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(54) **VLSI-BASED SYSTEM FOR DURABLE HIGH-DENSITY INFORMATION STORAGE**

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(51) **Int. Cl.**[7] **G03F 7/00**; G03F 7/20; G03F 9/00; G06F 17/50

(52) **U.S. Cl.** **430/311**; 430/22; 430/322; 716/19; 716/20; 716/21

(58) **Field of Search** 430/22, 311, 322; 716/19, 20, 21

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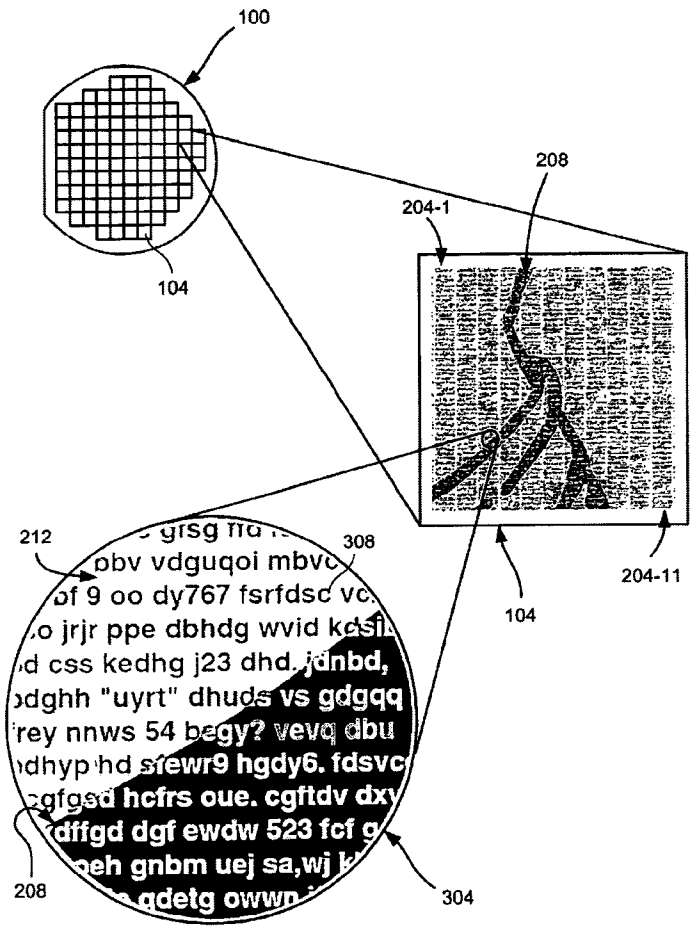
(57) **ABSTRACT**

The invention relates to using VLSI techniques to store information on a substrate. One embodiment of a die with text deposited upon the die uses semiconductor processing techniques during fabrication. Included in the die are a substrate, a first paragraph and a second paragraph. The first and second paragraphs are in contact with the substrate. The second paragraph is aligned with the first paragraph in a column.

22 Claims, 8 Drawing Sheets



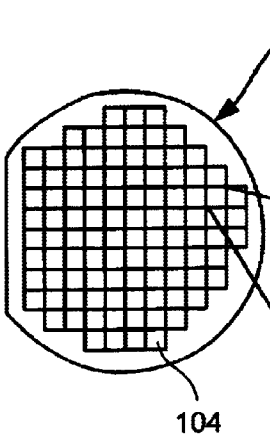


FIG. 1

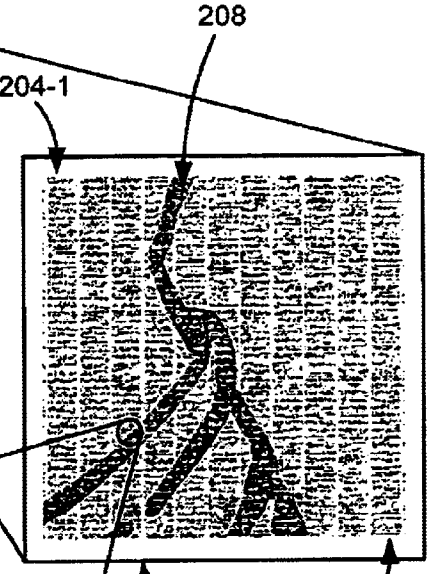


FIG. 2

FIG. 3

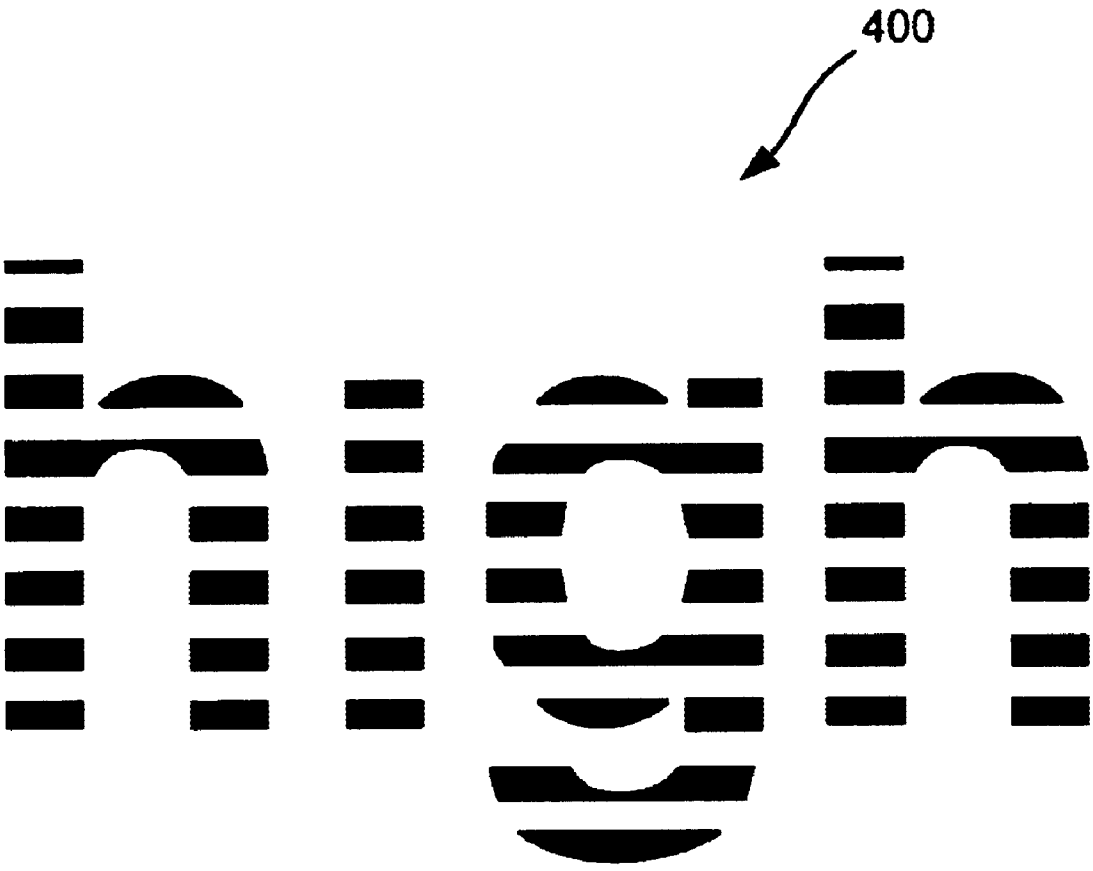


FIG. 4

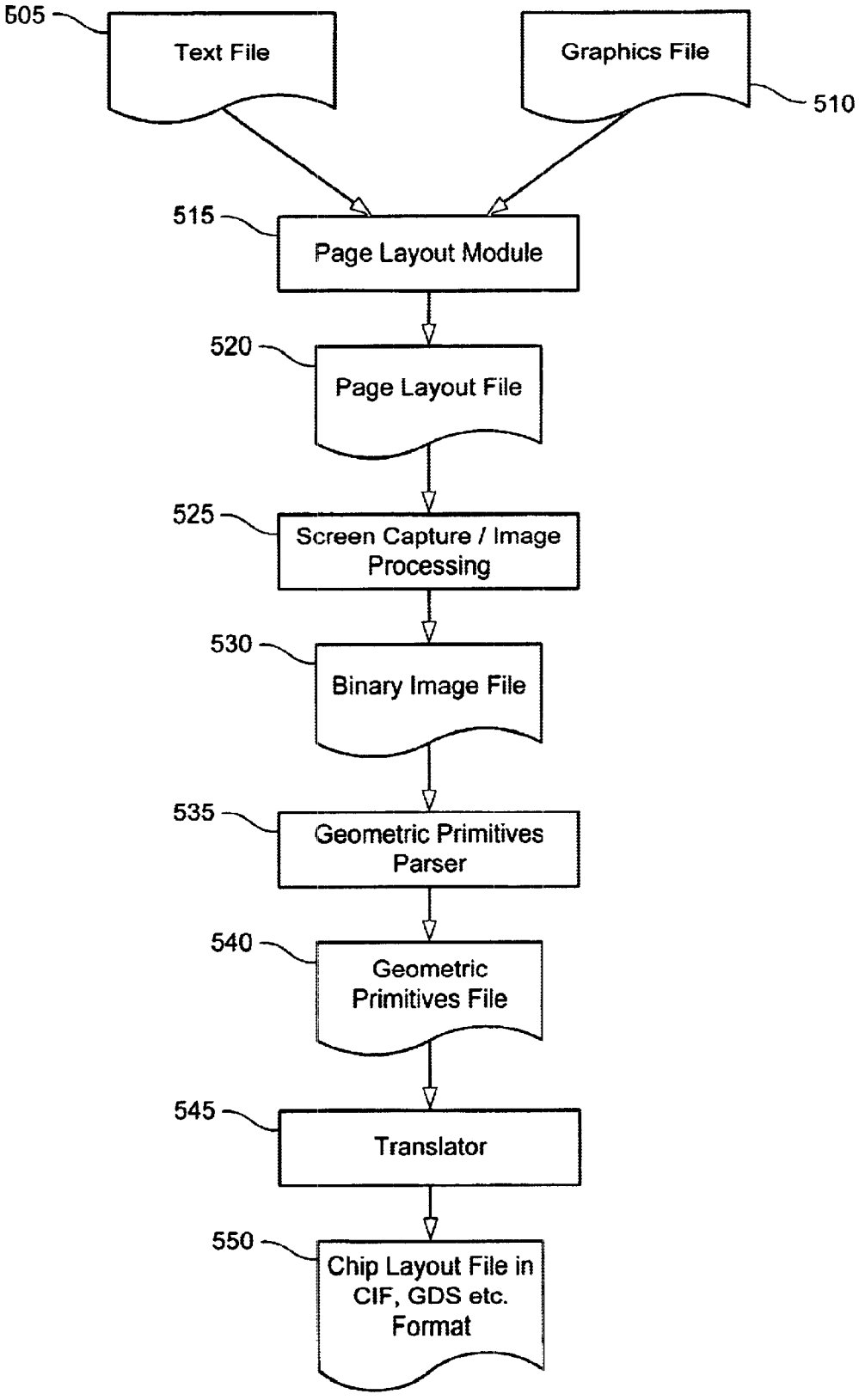

505
Text File
Graphics File
510
515
Page Layout Module
520
Page Layout File
525
Screen Capture / Image Processing
530
Binary Image File
535
Geometric Primitives Parser
540
Geometric Primitives File
545
Translator
550
Chip Layout File in CIF, GDS etc. Format

FIG. 5

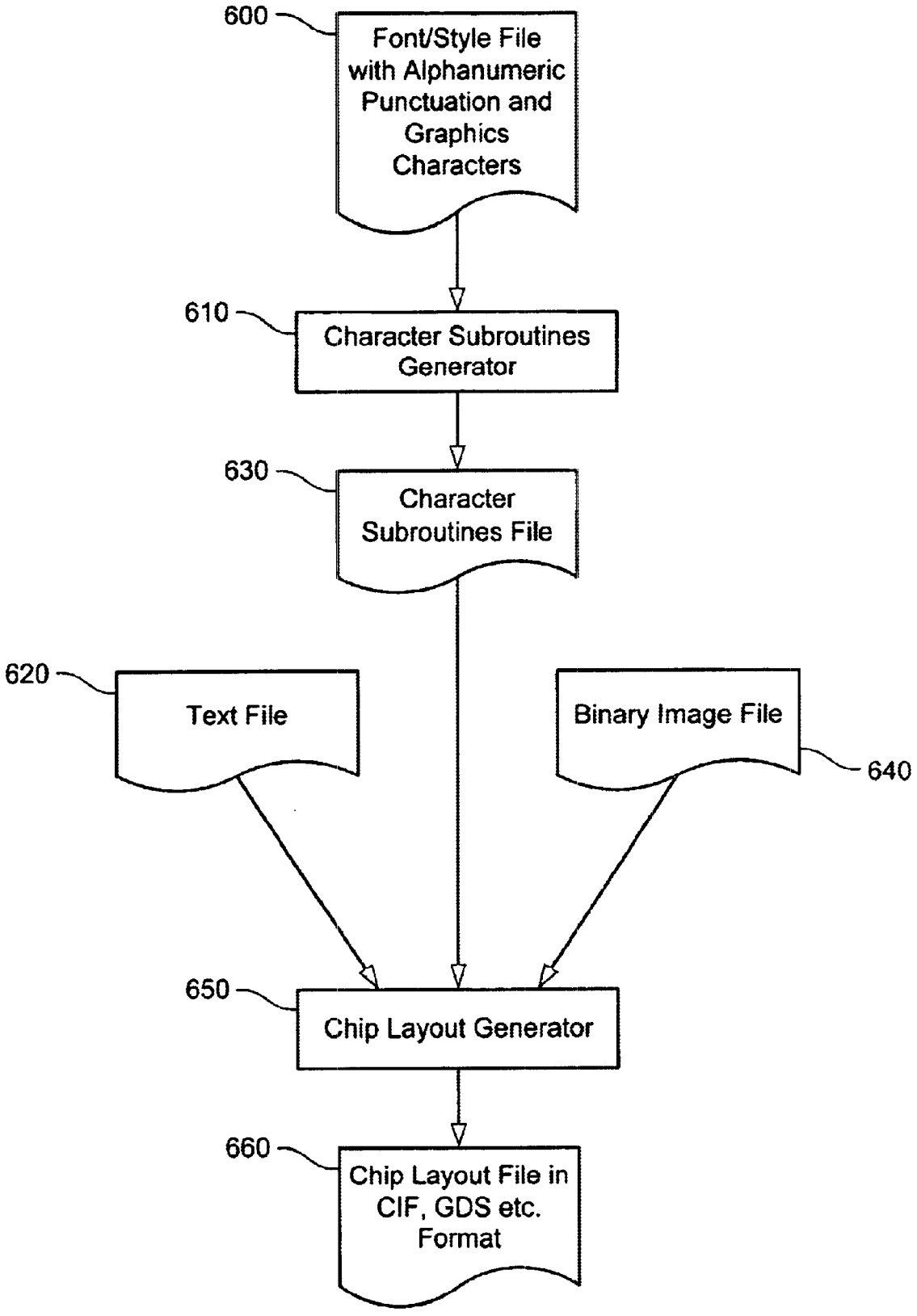

600
Font/Style File with Alphanumeric Punctuation and Graphics Characters
610
Character Subroutines Generator
630
Character Subroutines File
620
Text File
Binary Image File
640
650
Chip Layout Generator
660
Chip Layout File in CIF, GDS etc. Format

FIG. 6

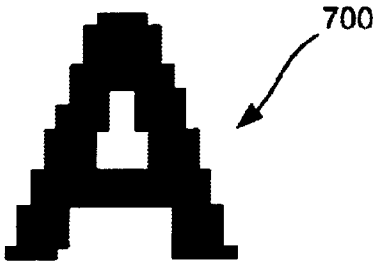


FIG. 7

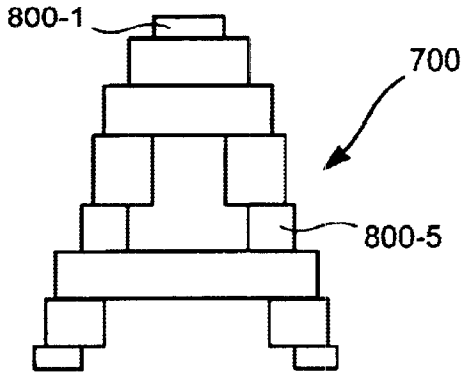


FIG. 8

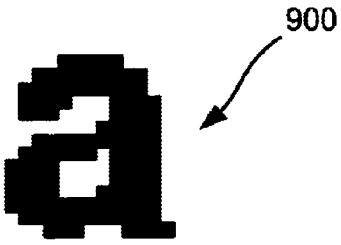


FIG. 9

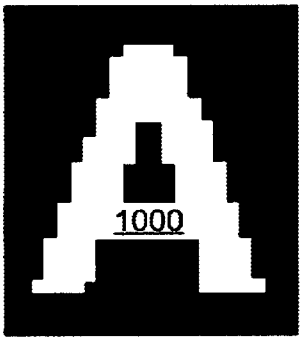


FIG. 10

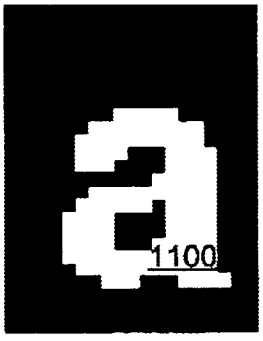


FIG. 11

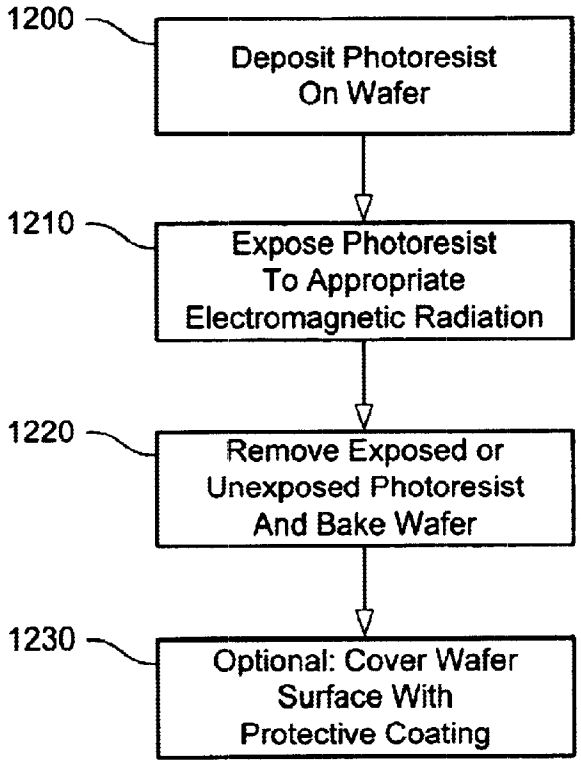

1200
Deposit Photoresist On Wafer
1210
Expose Photoresist To Appropriate Electromagnetic Radiation
1220
Remove Exposed or Unexposed Photoresist And Bake Wafer
1230
Optional: Cover Wafer Surface With Protective Coating

FIG. 12

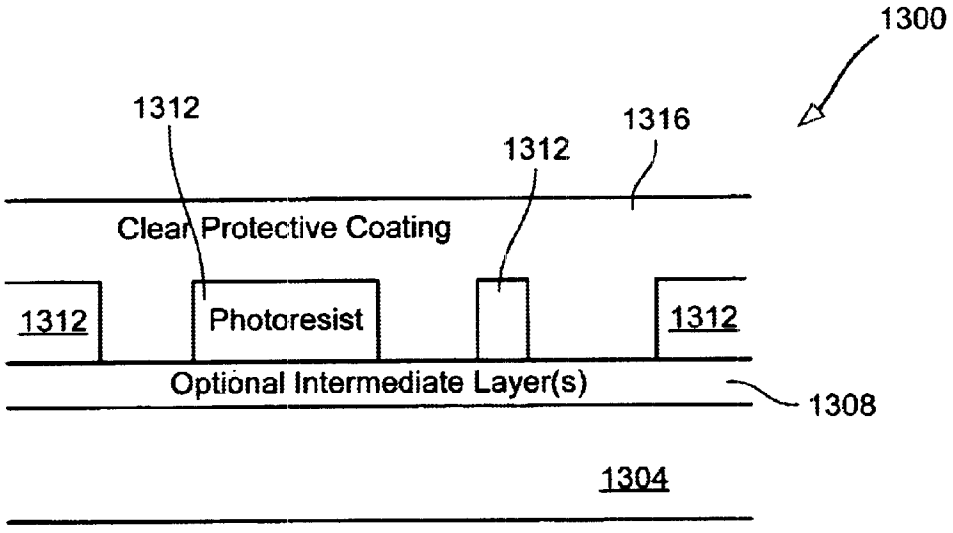

1300
1312
1316
1312
Clear Protective Coating
1312
Photoresist
1312
Optional Intermediate Layer(s)
1308
1304

FIG. 13

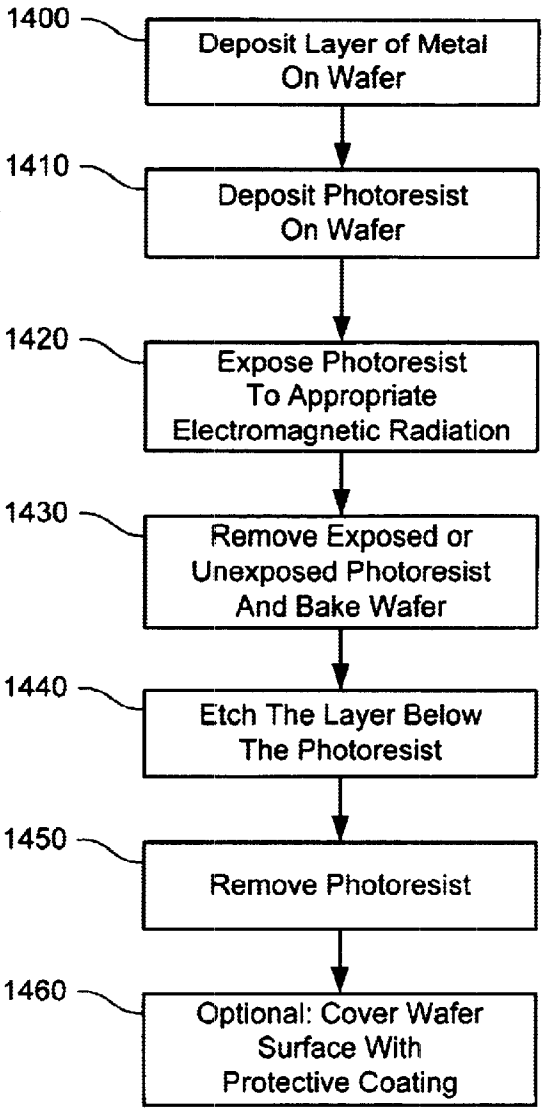

1400
Deposit Layer of Metal On Wafer
1410
Deposit Photoresist On Wafer
1420
Expose Photoresist To Appropriate Electromagnetic Radiation
1430
Remove Exposed or Unexposed Photoresist And Bake Wafer
1440
Etch The Layer Below The Photoresist
1450
Remove Photoresist
1460
Optional: Cover Wafer Surface With Protective Coating

FIG. 14

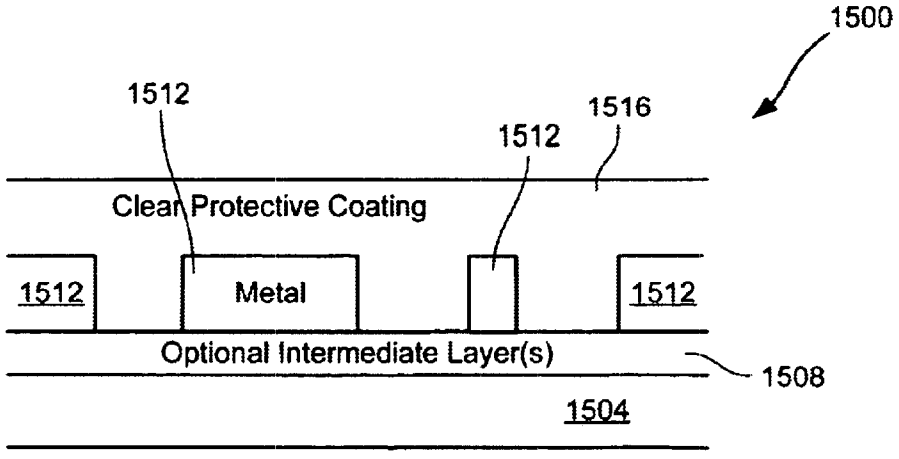

1500
1512
1516
1512
Clear Protective Coating
1512
Metal
1512
Optional Intermediate Layer(s)
1508
1504

FIG. 15

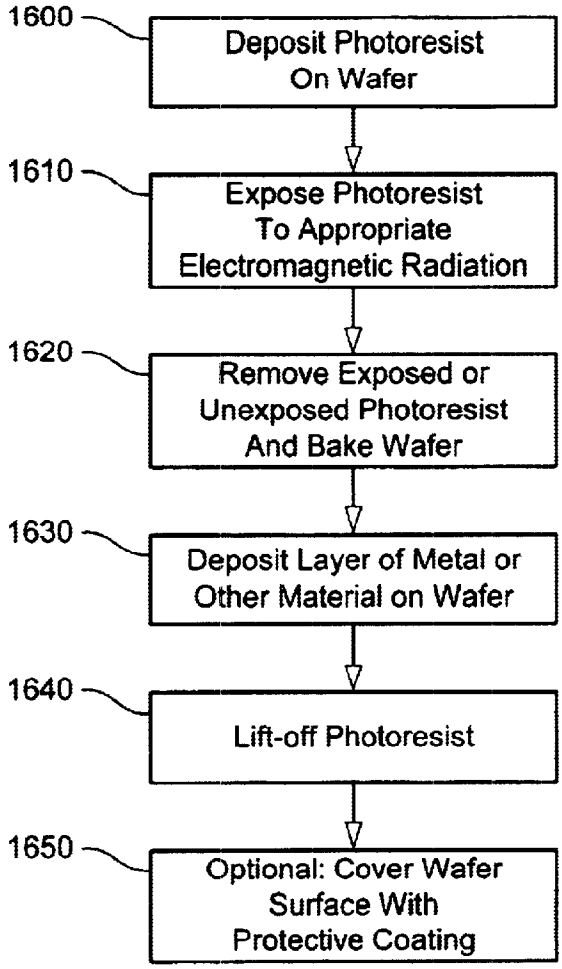

1600
Deposit Photoresist On Wafer
1610
Expose Photoresist To Appropriate Electromagnetic Radiation
1620
Remove Exposed or Unexposed Photoresist And Bake Wafer
1630
Deposit Layer of Metal or Other Material on Wafer
1640
Lift-off Photoresist
1650
Optional: Cover Wafer Surface With Protective Coating

FIG. 16

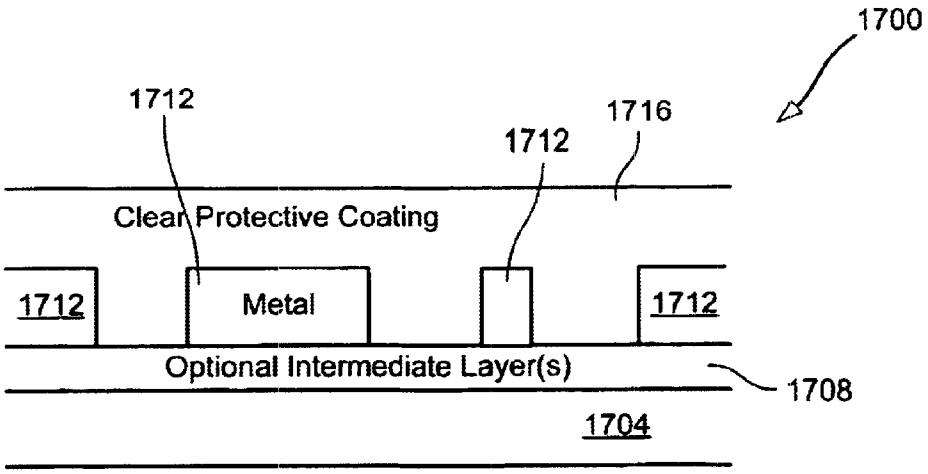

1700
1712
1716
1712
Clear Protective Coating
1712
Metal
1712
Optional Intermediate Layer(s)
1708
1704

FIG. 17

VLSI-BASED SYSTEM FOR DURABLE HIGH-DENSITY INFORMATION STORAGE

This application claims the benefit of U.S. Provisional Application No. 60/154,401 filed on Sep. 17, 1999.

BACKGROUND OF THE INVENTION

This invention relates in general to VLSI fabrication techniques and, more specifically, to using these techniques to store information.

Any unnecessary traces of a metal, an oxide or a polysemiconductor are avoided in semiconductor processing. Adding unnecessary traces makes the mask and fabrication more complex. This added complexity can increase the likelihood of defects in the finished semiconductor circuit. Consequently, semiconductor circuits avoid use of unnecessary traces.

Progress in VLSI technology over the past few decades has been phenomenal. Packing densities have increased by several orders of magnitude. However, to date, VLSI technology has been used largely for creating electronic circuits, micro-machines or sensors. Other uses for the VLSI technology are needed.

SUMMARY OF THE INVENTION

The invention relates to using VLSI techniques to store information on a substrate. One embodiment of a die with text deposited upon the die uses semiconductor processing techniques during fabrication. Included in the die are a substrate, a first paragraph and a second paragraph. The first and second paragraphs are in contact with the substrate. The second paragraph is aligned with the first paragraph in a column.

Reference to the remaining portions of the specification, including the drawings and claims, will realize other features and advantages of the present invention. Further features and advantages of the present invention, as well as the structure and operation of various embodiments of the present invention, are described in detail below with respect to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a depiction of an embodiment of a wafer having multiple die;

FIG. **2** is a depiction of an embodiment of a die from the wafer;

FIG. **3** is an illustration of an embodiment of a portion of a column from the die

FIG. **4** is an illustration of an embodiment of a word having diffraction gratings;

FIG. **5** is a flow diagram of an embodiment of a process for converting text and graphics into an electronic mask file;

FIG. **6** is a flow diagram of another embodiment of a process for converting text and graphics into an electronic mask file;

FIG. **7** is a depiction of an embodiment of an upper case "A" element;

FIG. **8** is a depiction of the embodiment of the upper case "A" element showing constituent rectangle primitives;

FIG. **9** is a depiction of an embodiment of a lower case "a" element;

FIG. **10** is a depiction of an embodiment of a upper case "A" element with reverse contrast;

FIG. **11** is a depiction of an embodiment of a lower case "a" element with reverse contrast;

FIG. **12** is a flow diagram of an embodiment of a process for lithographing text and/or graphics onto a semiconductor substrate;

FIG. **13** is a side elevational view of an embodiment of a semiconductor wafer with text and/or graphics lithographed thereon;

FIG. **14** is a flow diagram of another embodiment of a process for lithographing text and/or graphics onto a semiconductor substrate;

FIG. **15** is a side elevational view of another embodiment of a semiconductor wafer with text and/or graphics lithographed thereon;

FIG. **16** is a flow diagram of yet another embodiment of a process for lithographing text and/or graphics onto a semiconductor substrate; and

FIG. **17** is a side elevational view of yet another embodiment of a semiconductor wafer with text and/or graphics lithographed thereon.

DESCRIPTION OF THE SPECIFIC EMBODIMENTS

The present invention includes a novel use of Very Large Scale Integration (VLSI) technology for creating very durable and long-term repositories of textual and graphical information. The invention allows converting the information to be stored into an input form suitable for VLSI fabrication systems, allows fabricating the information repositories and allows accessing the stored information. The invention creates features representing textual and/or graphical information on a semiconductor (or other) wafer. These features may be created on the wafer surface itself or on a layer of material deposited on the wafer surface. Such materials can include, but are not limited to, metals, oxides and photoresists. In this way, large amounts of text are archived using VLSI technology.

In the Figures, similar components and/or features may have the same reference label. Further, various components of the same type may be distinguished by following the reference label by a dash and a second label that distinguishes among the similar components. If only the first reference label is used in the specification, the description is applicable to any one of the similar components having the same first reference label irrespective of the second reference label.

Referring first to FIG. **1**, a depiction of an embodiment of a wafer **100** having multiple die **104** is shown. The die **104** are generally aligned in a grid across the wafer **100**. Typically, all die **104** on the wafer **100** are the same. Although the die **104** in this embodiment is rectangular, other embodiments could have die of different shapes. For example, the die could be shaped as star or cross.

With reference to FIG. **2**, a depiction of an embodiment of a die **104** from the wafer **100** is shown. Approximately eleven columns **204** of text appear on the die **104**. Each column **204** includes a number of paragraphs. Each paragraph is separated by a hard return and a tab. In some cases the first character of a section or chapter is enlarged and/or ornately decorated to signify changing sections or chapters. A dark silhouette pattern **208** against a lighter background overlays the columns **204** of text. The silhouette pattern **208** is darker than the background in this embodiment, but other embodiments could reverse this. Although this embodiment shows an English character set, other embodiments could include character sets in any language as well as symbol character sets.

The features, once created on the wafer, can be overlaid with an optically clear protective coating using materials such as a resin, an optically clear overcoat (e.g., EXP980024 available from Brewer Science™ of Missouri), a thin and clear nitrite film, a spin-on glass film, or an aluminum oxide layer. Additionally, the back surface of the wafer can be metallized to add durability to the typically fragile wafer **100**.

Referring next to FIG. **3**, an illustration of an embodiment of a portion **212** of a column **204** from the die **104** is shown. The portion **212** is a magnification of a part of FIG. **2** that shows a test sample of text **308**. The portion **212** shows the dividing line **316** between the silhouette **208** and the background **312**. To allow for contrast, the text **308** on the silhouette **208** is a light color and the text **308** on the background **312** is a dark color.

With reference to FIG. **4**, an illustration of an embodiment of a word **400** having diffraction grating subpattem is shown. By adjusting the spacing of the diffraction gratings, the word **400** or character appears in different colors. The minimum size of the features is limited only by the capabilities of the VLSI fabrication technology used. For example, one-hundred and thirty nanometer features are being used today. In addition to colors, other embodiments could use bolding, underlining, italics, strikeout, subscripts, superscripts, shadows, small caps and other effects with the text **308**. Further, the diffraction lines the produce the different colors could be oriented at any angle with respect to the text **308** and not just horizontally as depicted in this embodiment.

Referring next to FIG. **5**, a flow diagram of an embodiment of a process for converting text and graphics into an electronic mask file is shown. The process begins in step **515** where a text file **505** and graphics file **510** are chosen and loaded into page layout software. The text **505** is in a file format such ASCII text or rich text. Included in the text file **505** are hard returns between paragraphs and markers for the beginning of a section or chapter. The graphics file **510** is preferably a two color silhouette.

Page layout software such as Adobe PageMaker™ or Quark Xpress™ is used to create and lay-out the text and graphics in a space proportional in size to the dimensions of the desired die **104**. The resolution of the drawing in the page layout software is chosen such that it corresponds to the feature size of the semiconductor process. The number of columns needed and font size for adequate resolution is chosen with the page layout software. A page layout file **520** is produced from the software in step **515**.

In step **525**, the page layout file **520** is converted into a binary image file **530**. This can be done using a screen capture program and an image manipulation program such as Hijaak Pro™ or Adobe PhotoShop™. Alternatively, custom software could perform this conversion to the binary image file **530**. In this embodiment, each pixel in the binary image corresponds to a rectangle in the die layout.

In step **535**, the text and graphical regions of binary image file **530** are represented as a collection of simple geometric primitives in a geometric primitives file **540** that can be fabricated with the available fabrication technology. Primitives such as rectangles are used in this embodiment to represent each pixel, but in other embodiments can also include general polygons, triangles, lines, curves, and circles. In alternative embodiments, several like and adjacent pixels can be grouped into larger primitives.

In addition to a binary image file, diffraction patterns and color materials, for example, could be used to change the color of a graphical image. Some embodiments could change the processing materials to suit the desired colors of the graphical image. Alternatively, colors in the graphical image could signify a different shaped primitive (e.g., a circle) or signify a different style.

In step **545**, each geometric primitive in the file **540** is translated into a basic chip layout command such as a "Box" command (corresponding to rectangles) in the CIF language to produce a CIF or GDS file **550**. In addition to the CIF and GIF format, any other chip layout format could be used. The complete collection of primitives corresponding to the whole binary file would, by this process, result in a list of"Box"-like commands. It is noted, we use the phrase 'box command' to mean any of a variety of commands corresponding to simple geometric primitives in the rest of this document. This list constitutes the chip layout file, which can be used by a VLSI fabrication facility to create the patterns for the masks used in lithographing the die **104**.

With reference to FIG. **6**, a flow diagram of another embodiment of a process for converting text and graphics into an electronic mask file is shown. The process begins in step **610** where for each of the elements (e.g. letters of the alphabet, punctuation marks, numerals, and graphic characters) a binary pattern that represents that character is generated for a particular font in a font/style file **600**. All these binary patterns are collected into one or more 'font/style files'. For each element of the font/style files **600**, a list of primitives that make the element is generated. This yields a "subroutine" for generating that element.

The list of primitives that make up an element can be generated in a variety of ways. In one embodiment, each pixel of the element is treated as a separate rectangular primitive. The primitives generated from the font/style file **600** are stored in a character subroutine file **630**. Some embodiments may include special features in the character subroutine file **630** such as printing a special character at the beginning of a chapter or section. At this point in the process, the text can be processed to produce characters in the desired font.

A text file **620**, the character subroutines file **630** and a binary image file **640** are loaded into the chip layout generator in step **650** to produce a chip layout file **660**. In this embodiment, the text file is an ASCII file and the binary image file is a TIFF file. If only a text file **620** is specified without a binary image file **640**, each element in the text file **620** is read and corresponding subroutine from the character subroutine file **630** is looked-up. The sequence of elements is translated into the corresponding sequence of subroutine calls and a chip layout file is created. The set of subroutine calls may be appended to the subroutines.

If only a binary image or graphics file **640** is specified without a text file **620**, each pixel in the graphics file **640** is read and translated into an appropriate 'box' command. These 'box' commands form a chip layout file **660**.

In some instances, a graphics file **640** may be combined with a text file **620** to create a chip layout file **660**. There are several options for accomplishing this. One option is to have the text wrap around the graphics. The graphic itself is represented as a collection of geometric primitives like rectangles. By knowing the position of the graphics, the text can be wrapped around the graphics.

Another option is to have the text overlay the graphic, but to have the text change polarity (normal or reverse contrast) depending on whether it is inside or outside the graphic element. The text may change features other than polarity. For instance, it could change style (normal or bold), change fonts (e.g. Geneva to Helvetica), or change from one type of

element to another. Once the style or type of element is determined from both the graphics and text file, the appropriate subroutine is looked up from set of subroutines generated in the character subroutine file **630** and outputted to the chip layout file **660**.

The mask corresponding to the chip layout file **660** described above (e.g., CIF or GDS format) can be created using E-Beam Lithography, X-Ray Lithography, or any of a variety of techniques commonly used now or in the future for VLSI. The input to the process is the chip layout file **660** and the polarity of the mask. The mask can be a **1**-to-**1** contact mask or a minification mask suitable for use in a stepper configuration.

Referring next to FIG. **7**, a depiction of an embodiment of an upper case "A" element **700** is shown. The element **700** approximates the font Helvetica using a number of rectangles. Other embodiments could use other fonts. The black regions denote "pixels" of the element. Similarly, FIG. **9** shows a depiction of an embodiment of a lower case "a" element **900**.

With reference to FIG. **8**, a depiction of the embodiment of the upper case "A" element **700** showing constituent rectangle primitives **800** is shown. The primitives **800** are rectangles of different sizes positioned to approximate the element **700**. Each primitive is comprised of "box" commands each being a square defined by the feature size of the process. Some embodiments are not limited by the feature size of the process. Since the die is not a functional circuit, the only limitation on size and shape is defined by the state of the art in mask fabrication. Although this embodiment uses rectangular primitives, other embodiments could have primitives of any geometric shape.

Referring next to FIGS. **10** and **11**, shown are depictions of embodiments of an upper case "A" and a lower case "a" elements **1000**, **1100** with reverse contrast. Reverse contrast provides contrast for text overlaying a dark background or a dark silhouette.

With reference to FIG. **12**, a flow diagram of an embodiment of a process for lithographing text and/or graphics onto a semiconductor substrate is shown. A variety of methods can be used for fabricating chips **104** based on mask described above. The process begins in step **1200** by depositing photoresist directly on the wafer or on a layer of some other material that has first been deposited on the wafer. Next, expose the photoresist to electromagnetic radiation of the appropriate wavelength through the mask in step **1210**. Etch away the exposed or unexposed photoresist to leave a positive or negative impression and bake the photoresist to increase its durability in step **1220**. Optionally, the wafer is coated with an optically clear protective material.

Referring next to FIG. **13**, a side elevational view of an embodiment of a semiconductor wafer **1300** with text and/or graphics lithographed thereon is shown. To produce the semiconductor wafer **1300** depicted, the process of FIG. **12** was employed. The bottommost portion is a substrate **1304**. An optional intermediate layer(s) **1308** may be deposited upon the substrate **1304**. A photoresist pattern **1312** is on the optional intermediate layer(s) **1308**. A clear protective coating **1316** envelopes the photoresist **1312**.

With reference to FIG. **14**, a flow diagram of another embodiment of a process for lithographing text and/or graphics onto a semiconductor substrate is shown. The process begins in step **1400** where one or more layers of materials such as metals or polysilicons are deposited on the substrate. Next, photoresist is deposited in step **1410**. In step **1420**, the photoresist is exposed to electromagnetic radiation of the appropriate wavelength through the mask.

Etch away the exposed or unexposed photoresist to leave a positive or negative impression in step **1430**. The layer below the photoresist is etched through the cavities created in the photoresist layer in step **1440**. Any photoresist left behind is removed to reveal the patterned layer of material in step **1450**. Optionally, coat the wafer with an optically clear protective material in step **1460**.

Referring next to FIG. **15**, a side elevational view of another embodiment of a semiconductor wafer **1500** with text and/or graphics lithographed thereon is shown. To produce the semiconductor wafer **1500** depicted, the process of FIG. **14** was employed. The bottommost portion is a substrate **1504**. An optional intermediate layer(s) **1508** may be deposited upon the substrate **1504**. A metal pattern **1512** is on the optional intermediate layer(s) **1508**. A clear protective coating **1516** envelopes the metal pattern **1512**.

With reference to FIG. **16**, a flow diagram of yet another embodiment of a process for lithographing text and/or graphics onto a semiconductor substrate is shown. The process begins in step **1600** where photoresist is deposited directly on the substrate or on a layer of some other material that has first been deposited on the substrate. In step **1610**, the photoresist is exposed to electromagnetic radiation of the appropriate wavelength through the mask. The exposed or unexposed photoresist is etched away in step **1620** to leave a positive or negative impression. Next, a material such as a metal or a polysilicon is deposited on the patterned photoresist in step **1630**. The photoresist is lifted off in step **1640** leaving behind the material from step **1630** in the cavities of the photoresist pattern. Optionally, the wafer is coated with an optically clear protective material in step **1650**.

Referring next to FIG. **17**, is a side elevational view of yet another embodiment of a semiconductor wafer with text and/or graphics lithographed thereon is shown. To produce the semiconductor wafer **1700** depicted, the process of FIG. **16** was employed. The bottommost portion is a substrate **1704**. An optional intermediate layer(s) **1708** may be deposited upon the substrate **1704**. A metal pattern **1712** is on the optional intermediate layer(s) **1708**. A clear protective coating **1716** envelopes the metal pattern **1712**.

The information stored in text and graphics may be accessed. A magnification device equipped with an illuminator that can cast light on the chip from above can be used to aid the human eye to see the fine details of the information on the chip. The chip can be mounted on a stage capable of precise movements under the magnifying device. The magnification device may be coupled to an electronic or photographic capture device, such as a film camera or an electronic camera.

If the chip is imaged by the magnification device and captured by an electronic capture device, the resulting electronic image may be processed. For instance, one could compare the electronic images of two chips to see if they are identical. This capability could be used for access control or security applications. One could also perform automated character recognition. The output could be printed, searched for specific items or translated into an audio signal and transmitted so that the chip could be "read out loud" to a human or a listening device.

In light of the above description, a number of advantages of the present invention are readily apparent. First, the density of information storage can be very high. This is due to the very small features that can be fabricated with modem VLSI technology. Second, the information storage is very durable against disruptive influences such as radioactivity,

strong electromagnetic fields, high temperatures, moisture, chemicals and mechanical strain. Existing means of information storage, such as magnetic discs, tapes and CDs tend to fall prey to one or more of these factors. In fact, even electronic memories fabricated using VLSI technology can not robustly tolerate these influences. Third, information access from our devices is straightforward. Finally, this means of information storage is very cost effective and easy to manufacture in large quantities.

A number of variations and modifications of the invention can also be used. For example, the substrates used could be an insulator. The layers could be formed over the insulator using VLSI techniques.

Although the invention is described with reference to specific embodiments thereof, the embodiments are merely illustrative, and not limiting, of the invention, the scope of which is to be determined solely by the appended claims.

What is claimed is:

1. A method for depositing a plurality of paragraphs of text on a substrate with semiconductor processing techniques, the method comprising:

reading a first paragraph from an electronic source;

reading a second paragraph from the electronic source;

positioning the first and second paragraphs into a column;

generating an electronic file at least partially representative of the column; and

imaging the substrate with the column, wherein the substrate is a semiconductor wafer.

2. The method for depositing the plurality of paragraphs of text on the substrate with semiconductor processing techniques as recited in claim **1**, wherein the imaging the substrate includes lithographing the substrate with a mask.

3. The method for depositing the plurality of paragraphs of text on the substrate with semiconductor processing techniques as recited in claim **1**, the method further comprising:

converting a first character of the first paragraph into a first pattern;

converting a second character of the first paragraph into a second pattern; and

aligning the first and second characters on a line.

4. The method for depositing the plurality of paragraphs of text on the substrate with semiconductor processing techniques as recited in claim **1**, the method further comprising determining an end of a first line in the first paragraph and beginning a second line.

5. The method for depositing the plurality of paragraphs of text on the substrate with semiconductor processing techniques as recited in claim **1**, the method further comprising determining an end of the first paragraph and beginning the second paragraph on the next line of the column.

6. The method for depositing the plurality of paragraphs of text on the substrate with semiconductor processing techniques as recited in claim **1**, the method further comprising detecting an end of a first column and depositing a next line in a second column.

7. The method for depositing the plurality of paragraphs of text on the substrate with semiconductor processing techniques as recited in claim **1**, the method further comprising:

determining a first color for a first character; and

determining a second color for a second character.

8. The method for depositing the plurality of paragraphs of text on the substrate with semiconductor processing techniques as recited in claim **1**, wherein the generating the electronic file comprises overlaying a silhouette over at least part of the column.

9. A method for depositing text and an image on a substrate with semiconductor processing techniques, the method comprising:

loading a phrase;

loading a silhouette image;

generating an electronic file at least partially representative of the phrase and the silhouette image, wherein the generating step comprises overlaying a silhouette over at least part of the phrase; and

imaging the substrate with the electronic file.

10. The method for depositing text and the image on the substrate with semiconductor processing techniques as recited in claim **9**, wherein the imaging the substrate includes lithographing the substrate with a mask.

11. The method for depositing text and the image on the substrate with semiconductor processing techniques as recited in claim **9**, the method further comprising:

converting a first character of the phrase into a first pattern;

converting a second character of the phrase into a second pattern; and

aligning the first and second characters on a line.

12. The method for depositing text and the image on the substrate with semiconductor processing techniques as recited in claim **9**, wherein the substrate is a semiconductor wafer.

13. The method for depositing text and the image on the substrate with semiconductor processing techniques as recited in claim **9**, the method further comprising:

determining a first color for a first character; and

determining a second color for a second character.

14. A method for depositing a plurality of paragraphs of text on a substrate with semiconductor processing techniques, the method comprising:

reading a first paragraph from an electronic source;

reading a second paragraph from the electronic source;

positioning the first and second paragraphs into one or more columns;

generating an electronic file at least partially representative of the column; and

producing the column on the substrate using semiconductor processing techniques.

15. The method for depositing the plurality of paragraphs of text on the substrate with semiconductor processing techniques as recited in claim **14**, wherein the producing step includes lithographing the substrate with a mask.

16. The method for depositing the plurality of paragraphs of text on the substrate with semiconductor processing techniques as recited in claim **14**, the method further comprising:

converting a first character of the first paragraph into a first pattern;

converting a second character of the first paragraph into a second pattern;

aligning the first and second characters on a line.

17. The method for depositing the plurality of paragraphs of text on the substrate with semiconductor processing techniques as recited in claim **14**, wherein the substrate is a semiconductor wafer.

18. The method for depositing the plurality of paragraphs of text on the substrate with semiconductor processing

techniques as recited in claim **14**, the method further comprising determining an end of a first line in the first paragraph and beginning a second line.

19. The method for depositing the plurality of paragraphs of text on the substrate with semiconductor processing techniques as recited in claim **14**, the method further comprising determining an end of the first paragraph and beginning the second paragraph on the next line of the column.

20. The method for depositing the plurality of paragraphs of text on the substrate with semiconductor processing techniques as recited in claim **14**, the method further comprising detecting an end of a first column and depositing a next line in a second column.

21. The method for depositing the plurality of paragraphs of, text on the substrate with semiconductor processing techniques as recited in claim **14**, the method further comprising:

determining a first color for a first character; and

determining a second color for a second character.

22. The method for depositing the plurality of paragraphs of text on the substrate with semiconductor processing techniques as recited in claim **14**, wherein the generating the electronic file comprises overlaying a silhouette over at least part of the column.

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