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(54) Title: METHODS OF USING POLISHED SILICON WAFER STRIPS FOR EUV HOMOGENIZER

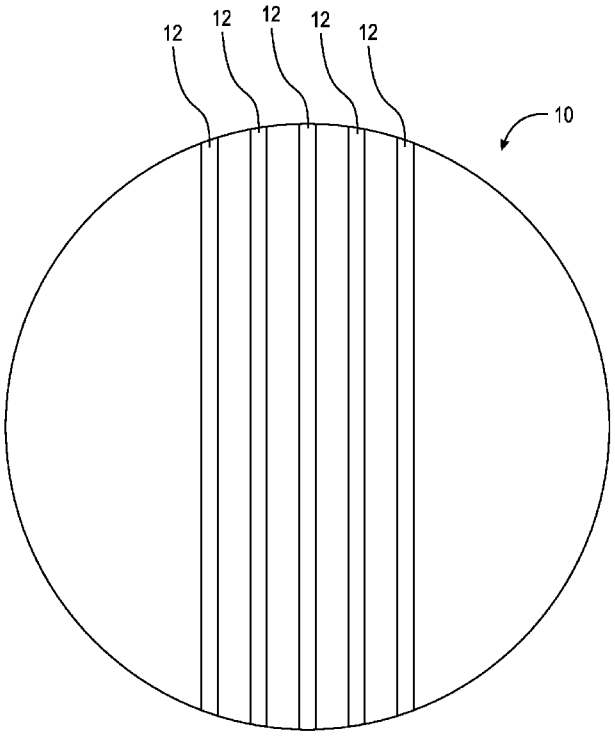


Fig. 1

(57) Abstract: The present invention is a light homogenizer or light tunnel with highly reflective sides that enable the focusing of EUV illumination. The sides of the homogenizer are cut from a highly polished silicon wafer. The wafer is coated with a reflective coating before the strips are cut from the wafer. The invention also includes a method for flattening the strips and applying a backing to the strips enabling easier manipulation of the strips during assembly and use.

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METHODS OF USING POLISHED SILICON WAFER STRIPS FOR EUV HOMOGENIZER

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This patent application claims the benefit under 35 U.S.C. §119(e) of U.S. Provisional Application No. 61/732,213, filed November 30, 2012, which application is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

[0002] The field of the present invention is extreme ultraviolet light (EUV) reticle inspection systems, particularly regarding the uniformity of EUV light impinging on the target reticles, and more particularly on devices to improve the uniformity of EUV light impinging on the target reticles.

BACKGROUND OF THE INVENTION

[0003] Optical homogenization is required to improve the illumination field uniformity and pupil stability for EUV reticle inspection systems. Directing EUV light through a long, narrow, reflective tunnel ("homogenizer") is one method used to achieve the required light homogenization. A homogenizer tunnel is comprised of four pieces of long mirrors forming a rectangular tunnel with open ends and with or without a mechanical taper in the tunnel.

[0004] Because of the small dimensions of EUV light tunnels, it is difficult and expensive to manufacture the mirrors for the tunnel due to the high cost of polishing and coating large surfaces. In addition, in order to achieve a high degree of light homogenization, light must reflect off the sides of the light tunnel at a grazing angle of less than 2 degrees. This requires a high degree of flatness in the range of less than 1 μm. Depending on specific operational requirements, it may be necessary that the light tunnel include a mechanical taper to further narrow or expand the width and/or height of the EUV illumination as it emerges from the homogenizer.

[0005] Therefore, there is a need in the field for a less expensive method of assembling an EUV light homogenization tunnel having the required shape, length, and reflectivity on the interior surface to effectively direct EUV illumination onto a reticle during the reticle inspection process.

SUMMARY OF THE INVENTION

[0006] The present invention broadly comprises a EUV light homogenizer for a EUV reticle inspection system comprising a hollow four sided tunnel. The four sided tunnel includes four strips with each of the four strips having an inner surface and an outer surface. Each of the inner surfaces is coated with a high reflectivity coating. The four strips are joined to form the four-sided tunnel with the four inner surfaces facing the interior of the light tunnel. In one embodiment, the light homogenizer is tapered.

[0007] The present invention also broadly comprises a method of assembling a light tunnel for a EUV illumination reticle inspection system the method comprising: polishing a silicon wafer; coating the silicon wafer with a high reflectivity coating; and cutting the silicon wafer into at least four strips. Each of the four strips has a first side and a second side with the high reflectivity coating applied onto the first side. Mounting substrate is applied to the second side of each of the at least four strips. Each of the strips is flattened against a flat surface; and, assembled to form the light tunnel such that each first side of the at least four strips forms the interior surface of the light tunnel. In one embodiment, each of the four strips is tapered to form a tapered light homogenizer when the at least four strips are joined to form the homogenizer.

[0008] One object of the invention is to present a EUV illumination homogenizer that is fabricated without individually polishing and coating the small components of the homogenizer.

[0009] A second object of the invention is to provide a method of fabricating a EUV illumination homogenizer that simplifies the polishing, coating, and assembly steps in fabricating the device.

[0010] A third object of the invention is to describe a EUV illumination homogenizer fabricated from easily available materials.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0011] The nature and mode of the operation of the present invention will now be more fully described in the following detailed description of the invention taken with the accompanying drawing Figures, in which:

[0012] Figure 1 is a schematic depiction of a silicon wafer in which at least four strips are cut or divided out from the body of the wafer;

[0013] Figure 2 depicts the separate strips cut from a single wafer;

[0014] Figure 2A shows tapered strips cut from a single wafer;

[0015] Figure 3 demonstrates schematically a method used to flatten individual wafer strips;

[0016] Figure 4 is an exploded end view showing the individual strips with backing in position to be assembled into the light homogenizer;

[0017] Figure 5 is a side perspective view of the assembled light tunnel of the present invention also depicting purge gas passing through the light tunnel; and,

[0018] Figure 6 is a side perspective view of the light tunnel schematically demonstrating the light reflective capability of the tunnel.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0019] At the outset, it should be appreciated that like drawing numbers on different drawing views identify identical structural elements of the invention. It also should be appreciated that figure proportions and angles are not always to scale in order to clearly portray the attributes of the present invention.

[0020] While the present invention is described with respect to what is presently considered to be the preferred embodiments, it is understood that the invention is not limited to the disclosed embodiments. The present invention is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

[0021] Furthermore, it is understood that this invention is not limited to the particular methodology, materials and modifications described and as such may, of course, vary. It is also understood that the terminology used herein is for the purpose of describing particular aspects only, and is not intended to limit the scope of the present invention, which is limited only by the appended claims.

[0022] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood to one of ordinary skill in the art to which this invention belongs. It should be appreciated that the term “substantially” is synonymous with terms such as "nearly", "very nearly”, “about", "approximately", "around", "bordering on", "close to", "essentially", "in the neighborhood of", “in the vicinity of”, etc., and such terms may be used interchangeably as appearing in the specification and claims. It should be appreciated that the term "proximate" is synonymous with terms such as "nearby", "close", "adjacent", "neighboring", "immediate", "adjoining", etc., and such terms may be used interchangeably as appearing in the specification and claims. Although any methods, devices or materials similar or

equivalent to those described herein can be used in the practice or testing of the invention, the preferred methods, devices, and materials are now described.

[0023] Adverting to the drawings, Figure 1 is a schematic depiction of a wafer **10**, e.g. a silicon wafer, in which at least four strips **12** are cut or divided out from the body of wafer **10**. Before cutting strips **12**, wafer **10** is polished in a known manner used with wafers **10** that may be used for other purposes. After polishing, wafer **10** is coated with a high reflectivity coating such as ruthenium. By high reflectivity is meant a coating suitable to achieve a high reflectivity for EUV light as a grazing incident angle of less than 2 degrees.

[0024] Figure 2 depicts the separate strips **12** cut from wafer **10**. The dimension of an individual strip **12** is determined by the dimensions of the homogenizer, or light tunnel, to be fabricated and the size of wafer **10**. For example, with an industry standard 300 mm wafer **10**, the strip **12** can be range from about approximately 100 to 280 mm in length. For an industry standard 450 mm wafer **10**, strip **12** can range from about 280 to about 440 mm in length. Wafer **10** is cut along the high symmetric crystal orientation of wafer **10** so the formation of edge chip can be reduced. The width of each strip **12** can be 0.2-4 mm. Consequently, multiple strips **12** can be made from a single wafer **10**. Figure 2A depicts an alternate embodiment in which separate strips **12a** cut from wafer **10** are tapered. Lengths longer than 440 mm up to about 800 mm can be achieved by attaching two homogenizers together length-wise (end-to-end) using epoxy adhesive and/or nut and bolt assemblies.

[0025] Figure 3 demonstrates schematically a method used to flatten each strip **12**. Strips **12** or **12a** are placed on flat surface **30a** ("surface **30a**") of block **30**. Block **30** may be formed from granite or other dense material able to withstand heavy pressure. Surface **30a** is highly polished to form a surface flatness of less than 1μm. Pinholes **32** extend from surface **30a** to the opposing surface **30b** and enable strips **12** (or strips **12a**) to be drawn flat against flat surface **30a** by drawing a vacuum through pinholes **32** from opposing side **30b**.

[0026] While strips **12** are being flattened, they are mounted on substrate or backing **20** by laying backing strips against individual strips **12**. Pressing force, represented by the arrows, forces backing **20** onto strips **12** and it is fixedly attached to the strips using a layer **22** of epoxy adhesive. Backing **20** may be fabricated from ceramic or metal. In one embodiment, spacers **24** of equal size are interspersed in the epoxy layer **22** to produce an even gap between strip **12** and backing **20** as spacers **24** will maintain an even gap throughout the area of strip **12** as pressure is

applied to backing **20**. In one embodiment, spacers **24** are glass beads. In one embodiment, the gap is 0.0005 inches.

[0027] Figure 4 is an exploded end view of homogenizer **50**. Strips **12** with backing **20** are in position to be assembled into homogenizer **50**. The epoxy layer **22** and spacers **24** are seen between strip **12** and backing **20**. Additional epoxy and/or appropriate nut and bolt assemblies may be used to assemble strips **12** to form the constructed light homogenizer or light tunnel **50** in a known manner. An assembled homogenizer **50** will have a substantially rectangular shape with square ends. By substantially in this context is meant that homogenizer **50** appears visually to be a rectangular shaped tunnel with similarly sized heights and widths and a length greater than the heights and widths. A tapered homogenizer (not shown) would include similar sized widths and heights that would narrow or expand along the length of the tapered homogenizer.

[0028] Figure 5 is a side perspective view of the assembled light tunnel **50** with backing **20** and epoxy layer **22** removed for clarity. Arrows **60** represent purge gas passing through light tunnel **50** to capture or entrain gases produced by the epoxy adhesive. By entrain is meant to draw in and transport (as solid particles or gas) by the flow of a fluid. In this case, the fluid is a gas such as hydrogen or helium. In a preferred embodiment, the epoxy adhesive will be a low outgassing producer.

[0029] Figure 6 is a side perspective view of assembled light homogenizer **50** with the arrows depicting the light **70** reflective capability of homogenizer **50**. The reflective coating and flat inner surface of the strips **12** created with the vacuum method discussed above endows homogenizer **50** with a reflectivity that can be greater than 98 percent. Consequently, after multiple reflections, the total reflectivity loss can be limited to less than 10 percent. Therefore, homogenizer **50** of the present invention not only acts to focus EUV light onto the inspection optics it also reduces loss of EUV light so that a greater amount of EUV light illuminates the reticle inspection optics. It should be recognized that purging, as described above, may tale place while EUV illumination is passed through homogenizer **50**.

[0030] Thus it is seen that the objects of the invention are efficiently obtained, although changes and modifications to the invention should be readily apparent to those having ordinary skill in the art, which changes would not depart from the spirit and scope of the invention as claimed.

What is claimed is:

1. A EUV light homogenizer for a EUV reticle inspection system comprising:

a hollow four sided tunnel, wherein said four sided tunnel include four flat strips, each of said four flat strips having an inner surface and an outer surface;

wherein each of said inner surfaces is coated with a high reflectivity coating; and,

wherein said four strips are joined to form said four-sided tunnel.

2. The EUV light homogenizer as recited in Claim 1 further comprising a mounting substrate applied to said outer surface.

3. The EUV light homogenizer as recited in Claim 2 wherein said mounting substrate is a ceramic material.

4. The EUV light homogenizer as recited in Claim 2 wherein said mounting substrate is metal.

5. The EUV light homogenizer as recited in Claim 1 wherein said high reflectivity coating is ruthenium.

6. The EUV light homogenizer as recited in Claim 1 wherein said four strips are joined to form said four-sided tunnel using an epoxy, said epoxy having a low outgassing rate.

7. The EUV light homogenizer as recited in Claim 1 wherein said four-sided tunnel ranges in length from about 100 mm to about 800 mm.

8. The EUV light homogenizer as recited in Claim 7 wherein said EUV light homogenizer comprises two attached EUV light homogenizers, wherein said two attached EUV light homogenizers are attached lengthwise end-to-end.

9. The EUV light homogenizer as recited in Claim 1 wherein each of said four strips ranges in width from about 0.2 mm to about 4 mm.

10. The EUV light homogenizer as recited in Claim 1 wherein said four-sided tunnel is substantially rectangular in shape.

11. The EUV light homogenizer as recited in Claim 1 wherein purge gas is passed through said EUV light homogenizer.

12. The EUV light homogenizer as recited in Claim 11 wherein said purge gas is hydrogen.

13. The EUV light homogenizer as recited in Claim 11 wherein said purge gas is helium.

14. A method of assembling a light tunnel for a EUV illumination reticle inspection system comprising:

polishing a silicon wafer;

coating said silicon wafer with a high reflectivity coating;

cutting said silicon wafer into at least four strips, each of said at least four strips having a first side and a second side, wherein said high reflectivity coating is on said first side;

applying mounting substrate to said second side of each of said at least four strips;

flattening each of said at least four strips against a flat surface; and,

assembling said at least four strips to form said light tunnel;

wherein each first side of said at least four strips forms a single interior surface of said light tunnel.

15. The method of assembling a light tunnel for a EUV illumination reticle inspection as recited in Claim 14 wherein said substrate mounting is ceramic.

16. The method of assembling a light tunnel for a EUV illumination reticle inspection as recited in Claim 14 wherein said substrate mounting is metal.

17. The method of assembling a light tunnel for a EUV illumination reticle inspection as recited in Claim 14 wherein flat surface defines a plurality of holes extending from a top of said

flat surface through a bottom of said flat surface and wherein each of said at least four strips is flattened against said flat surface by a vacuum.

18. The method of assembling a light tunnel for a EUV illumination reticle inspection as recited in Claim 14 further comprising pressing each of said at least four strips against said flat surface.

19. The method of assembling a light tunnel for a EUV illumination reticle inspection as recited in Claim 14 further comprising the step of directing a purge gas through said tunnel.

20. The method of assembling a light tunnel for a EUV illumination reticle inspection as recited in Claim 19 wherein said purge gas is hydrogen.

21. The method of assembling a light tunnel for a EUV illumination reticle inspection as recited in Claim 19 wherein said purge gas is helium.

22. The method of assembling a light tunnel for a EUV illumination reticle inspection as recited in Claim 14 wherein said assembly of said at least four strips is performed using epoxy.

23. The method of assembling a light tunnel for a EUV illumination reticle inspection as recited in Claim 14 wherein said assembly of said at least four strips is performed using nut and bolt assemblies.

24. The method of assembling a light tunnel for a EUV illumination reticle inspection as recited in Claim 14 wherein said high reflectivity coating is ruthenium.

25. The method of assembling a light tunnel for a EUV illumination reticle inspection as recited in Claim 14 further comprising the step of attaching two assembled light tunnels lengthwise end-to-end.

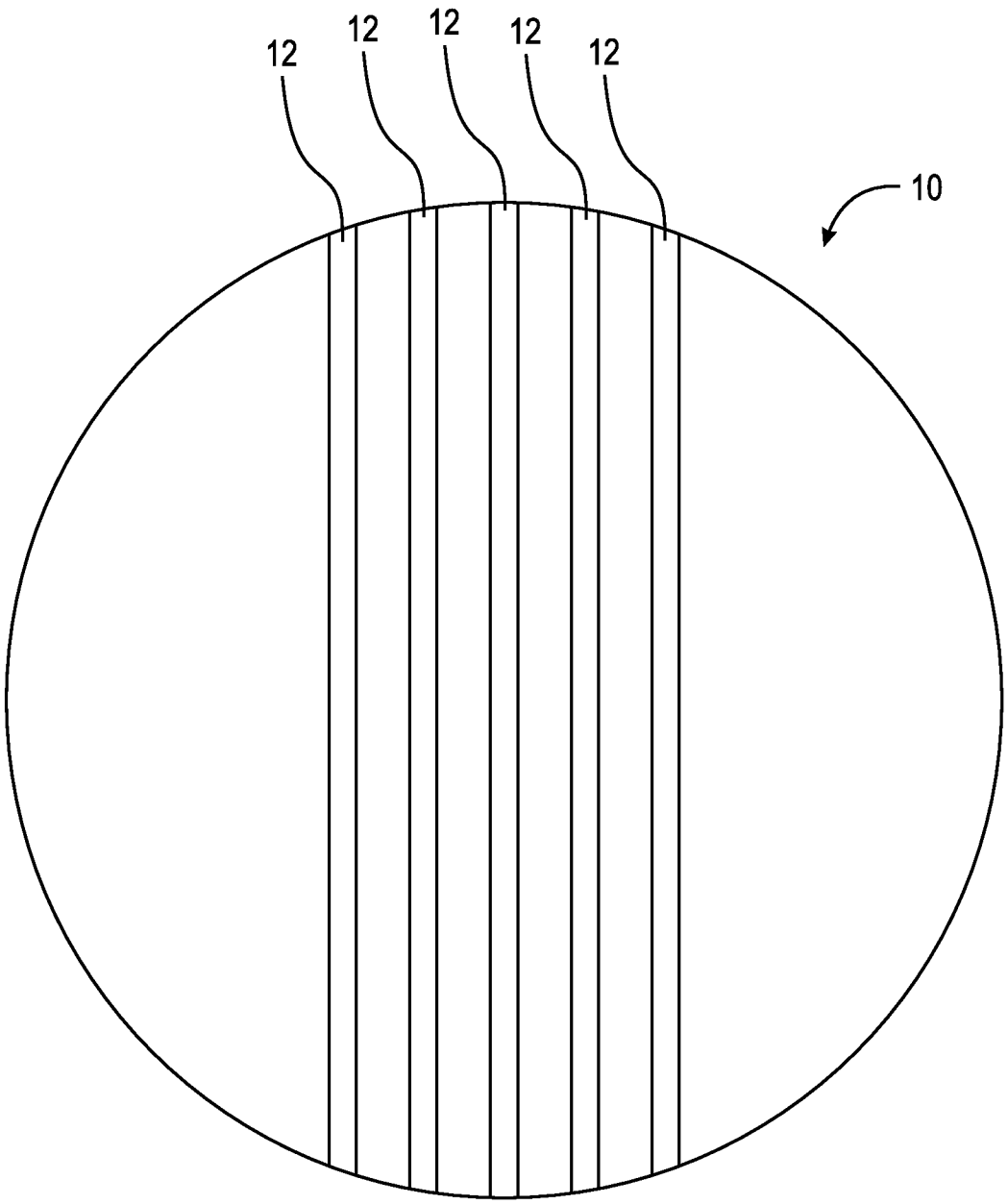


Fig. 1

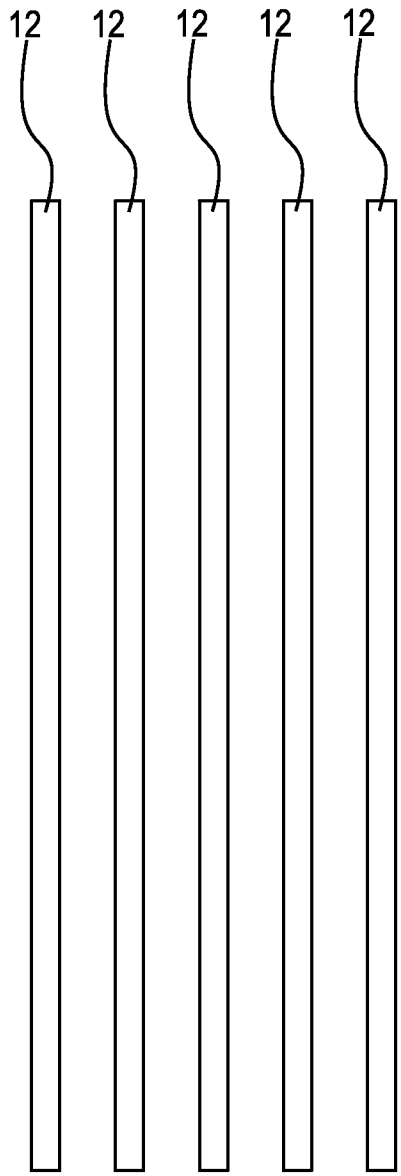


Fig. 2

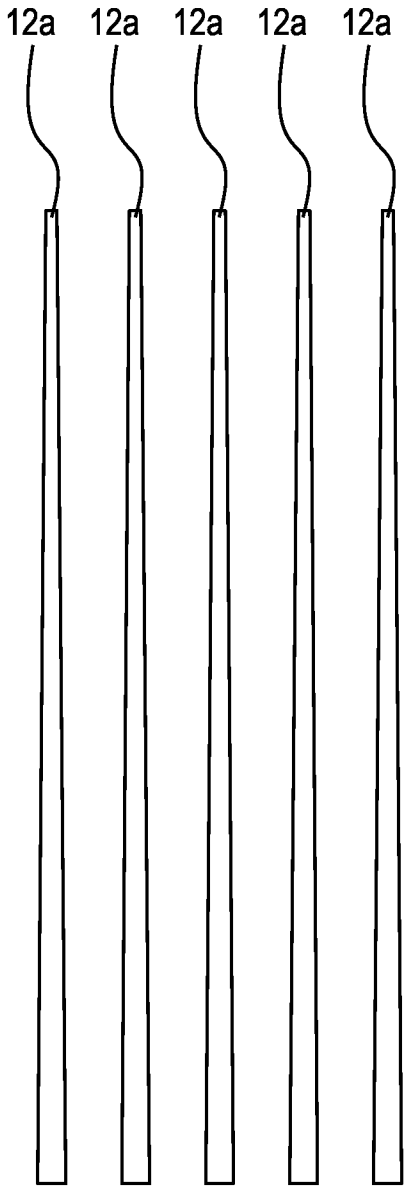


Fig. 2a

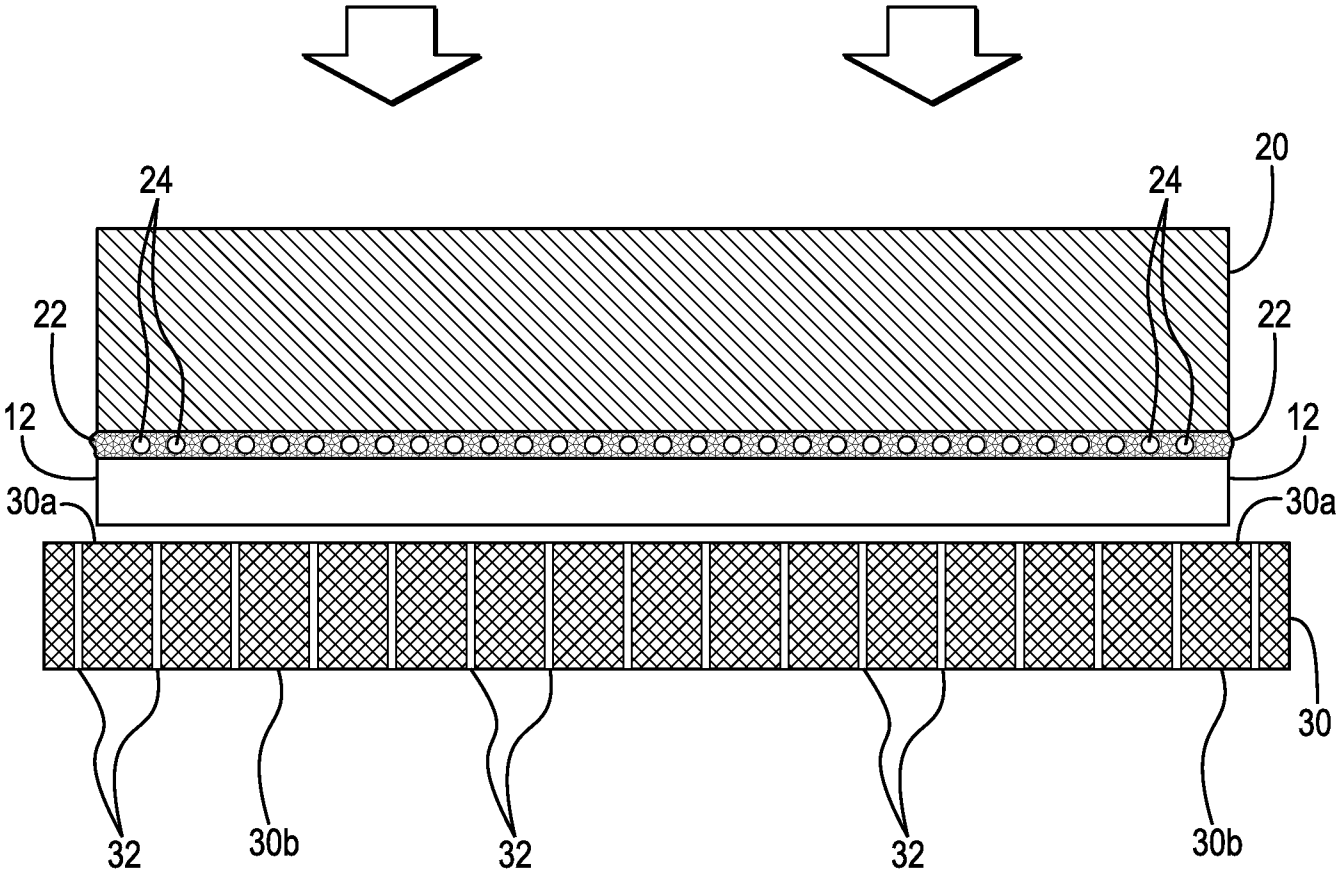


Fig. 3

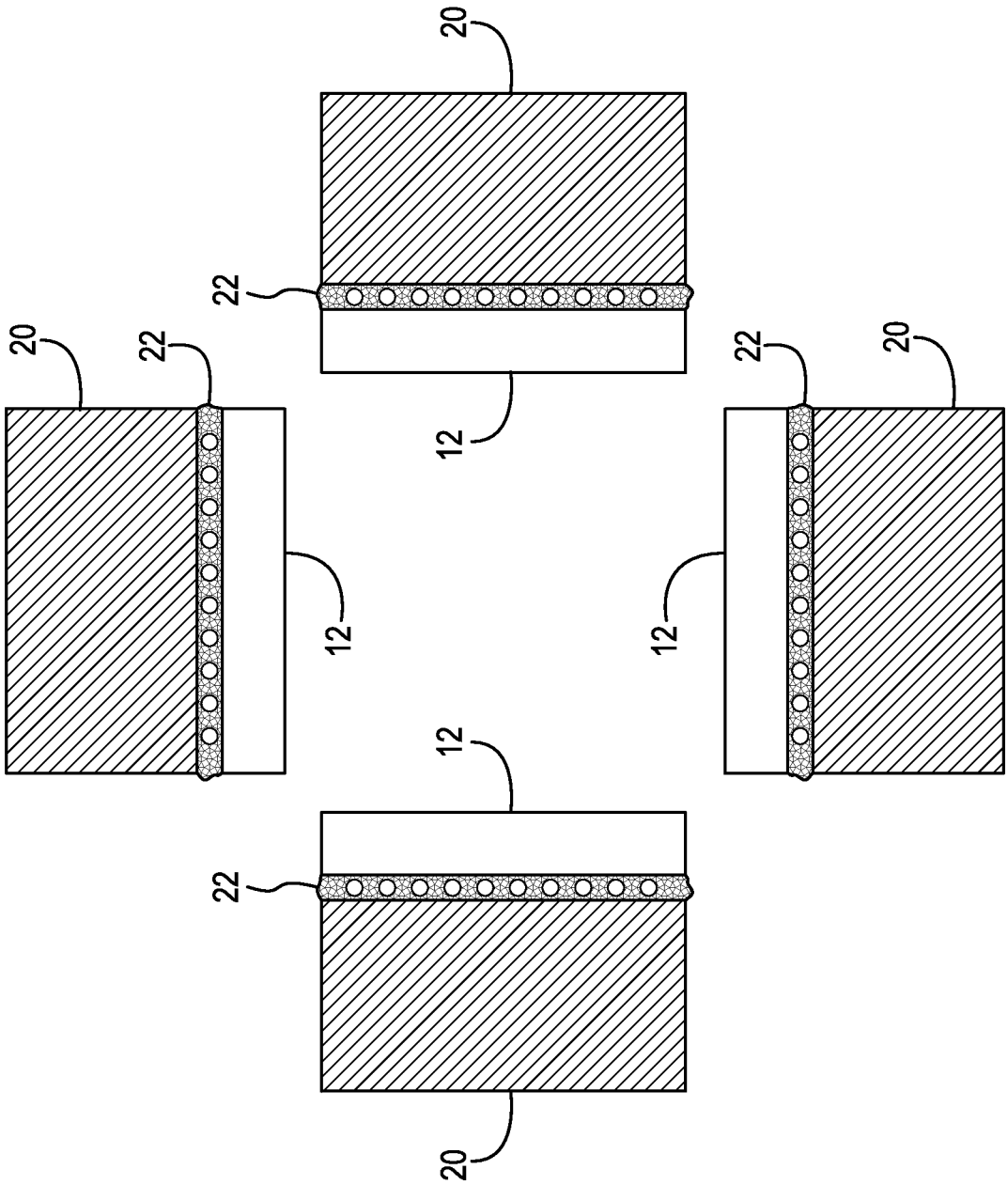


Fig. 4

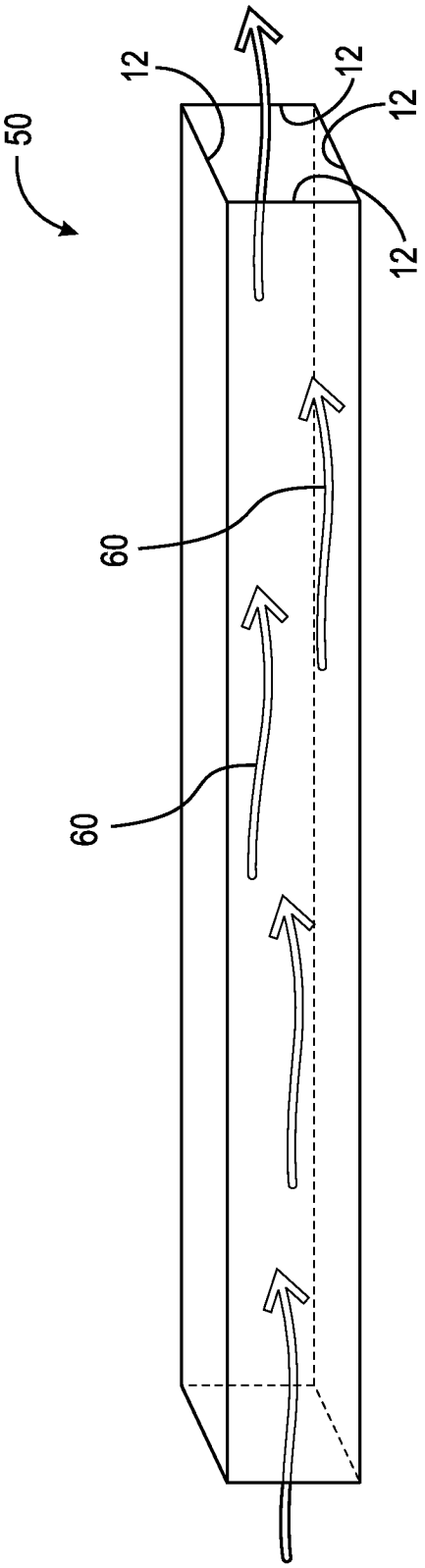


Fig. 5

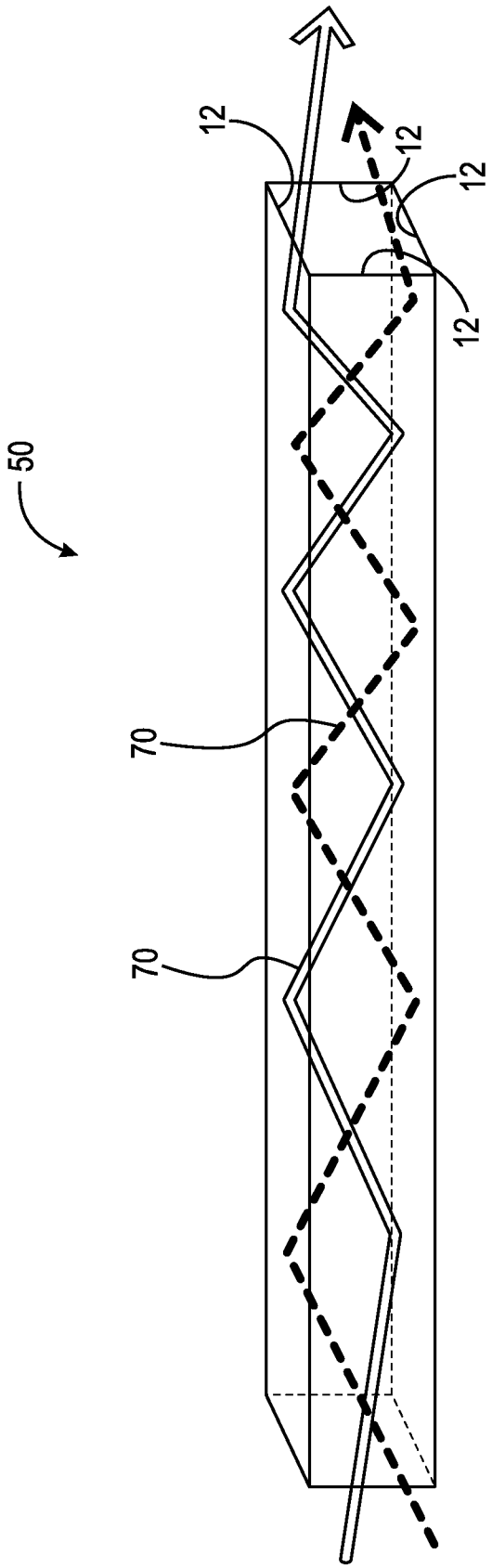


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/071986

A. CLASSIFICATION OF SUBJECT MATTER

G02B 27/09(2006.01)i, G01N 21/88(2006.01)i, H01L 21/027(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G02B 27/09; B24B 13/00; F21K 27/06; G03F 1/08; G01B 11/24; G02B 21/06; C03C 15/02; G02B 6/00; G01N 21/88; H01L 21/027

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: reticle inspection, homogenizer, tunnel

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010-0158461 A1 (BONITATIBUS) 24 June 2010 See paragraphs [0041]-[0042] and figures 5B-6.	1-13
Y		14-25
Y	US 2011-0062111 A1 (YEO et al.) 17 March 2011 See paragraphs [0028], [0030], [0034], [0043], [0052] and figure 14.	14-25
A		1-13
A	US 6672739 B1 (ARGYLE et al.) 06 January 2004 See column 2, lines 2-15, column 3, line 52 - column 4, line 5 and figure 5.	1-25
A	JP 2001-235853 A (APPLIED MATERIALS INC.) 31 August 2001 See paragraphs [0018]-[0019], [0021]-[0025] and figure 1.	1-25
A	US 2011-0164313 A1 (STROESSNER) 07 July 2011 See abstract, claim 1, paragraphs [0091]-[0094] and figure 4.	1-25

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

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 March 2014 (13.03.2014)	**13 March 2014 (13.03.2014)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
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