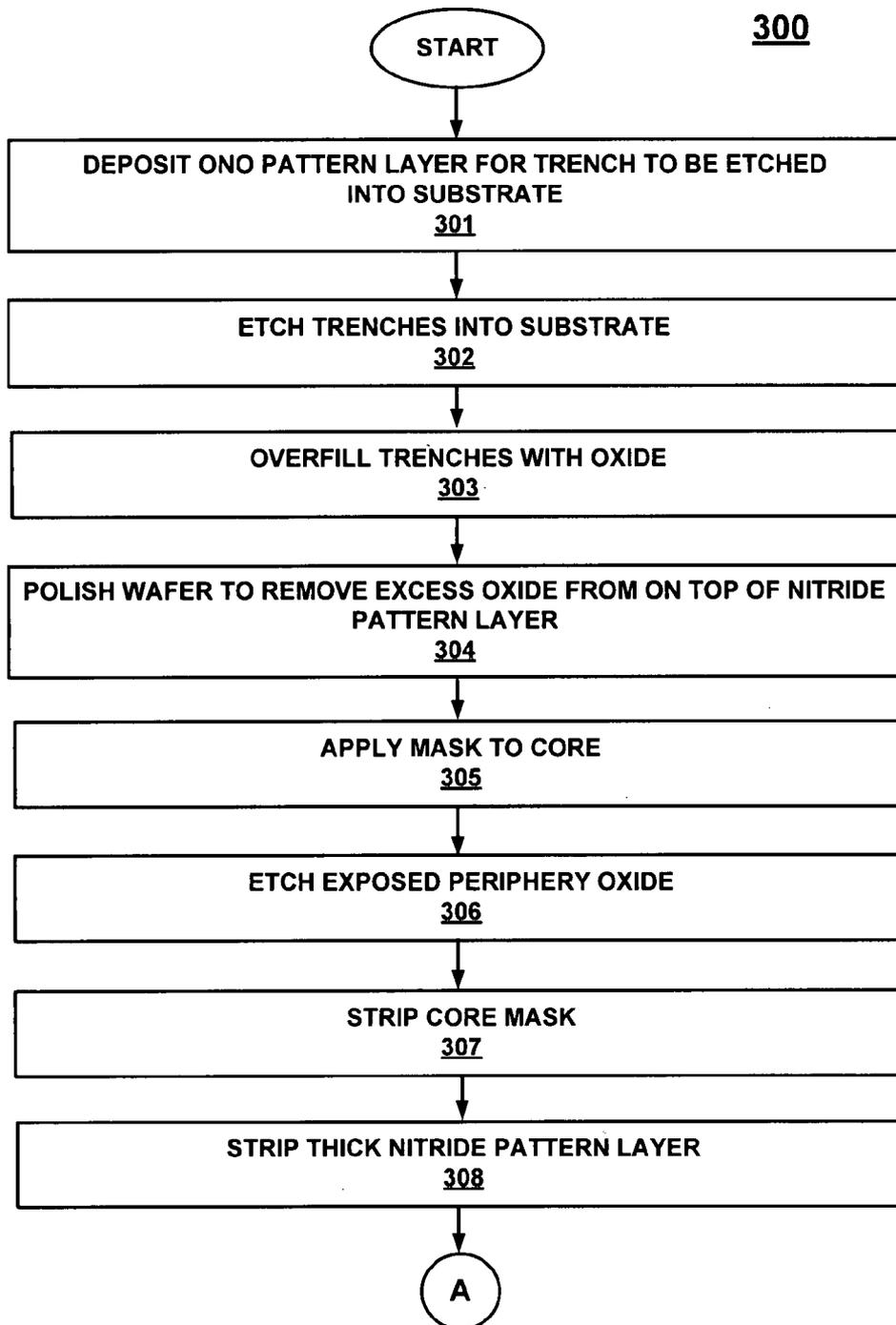


FIG. 31A

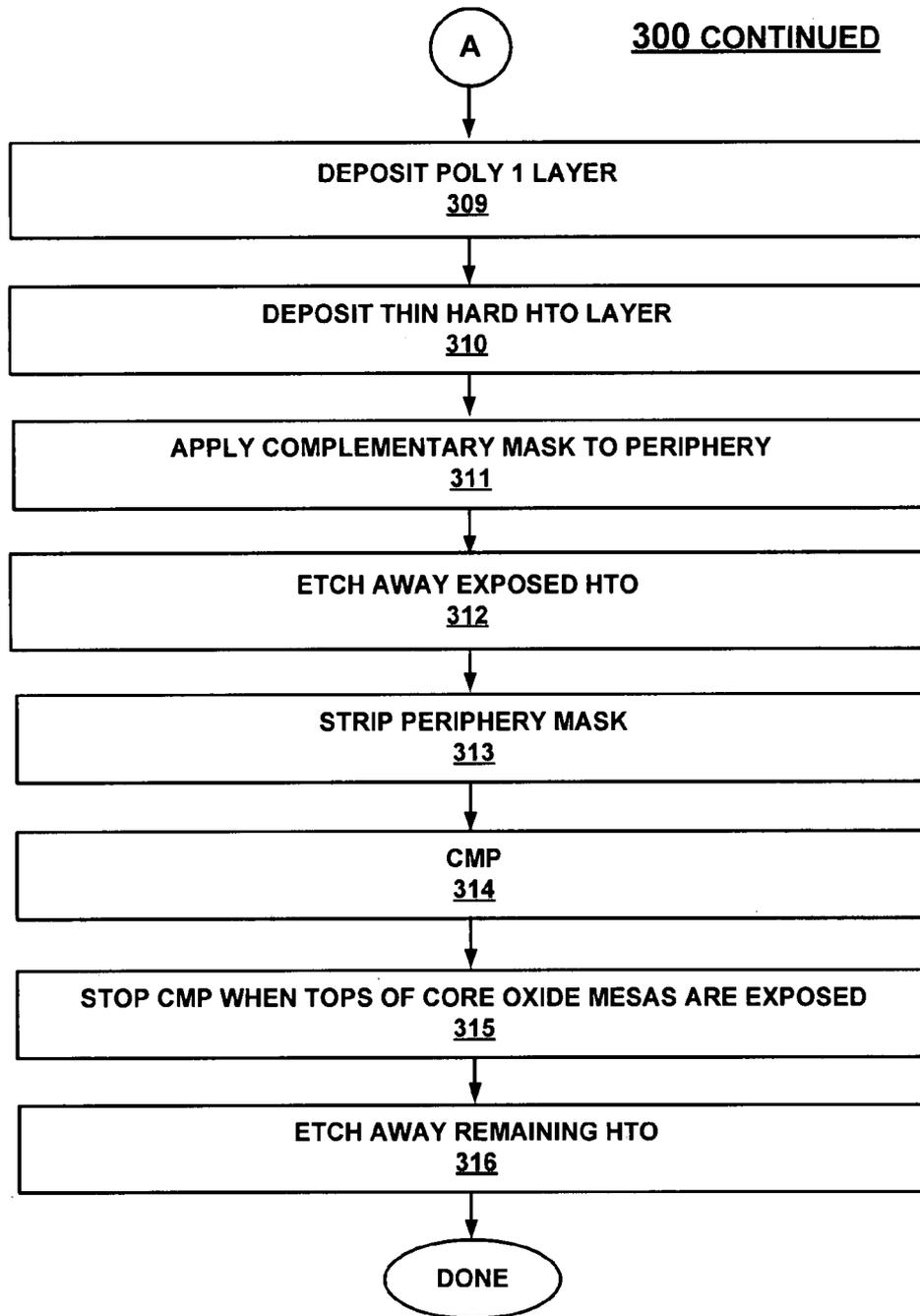


FIG. 31B

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**NON-CRITICAL COMPLEMENTARY
MASKING METHOD FOR POLY-1
DEFINITION IN FLASH MEMORY DEVICE
FABRICATION**

FIELD

The present invention relates to semiconductor wafer fabrication. Specifically, the present invention relates to a method for using complimentary non-critical masks to define the first polysilicon, or "poly-1" layer during flash memory device fabrication.

BACKGROUND

According to Moore's Law, the historical trend of the semiconductor industry, the level of complexity of semiconductor devices doubles every eighteen months. The size of the smallest structure in a semiconductor device now is 70% the size of the smallest structure three years ago. As structure size shrinks, chips become more densely populated permitting faster and more powerful machines. The aim of engineers within the semiconductor industry is to constantly find ways to pack more structures on each chip while maintaining fabrication process robustness and keeping the consumer cost per function to a minimum.

One set of the hundreds of steps in the semiconductor wafer fabrication process for flash memory devices is devoted to the definition of the first polysilicon, or "poly-1" layer above the substrate **101** (shown in FIG. 1). FIG. 1 is a cross-sectional view of a semiconductor wafer in one stage of the fabrication process. Before the deposition of the poly-1 layer, trenches **103** are formed in the substrate. Trench etch into silicon substrate **101** is performed through conventional methods by depositing a layer of barrier oxide and a nitride layer (ON) **102** is used as an etch mask.

Following trench formation, the trenches are over-filled with a dielectric oxide material **106**, or "field oxide," as shown in FIG. 2. As illustrated in FIG. 3, the wafer is then polished by a Chemical Mechanical Polish, or Chemical Mechanical Planarization (CMP) process **107** to remove the excess field oxide from on top of the nitride layer **102**. The effect of CMP **107** is depicted in FIG. 4. Then, the nitride layer **102** is stripped with an etch or polish process **108**, shown in FIG. 5. It is important that after the nitride strip, the remaining field oxide trench-fills form mesas **109** which protrude from the substrate, as shown in FIG. 6. The height of these mesas **109** is determined by the thickness **118** of the nitride layer of the ON mask **102**. Using a conventional method, the thickness of the nitride layer is approximately 700-1500 angstroms.

Filled trenches may be used to isolate devices from each other in the core **104**, a technique known as Shallow Trench Isolation (STI). STI has emerged as the primary technique for device isolation for advanced Ultra Large Scale Integration (ULSI) Complimentary Metal-Oxide-Semiconductor (CMOS) technologies. Filled trenches may also be utilized in the periphery **105** for the active transistor isolation.

The next step in the conventional method is poly-1 **110** deposition, shown in FIG. 7, followed by poly-1 definition. The definition of the poly-1 layer is complicated by two factors. The first of these factors is that in the core **104**, the mesas of trench-fill oxides **109** must not be covered by polysilicon **110**, while the mesas of trench-fill oxides in the periphery **117** must be covered by a layer of polysilicon **110** of a certain thickness **116**, as shown in FIG. 8.

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In order to achieve proper poly-1 definition, the conventional method employs a mask and etch process. As FIG. 8 depicts, a mask **111** is lithographically applied to the top of the poly-1 layer **110**. FIG. 9 illustrates how in the conventional method, once the poly-1 definition mask **111** is applied, an etch **113** is performed to remove polysilicon **110** from on top of the core mesas **109**, as shown in FIG. 10. A stripping process **115**, shown in FIG. 11, is then employed to remove the poly-1 definition mask **111**. Once the poly 1 definition mask **111** is removed, as shown in FIG. 12, the poly-1 layer **110** is properly defined and the wafer proceeds to the rest of the fabrication process.

Proper alignment of the poly-1 definition mask is imperative. A misalignment of the poly-1 definition mask could result in portions of the poly-1 layer overlapping onto sensitive areas, which could compromise the optimum functioning of the chips, or perhaps render the entire wafer useless.

SUMMARY

Embodiments of the present invention, a method for poly-1 definition in the semiconductor wafer fabrication process using complimentary non-critical masks, are presented. Layers of barrier oxide and nitride (700-1600 Å) are used to define the trenches in the substrate. The STI trenches are over-filled with oxide material. The wafer is polished to remove excess oxide material from on top of the barrier oxide and nitride layers, and before the nitride layer is stripped, a first non-critical mask is applied to core areas, leaving the periphery and scribe line areas exposed. An etch is applied to recess the exposed oxide material in the periphery by an amount approximately equal to the desired final poly-1 thickness. After the first non-critical mask is stripped, the nitride layer is also stripped, followed by poly-1 deposition. A thin oxide or other hard masking layer is deposited, followed by the application of a second non-critical mask over the periphery. The exposed thin hard mask is etched away, and the second non-critical mask is stripped, leaving a thin hard mask over the periphery and the core exposed. CMP is applied to the core until the tops of the core oxide mesas are exposed. Then remaining thin hard mask is stripped, leaving behind a properly defined poly-1 layer.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings and in which like reference numerals refer to similar elements and in which:

FIG. 1 illustrates a cross-section of a semiconductor substrate **101** and trench formation masking layer **102** in accordance with the prior art method of poly-1 definition.

FIG. 2 illustrates a cut-away view of a subsequent stage of the prior art process.

FIG. 3 illustrates a cut-away view of a subsequent stage of the prior art process.

FIG. 4 illustrates a cut-away view of a subsequent stage of the prior art process.

FIG. 5 illustrates a cut-away view of a subsequent stage of the prior art process.

FIG. 6 illustrates a cut-away view of a subsequent stage of the prior art process.

FIG. 7 illustrates a cut-away view of a subsequent stage of the prior art process.

FIG. 8 illustrates a cut-away view of a subsequent stage of the prior art process.

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FIG. 9 illustrates a cut-away view of a subsequent stage of the prior art process.

FIG. 10 illustrates a cut-away view of a subsequent stage of the prior art process.

FIG. 11 illustrates a cut-away view of a subsequent stage of the prior art process.

FIG. 12 illustrates a cut-away view of a subsequent stage of the prior art process.

FIG. 13 illustrates a cross-section of a semiconductor substrate 13 and trench formation masking layer 11 in accordance with the present invention method of poly-1 definition.

FIG. 14 illustrates a cut-away view of a subsequent stage of the present invention process.

FIG. 15 illustrates a cut-away view of a subsequent stage of the present invention process.

FIG. 16 illustrates a cut-away view of a subsequent stage of the present invention process.

FIG. 17 illustrates a cut-away view of a subsequent stage of the present invention process.

FIG. 18 illustrates a cut-away view of a subsequent stage of the present invention process.

FIG. 19 illustrates a cut-away view of a subsequent stage of the present invention process.

FIG. 20 illustrates a cut-away view of a subsequent stage of the present invention process.

FIG. 21 illustrates a cut-away view of a subsequent stage of the present invention process.

FIG. 22 illustrates a cut-away view of a subsequent stage of the present invention process.

FIG. 23 illustrates a cut-away view of a subsequent stage of the present invention process.

FIG. 24 illustrates a cut-away view of a subsequent stage of the present invention process.

FIG. 25 illustrates a cut-away view of a subsequent stage of the present invention process.

FIG. 26 illustrates a cut-away view of a subsequent stage of the present invention process.

FIG. 27 illustrates a cut-away view of a subsequent stage of the present invention process.

FIG. 28 illustrates a cut-away view of a subsequent stage of the present invention process.

FIG. 29 illustrates a cut-away view of a subsequent stage of the present invention process.

FIG. 30 illustrates a cut-away view of a subsequent stage of the present invention process.

FIG. 31A is a flow chart depicting a first part of poly-1 deposition in accordance with the present invention.

FIG. 31B is a continuation of FIG. 31A, a flow chart depicting a second part of poly-1 deposition in accordance with the present invention.

DETAILED DESCRIPTION

Reference will now be made in detail to various embodiments of the invention, examples of which are illustrated in the accompanying drawings. While the invention will be described in conjunction with various embodiments, it will be understood that they are not intended to limit the invention to these embodiments. On the contrary, the invention is intended to cover alternatives, modifications and equivalents, which may be included within the spirit and the scope of the invention as defined by the appended claims. Furthermore, in the following detailed description of the present invention, numerous specific details are set forth in order to provide a thorough understanding of the present invention. However, it will be apparent to one skilled in the art that the

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present invention may be practiced without these specific details. In other instances, well-known methods, procedures, components, structures and devices have not been described in detail so as to avoid unnecessarily obscuring aspects of the present invention.

Referring now to FIG. 13, a cross-section view of a semiconductor wafer, a patterned barrier oxide and nitride layers 232 are used to etch trenches 210 in the substrate 213, both in the core 215 and in the periphery 216 areas of the wafer. Some of the etched trenches 210 are shallow isolation trenches. Shallow trench isolation (STI) has become the preferred technique for isolating devices from each other on the chip. STI prevents leakage of ions in designated doped areas in the substrate, as well as other unwanted electronic interference between devices. Some of the trenches 212 etched into substrate 213 form the foundation for test structures or other periphery structures 218. Some trenches 218 require a layer of polysilicon on top of the oxide fill material.

The thickness of the nitride layer 211 can be varied. In a preferred embodiment of the present invention, the thickness 227 of the nitride layer 211 is approximately 1580 Å.

Once the trenches are formed in the substrate 213, the trenches 212 are filled with a dielectric oxide material 214, as shown in FIG. 14. In a preferred embodiment, trenches 212 are filled by a High Density Plasma (HDP) process with silicon dioxide. In another embodiment, a TEOS (tetraethylorthosilicate) deposition process is employed. The trenches 212 are over-filled, as FIG. 14 illustrates, such that the barrier oxide and nitride pattern layers 232 are covered with the oxide material 214. Overfilling of the oxide material 214 into the trenches 212 ensures that the trenches 212 are sufficiently filled for STI. Then, as FIG. 15 shows, a polish 228 is performed. In a preferred embodiment, CMP 228 is performed to remove excess oxide material. In a preferred embodiment, polishing process 215 stops when the top of the nitride layer 211 is exposed, as depicted in FIG. 16.

Once the polishing process 228 is complete, a first non-critical mask 217 is applied to a core region 215 of the wafer, as shown in FIG. 17. The first non-critical mask 217 covers the core 215 and leaves the periphery 216 exposed. The first non-critical mask 217 can be created using i-line lithography. I-line lithography utilizes ultraviolet radiation to permit a masking resolution of 300-400 nm, which is sufficient to accomplish poly-1 definition according to the present invention method. I-line lithography has a much lower cost per layer than ArF lithography.

The application of the first non-critical mask 217 is followed by an etch 219, depicted in FIG. 18, to recess exposed oxide material 214 in the trenches 218 of the periphery 216 by an amount 226 approximately equal to the final poly-1 thickness. The result of etch 219 is depicted in FIG. 19. The oxide material 214 within the trenches 210 in the core region 215 are not etched, as they are covered by the first non-critical mask 217.

Once the first non-critical mask 217 is stripped (FIG. 20), the nitride 232 layer is stripped (FIG. 21). The stripping of the nitride layer 232 leaves behind trench fill mesas 228 made of the oxide material 214. It is important that these oxide mesas 228 protrude above the substrate and laterally recessed due to subsequent oxidation and clean steps. The core oxide mesas 228 are taller than the periphery oxide mesas 229. In a preferred embodiment of the present invention, the core oxide mesas protrude out of the substrate by a height in the range of 600-1500 Å. Tall "field oxide" areas where poly-1 will later be damascened, and other areas

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which are recessed with the first non-critical mask where poly-1 will not be damascened.

Following the nitride strip, a layer of polysilicon is deposited **220**, as shown in FIG. **22**. This deposition forms the poly-1 layer **220** over the core **215** and periphery **216**. As depicted in FIG. **23**, following poly-1 **220** deposition, a thin hard oxide or other hard masking material **221** is deposited on top of the poly-1 layer **220**. The thin hard oxide layer **221** is also known as an oxide hardmask. In a preferred embodiment of the present invention, a next step is the lithographic application of a second complimentary non-critical mask **222** on top of the thin hard mask **221**, masking the periphery **216** and leaving the core **215** exposed, as shown in FIG. **24**. FIG. **25** shows the next step: the exposed thin hard mask **221** is etched away. FIG. **26** depicts the result of etch **223**. As illustrated in FIG. **26**, the poly-1 layer **220** over the periphery **216** is masked, while the poly-1 **220** over the core **215** is exposed. The second complimentary non-critical mask **222** is then etched away, leaving a thin hard oxide mask **221** over the periphery **216**, as shown in FIG. **27**.

Following the removal of the second complimentary mask **222**, CMP **224** is applied to the wafer, as shown in FIG. **28**. CMP **224** is applied until the polysilicon **220** is planar with the thin hard oxide mask **221**. At this point, the tops of the core oxide mesas **225** are exposed. This is a self-aligning method for properly defining the poly-1 layer **220** over the core **215**. FIG. **29** illustrates the cross section of a portion of the wafer after CMP **224** is stopped. Following CMP **224**, the thin hard oxide mask **221** is etched away, leaving the poly-1 layer **220** properly defined and ready for the next step in the fabrication process. FIG. **30** depicts the wafer after poly-1 definition in accordance with the present invention.

The increased thickness of the nitride layer **211** within the trench-etch mask **232** creates very tall core oxide mesas **228**, which is desirable. The nitride layer is deposited to a depth of 1000-1700 angstroms. The recessing etch **219** of the periphery trench oxides **218**, shown in FIG. **18**, ensure that the periphery oxides **218** will be covered with an adequate thickness **226** of polysilicon **220**, post poly-1 definition, as illustrated in FIG. **30**.

Flowchart **300**, the first part of which is shown in FIG. **31A**, displays steps of the present invention in a preferred order. First, a thick nitride layer on top of the substrate is patterned for trench formation **301**. Following the nitride pattern creation **301**, the trenches are etched into the substrate **302**. Following trench formation **302**, a layer of oxide material is deposited on the substrate until the trenches are over-filled **303**. Following oxide overfill **303**, the wafer is polished to remove excess oxide material from on top of the nitride pattern layer **304**. Following the removal of excess oxide material **304**, a first non-critical mask is applied to the core **305**. While the first non-critical mask is in place over the core, the periphery is etched to recess the exposed oxides in the peripheral trenches **306** by an amount approximately equal to the final poly-1 layer thickness. After the peripheral oxide etch **306**, the first non-critical mask over the core is stripped **307**, followed by the stripping of the nitride pattern layer **308**.

Continuing flowchart **300** in FIG. **32B**, box **309** contains a next step in a preferred embodiment of the present invention: the deposition of polysilicon for the formation of the poly-1 layer. Following poly-1 deposition **309**, a thin hard oxide layer is deposited over the wafer **310**. In a preferred embodiment, the thin hard oxide layer comprises High

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Thermal Oxide (HTO). After the thin hard oxide layer is deposited **310**, a second, complimentary non-critical mask is applied to the core **311**. The second, complimentary non-critical mask is approximately a reverse of the first non-critical mask. The first mask covered the core and left the periphery exposed. The second mask covers the periphery and scribe line areas and leaves the core exposed, once the thin hard oxide layer not covered by the complimentary non-critical mask is etched away **312**. The remaining hard oxide layer is a good stopping mask for chemical-mechanical planarization process, so the complimentary non-critical mask over the periphery can be stripped away **313**. After the second, complimentary mask is removed **313**, a thin hard oxide mask remains over the periphery. Chemical-mechanical polishing (CMP) is then applied to the wafer **315**. Once poly-1 layer over the core is polished even with the hard oxide mask, the tops of the oxide mesas in the core are exposed and CMP is stopped **314**. The remaining hard oxide layer is then etched away **316**, leaving the poly-1 layer properly defined.

While the method illustrated in flow charts **300** shows a specific sequence and quantity of steps, the present invention is suitable to alternative embodiments. For example, the sequence of the steps may be modified to produce the same desired poly-1 definition using the complimentary masking approach of the present invention. Also, not all the steps provided for in the methods illustrated in flow chart **300** are required for the present invention. Furthermore, additional steps can be added to the steps presented in the present embodiment. Likewise, the sequences of the steps can be modified depending upon the application.

The preferred embodiments of the present invention, a complimentary masking method for defining the poly-1 layer of a semiconductor device during wafer fabrication, is thus described. While the present invention has been described in particular embodiments, it should be appreciated that the present invention should not be construed as limited by such embodiments, but rather construed according to the below claims.

What is claimed is:

1. A method of defining a poly-1 layer of a semiconductor chip, said semiconductor chip comprising a core memory area and a peripheral region, comprising:

depositing a thick nitride barrier level above a substrate of said semiconductor chip;

etching shallow isolation trenches into said nitride layer and said substrate;

filling said shallow isolation trenches with oxide material; removing excess of said oxide material from on top of remainder of said nitride layer;

depositing a first non-critical mask on said core memory area, leaving said peripheral region exposed;

recessing said oxide material in said exposed peripheral region by an amount approximately equal to a final polysilicon thickness;

stripping said first non-critical mask;

stripping a remainder of said nitride barrier layer, thereby leaving mesas of oxide material in said core memory area;

depositing a layer of polysilicon, called the poly-1 layer, over said core memory area and said peripheral region; depositing a thin hard mask over said core memory area and said peripheral region;

depositing a second non-critical complimentary mask over said peripheral region;

etching away an exposed portion of said thin hard mask over said core memory area;

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- polishing an exposed core memory area to remove said polysilicon from on top of said mesas of field oxide in said core memory area;
- stripping said complimentary mask;
- stripping a remaining portion of said thin hard mask.
- 2. The method of claim 1, wherein said thick nitride layer deposited to a depth of 1000-1700 angstroms.
- 3. The method of claim 1, wherein said thick nitride layer is deposited on top of a thin layer of oxide material.
- 4. The method of claim 1, wherein said polishing to remove said excess field oxide from on top of remainder of said nitride layer is accomplished by chemical mechanical polishing (CMP).
- 5. The method of claim 1, wherein said recessing of said field oxide is accomplished by a wet etch.
- 6. The method of claim 1, wherein said recessing of said field oxide is accomplished by a dry etch.

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- 7. The method of claim 1, wherein said mesas of field oxide remaining in said core memory area after said nitride stripping have heights of 500-1000 angstroms.
- 8. The method of claim 1, wherein said complimentary mask comprises an oxide hardmask.
- 9. The method of claim 1, wherein said polishing of said exposed core memory area to remove said polysilicon from on top of mesas of field oxide in said core memory area comprises chemical mechanical planarization.
- 10. The method of claim 1 further comprising:
 - depositing a layer of photoresist on said thick nitride barrier layer;
 - lithographically patterning at least one shallow isolation trench onto said nitride barrier layer.

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