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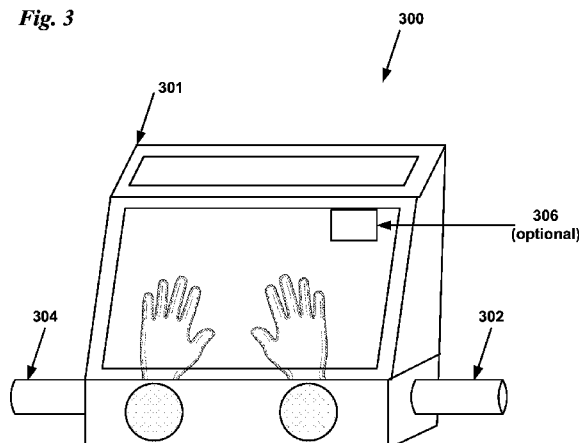
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(54) Title: APPARATUS AND METHOD FOR PROVIDING A HUMIDITY-CONTROLLED ENVIRONMENT IN WHICH TO
PERFORM OPTICAL CONTACTING

Fig. 3



(57) Abstract: An apparatus and method for providing a humidity-controlled environment in which to perform optical contacting are described. In use, an environment having a substantially ambient temperature is created. A humidity level of the environment is further controlled by flowing an inert gas through the environment. Within the humidity-controlled environment, a plurality of sub-components are then optically contacted to form an optical component.



APPARATUS AND METHOD FOR PROVIDING A HUMIDITY-CONTROLLED ENVIRONMENT IN WHICH TO PERFORM OPTICAL CONTACTING

RELATED APPLICATION(S)

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 62/086,138 filed December 1, 2014, the entire contents of which are incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to optical contacting, and more particularly to environments in which optical contacting is performed.

BACKGROUND

[0003] Optical contacting is the process by which contact is made between a surface of each of two or more sub-components such that the sub-components are joined to form a single optical component. In some examples, the contacted sub-components may be prisms, lenses, etc. and the resulting optical component may be a polarizer, beam splitter, etc. Current techniques for performing optical contacting have, unfortunately, exhibited various limitations.

[0004] For example, optical contacting has traditionally been performed within an environment (e.g. clean room, etc.) in which humidity is not controlled. When performing optical contacting, however, humidity above a certain level has recently been found to cause absorption of the humidity onto the sub-component surfaces being contacted. This water absorption then causes water to be trapped between the contacted surfaces, and thus within the formed optical component, which ultimately negatively

affects the functionality of the optical component. In particular, light in the deep ultra-violet (DUV) or vacuum UV (VUV) wave length range may not react as expected upon contacting an optical component having water therewithin. Further, delamination between the contacted sub-component surfaces may also occur when water has been absorbed by the surfaces during the contacting process.

[0005] To date, optical contacting processes have not addressed specifically the surrounding humidity in such a way to avoid the above mentioned problems and/or other problems resulting directly from performing optical contacting in a humid environment. There is thus a need for addressing these and/or other issues associated with the prior art optical contacting processes.

SUMMARY

[0006] An apparatus and method for providing a humidity-controlled environment in which to perform optical contacting are described. In use, an environment having a substantially ambient temperature is created. A humidity level of the environment is further controlled by flowing an inert gas through the environment. Within the humidity-controlled environment, a plurality of sub-components are then optically contacted to form an optical component.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Figure 1 shows a schematic of an exemplary metrology tool, in accordance with the prior art.

[0008] Figure 2 illustrates a method for providing a humidity-controlled environment in which to perform optical contacting, in accordance with an embodiment.

[0009] Figure 3 illustrates an apparatus providing a humidity-controlled environment in which to perform optical contacting, in accordance with another embodiment.

DETAILED DESCRIPTION

[0010] The following description discloses a method and apparatus for providing a humidity-controlled environment in which to perform optical contacting. Ultimately, the optical contacting forms an optical component, which may be implemented in inspection systems (e.g. wafer inspection, reticle inspection, etc.) used for identifying defects in a target component, review systems used to relocate a defect found by an inspection system, and/or metrology systems used for measuring structures and/or target components. By way of background, metrology systems are described in more detail below.

[0011] In the field of semiconductor metrology, a metrology tool may comprise an illumination system which illuminates a target, a collection system which captures relevant information provided by the illumination system's interaction (or lack thereof) with a target, device or feature, and a processing system which analyzes the information collected using one or more algorithms. Metrology tools can be used to measure structural and material characteristics (e.g. material composition, dimensional characteristics of structures and films such as film thickness and/or critical dimensions of structures, overlay, etc.) associated with various semiconductor fabrication processes. These measurements are used to facilitate process controls and/or yield efficiencies in the manufacture of semiconductor dies.

[0012] The metrology tool can comprise one or more hardware configurations which may be used in conjunction with certain embodiments of this invention to, e.g., measure the various aforementioned semiconductor structural and material characteristics. Examples of such hardware configurations include, but are not limited to, the following.

[0013] Spectroscopic ellipsometer (SE)

[0014] SE with multiple angles of illumination

[0015] SE measuring Mueller matrix elements (e.g. using rotating compensator(s))

- [0016]** Single-wavelength ellipsometers
- [0017]** Beam profile ellipsometer (angle-resolved ellipsometer)
- [0018]** Beam profile reflectometer (angle-resolved reflectometer)
- [0019]** Broadband reflective spectrometer (spectroscopic reflectometer)
- [0020]** Single-wavelength reflectometer
- [0021]** Angle-resolved reflectometer
- [0022]** Imaging system
- [0023]** Scatterometer (e.g. speckle analyzer)

[0024] The hardware configurations can be separated into discrete operational systems. On the other hand, one or more hardware configurations can be combined into a single tool. One example of such a combination of multiple hardware configurations into a single tool is shown in Figure 1, incorporated herein from U.S. Patent No. 7,933,026 which is hereby incorporated by reference in its entirety for all purposes. Figure 1 shows, for example, a schematic of an exemplary metrology tool that comprises: a) a broadband SE (i.e., 18); b) a SE (i.e., 2) with rotating compensator (i.e., 98); c) a beam profile ellipsometer (i.e., 10); d) a beam profile reflectometer (i.e., 12); e) a broadband reflective spectrometer (i.e., 14); and f) a deep ultra-violet reflective spectrometer (i.e., 16). In addition, there are typically numerous optical elements in such systems, including certain lenses, collimators, mirrors, quarter-wave plates, polarizers, detectors, cameras, apertures, and/or light sources. The wavelengths for optical systems can vary from about 120 nm to 3 microns. For non-ellipsometer systems, signals collected can be polarization-resolved or unpolarized. Figure 1 provides an illustration of multiple metrology heads integrated on the same tool. However, in many cases, multiple metrology tools are used for measurements on a single or multiple metrology targets. This is described, for example,

in U.S. Patent No. 7,478,019, "Multiple tool and structure analysis," which is also hereby incorporated by reference in its entirety for all purposes.

[0025] The illumination system of the certain hardware configurations includes one or more light sources. The light source may generate light having only one wavelength (i.e., monochromatic light), light having a number of discrete wavelengths (i.e., polychromatic light), light having multiple wavelengths (i.e., broadband light) and/or light the sweeps through wavelengths, either continuously or hopping between wavelengths (i.e. tunable sources or swept source). Examples of suitable light sources are: a white light source, an ultraviolet (UV) laser, an arc lamp or an electrode-less lamp, a laser sustained plasma (LSP) source, for example those commercially available from Energetiq Technology, Inc., Woburn, Massachusetts, a super-continuum source (such as a broadband laser source) such as those commercially available from NKT Photonics Inc., Morganville, New Jersey, or shorter-wavelength sources such as x-ray sources, extreme UV sources, or some combination thereof. The light source may also be configured to provide light having sufficient brightness, which in some cases may be a brightness greater than about $1 \text{ W}/(\text{nm cm}^2 \text{ Sr})$. The metrology system may also include a fast feedback to the light source for stabilizing its power and wavelength. Output of the light source can be delivered via free-space propagation, or in some cases delivered via optical fiber or light guide of any type.

[0026] The metrology tool is designed to make many different types of measurements related to semiconductor manufacturing. Certain embodiments may be applicable to such measurements. For example, in certain embodiments the tool may measure characteristics of one or more targets, such as critical dimensions, overlay, sidewall angles, film thicknesses, process-related parameters (e.g., focus and/or dose). The targets can include certain regions of interest that are periodic in nature, such as for example gratings in a memory die. Targets can include multiple layers (or films) whose thicknesses can be measured by the metrology tool. Targets can include target designs placed (or already existing) on the semiconductor wafer for use, e.g., with alignment and/or overlay registration operations. Certain targets can be located at various places on the semiconductor wafer. For example, targets can be located within the scribe lines

(e.g., between dies) and/or located in the die itself. In certain embodiments, multiple targets are measured (at the same time or at differing times) by the same or multiple metrology tools as described in U.S. Patent No. 7,478,019. The data from such measurements may be combined. Data from the metrology tool is used in the semiconductor manufacturing process for example to feed-forward, feed-backward and/or feed-sideways corrections to the process (e.g. lithography, etch) and therefore, might yield a complete process control solution.

[0027] As semiconductor device pattern dimensions continue to shrink, smaller metrology targets are often required. Furthermore, the measurement accuracy and matching to actual device characteristics increase the need for device-like targets as well as in-die and even on-device measurements. Various metrology implementations have been proposed to achieve that goal. For example, focused beam ellipsometry based on primarily reflective optics is one of them and described in the patent by Piwonka-Corle et al. (US 5,608,526, "Focused beam spectroscopic ellipsometry method and system"). Apodizers can be used to mitigate the effects of optical diffraction causing the spread of the illumination spot beyond the size defined by geometric optics. The use of apodizers is described in the patent by Norton, U.S. Patent No. 5,859,424, "Apodizing filter system useful for reducing spot size in optical measurements and other applications". The use of high-numerical-aperture tools with simultaneous multiple angle-of-incidence illumination is another way to achieve small-target capability. This technique is described, e.g. in the patent by Opsal et al, U.S. Patent No. 6,429,943, "Critical dimension analysis with simultaneous multiple angle of incidence measurements".

[0028] Other measurement examples may include measuring the composition of one or more layers of the semiconductor stack, measuring certain defects on (or within) the wafer, and measuring the amount of photolithographic radiation exposed to the wafer. In some cases, metrology tool and algorithm may be configured for measuring non-periodic targets, see e.g. "The Finite Element Method for Full Wave Electromagnetic Simulations in CD Metrology Using Scatterometry" by P. Jiang et al (pending U.S. Patent Application No. 14/294,540, filed June 3, 2014, attorney docket no. P0463) or "Method of electromagnetic modeling of finite structures and finite illumination for metrology and

inspection” by A. Kuznetsov et al. (pending U.S. Patent Application No. 14/170,150, attorney docket no. P0482).

[0029] Measurement of parameters of interest usually involves a number of algorithms. For example, optical interaction of the incident beam with the sample is modeled using EM (electro-magnetic) solver and uses such algorithms as RCWA, FEM, method of moments, surface integral method, volume integral method, FDTD, and others. The target of interest is usually modeled (parameterized) using a geometric engine, or in some cases, process modeling engine or a combination of both. The use of process modeling is described in “Method for integrated use of model-based metrology and a process model,” by A. Kuznetsov et al. (pending U.S. Patent Application No. 14/107,850, attorney docket no. P4025). A geometric engine is implemented, for example, in AcuShape software product of KLA-Tencor.

[0030] Collected data can be analyzed by a number of data fitting and optimization techniques and technologies including libraries, Fast-reduced-order models; regression; machine-learning algorithms such as neural networks, support-vector machines (SVM); dimensionality-reduction algorithms such as, e.g., PCA (principal component analysis), ICA (independent component analysis), LLE (local-linear embedding); sparse representation such as Fourier or wavelet transform; Kalman filter; algorithms to promote matching from same or different tool types, and others.

[0031] Collected data can also be analyzed by algorithms that do not include modeling, optimization and/or fitting e.g. U.S. Patent Application No. 14/057,827.

[0032] Computational algorithms are usually optimized for metrology applications with one or more approaches being used such as design and implementation of computational hardware, parallelization, distribution of computation, load-balancing, multi-service support, dynamic load optimization, etc. Different implementations of algorithms can be done in firmware, software, FPGA, programmable optics components, etc.

[0033] The data analysis and fitting steps usually pursue one or more of the following goals:

[0034] Measurement of CD, SWA, shape, stress, composition, films, band-gap, electrical properties, focus/dose, overlay, generating process parameters (e.g., resist state, partial pressure, temperature, focusing model), and/or any combination thereof;

[0035] Modeling and/or design of metrology systems;

[0036] Modeling, design, and/or optimization of metrology targets.

[0037] Figure 2 illustrates a method 200 for providing a humidity-controlled environment in which to perform optical contacting, in accordance with an embodiment. As shown in operation 202, an environment having a substantially ambient temperature is created. The environment may be created using a clean room, glove box, bench, chamber, etc. Thus, the environment may be any area within an enclosure that is of sufficient size to perform optical contacting.

[0038] In addition, the environment has a substantially ambient temperature, such that the temperature of the environment is not necessarily controlled (i.e. to be higher or lower than the ambient temperature). In this way, the optical contacting performed within the environment, as described in further detail below, may be a process that is not dependent on any particular requirement that a temperature of the environment be controlled.

[0039] As shown in operation 204, a humidity level of the environment is controlled by flowing an inert gas through the environment. The inert gas may be dry air, argon, nitron gas, or any other inert gas capable of being flowed through the environment to control the humidity level of the environment. In one embodiment, controlling the humidity level of the environment may include maintaining the humidity level at or below a predefined relative humidity. It has been found that maintaining the humidity level at or below ($\leq$) 30% relative humidity may be optimal for optical contacting.

[0040] It should be noted that the inert gas may be flowed through the environment in any desired manner that allows the humidity level of the environment to be controlled. Just by way of example, the inert gas may flow through the environment using at least one pair of access points to the environment. In this example, the inert gas may enter the environment using a first access point of the pair of access points and may escape the environment using a second access point of the pair of access points. These access points may be, in one embodiment, openings in an enclosure for the environment to which tubes through which the inert gas is flowed are sealably coupled. Moreover, the flow of the inert gas may be directed using a vacuum or other method of pushing or pulling the inert gas through the environment.

[0041] As an option, the humidity level of the environment may also be monitored. For example, a humidity level gauge may be included within the enclosure for the environment to measure the humidity level of the environment. The humidity level of the environment may then be controlled in accordance with the monitoring, particularly by adjusting the flow of the inert gas through the environment as desired. Thus, greater flow of the inert gas through the environment may be provided when required to maintain the humidity level below a particular relative humidity.

[0042] As a further option, a control device (e.g. with a computer processor, logic, etc.) may be in communication with both the humidity level gauge and a source from which the inert gas is provided to the environment. The control device may accordingly receive or read a humidity level measurement from the humidity level gauge and may then control the flow of the inert gas through the environment (e.g. in an automated manner, etc.) based on the measured humidity level.

[0043] Within the humidity-controlled environment, a plurality of sub-components are then optically contacted to form an optical component, as shown in operation **206**. In other words, an optical contacting process is performed. Particularly, a surface of each of the sub-components is contacted within the humidity-controlled environment such that the surfaces are bonded to form the optical component. The surface material of each of the sub-components may be MgF₂ (Magnesium fluoride), Quartz, or CaF₂ (Calcium

fluoride), for example, such that the sub-components may be prisms, synthetic or non-synthetic quartz lenses, etc. Further, the optical component formed by contacting the sub-components may be a Rochon prism, Nomarski prism, Nicol prism, Glan-Thompson prism, Glan-Foucoult prism, senarmont prism, beam splitters, etc. The optical component may then be implemented in an inspection system, review system, metrology system, etc.

[0044] By performing the optical contacting process described above within the humidity-controlled environment, water may not be absorbed on the sub-component surfaces during contact thus avoiding moisture within the formed optical component, and further no delamination may appear when exposing the optical component to broadband light sources with output in the DUV to VUV wavelength range.

[0045] Figure 3 illustrates an apparatus **300** providing a humidity-controlled environment in which to perform optical contacting, in accordance with another embodiment. It should be noted that the aforementioned definitions may equally apply to the description below.

[0046] In the embodiment shown, the apparatus **300** includes a glove box **301** within which an environment is provided for performing an optical contacting process. However, as mentioned above, the environment may also be similarly provided using other known types of enclosures (e.g. clean room, bench, chamber, etc.). Within the glove box **301**, the environment is of a substantially ambient temperature.

[0047] The apparatus **300** also includes two access points **302** and **304** connected to the glove box **301** for flowing an inert gas through the glove box **301** to control a humidity level of the environment. The two access points **302** and **304**, as shown, are tubes that are connected to the glove box **301** at opposite ends. A seal exists between each of the access points **302** and **304** and the glove box **301** to prevent the inert gas from escaping at the point of contact between the access point **302**, **304** and the glove box **301**.

[0048] The inert gas enters the glove box **301** using a first access point **302** and then escapes the glove box **301** through a second access point **304**. While the access points **302** and **304** are shown as tubes, it should be noted that other forms of a flow-through

device are contemplated which allow for the inert gas to be flowed through the glove box **301** to control the humidity level of the environment within the glove box **301**. In one embodiment, the humidity level of the environment may be controlled by being maintained at or below 30% relative humidity

[0049] The apparatus **300** further includes one or more tools (not shown) for optically contacting, within the humidity-controlled environment, a plurality of sub-components to form an optical component. These tools are any that are well known in the art for use in performing an optical contacting process.

[0050] Strictly as an option, the apparatus **300** may include a monitoring device **306** for monitoring the humidity level of the environment. The monitoring device **306** may continuously monitor and optionally display the humidity level of the environment. As a further option, the apparatus **300** may include, or be coupled to, a control device (not shown) to adjust the flow of the inert gas through the environment, based on the monitoring. Accordingly, the control device may receive or read from the monitoring device **306** a current humidity level of the environment and may be coupled to a source of the inert gas for adjusting, as desired, the flow (e.g. strength, etc.) of the inert gas flowing through the environment.

[0051] While various embodiments have been described above, it should be understood that they have been presented by way of example only, and not limitation. Thus, the breadth and scope of a preferred embodiment should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

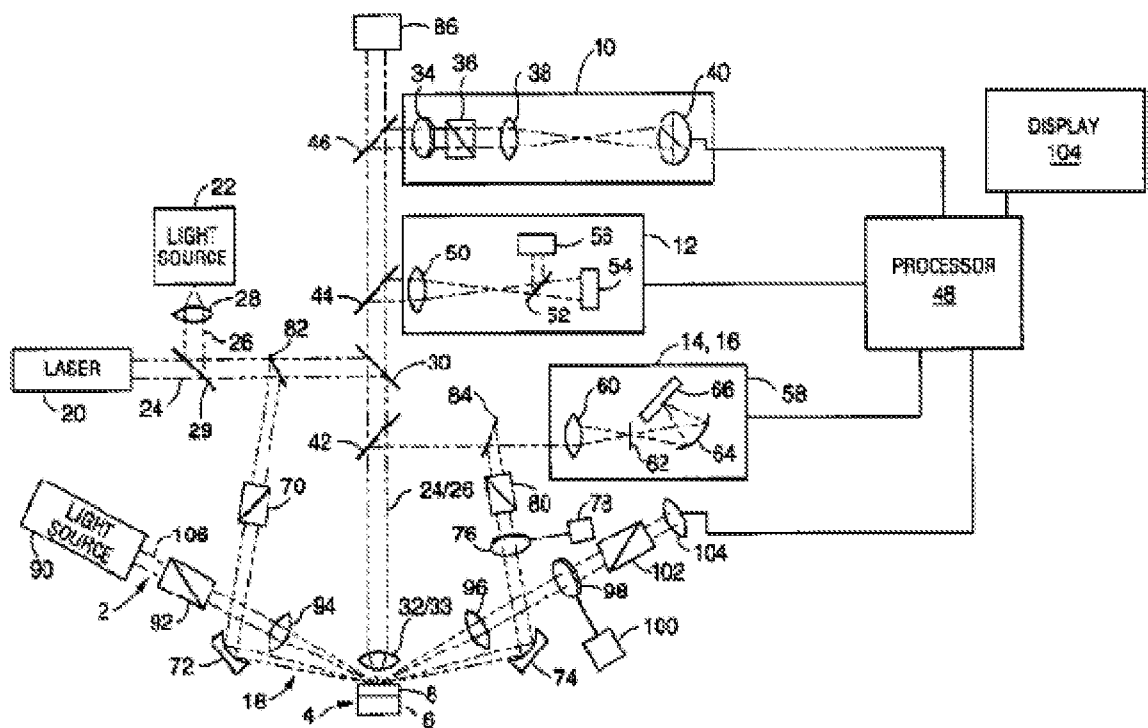
CLAIMS

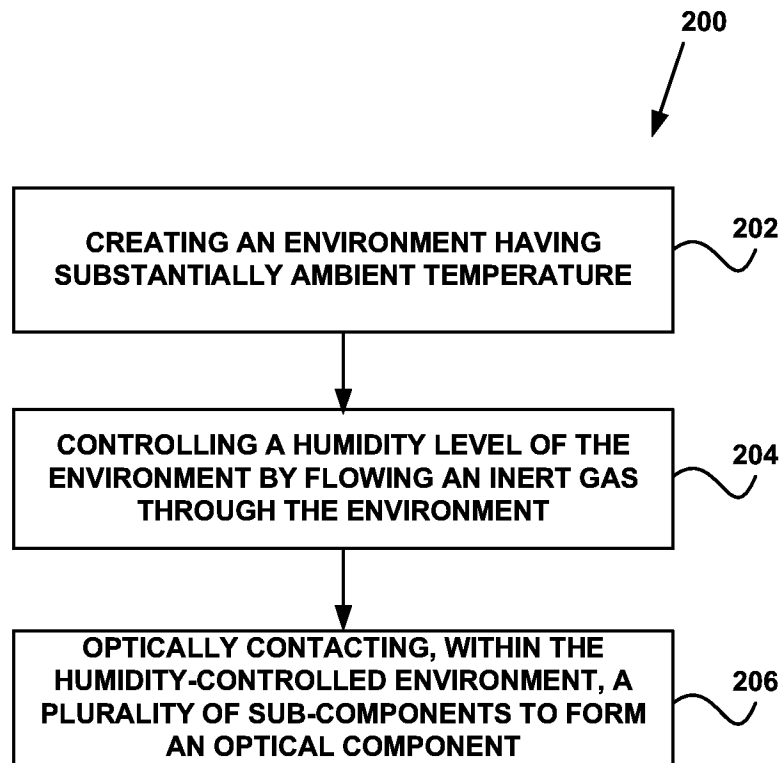
What is claimed is

1. A method, comprising:
creating an environment having a substantially ambient temperature;
controlling a humidity level of the environment by flowing an inert gas through the environment; and
optically contacting, within the humidity-controlled environment, a plurality of sub-components to form an optical component.
2. The method of claim 1, wherein the environment is created using a clean room.
3. The method of claim 1, wherein the environment is created using a glove box.
4. The method of claim 1, wherein the environment is created using a bench.
5. The method of claim 1, wherein the environment is created using a chamber.
6. The method of claim 1, wherein the inert gas flows through the environment using at least one pair of access points to the environment.
7. The method of claim 6, wherein the inert gas enters the environment using a first access point of the pair of access points and escapes the environment using a second access point of the pair of access points.
8. The method of claim 1, further comprising monitoring the humidity level of the environment.

9. The method of claim 8, wherein controlling the humidity level of the environment includes adjusting the flow of the inert gas through the environment, based on the monitoring.
10. The method of claim 1, wherein the humidity level of the environment is controlled by being maintained at or below 30% relative humidity.
11. An apparatus, comprising:
an enclosure within which an environment is provided that is of a substantially ambient temperature;
a flow-through device connected to the enclosure for flowing an inert gas through the enclosure to control a humidity level of the environment; and
one or more tools for optically contacting, within the humidity-controlled environment, a plurality of sub-components to form an optical component.
12. The apparatus of claim 11, wherein the enclosure is a clean room.
13. The apparatus of claim 11, wherein the enclosure is a glove box.
14. The apparatus of claim 11, wherein the enclosure is a bench.
15. The apparatus of claim 11, wherein the enclosure is a chamber.
16. The apparatus of claim 1, wherein the flow-through device includes at least one pair of access points to the enclosure.
17. The apparatus of claim 16, wherein the inert gas enters the enclosure using a first access point of the pair of access points and escapes the enclosure using a second access point of the pair of access points.

18. The apparatus of claim 11, further comprising a monitoring device for monitoring the humidity level of the environment.
19. The apparatus of claim 18, further comprising a control device to adjust the flow of the inert gas through the environment, based on the monitoring.
20. The apparatus of claim 11, wherein the humidity level of the environment is controlled by being maintained at or below 30% relative humidity.

*Fig. 1*

*Fig. 2*

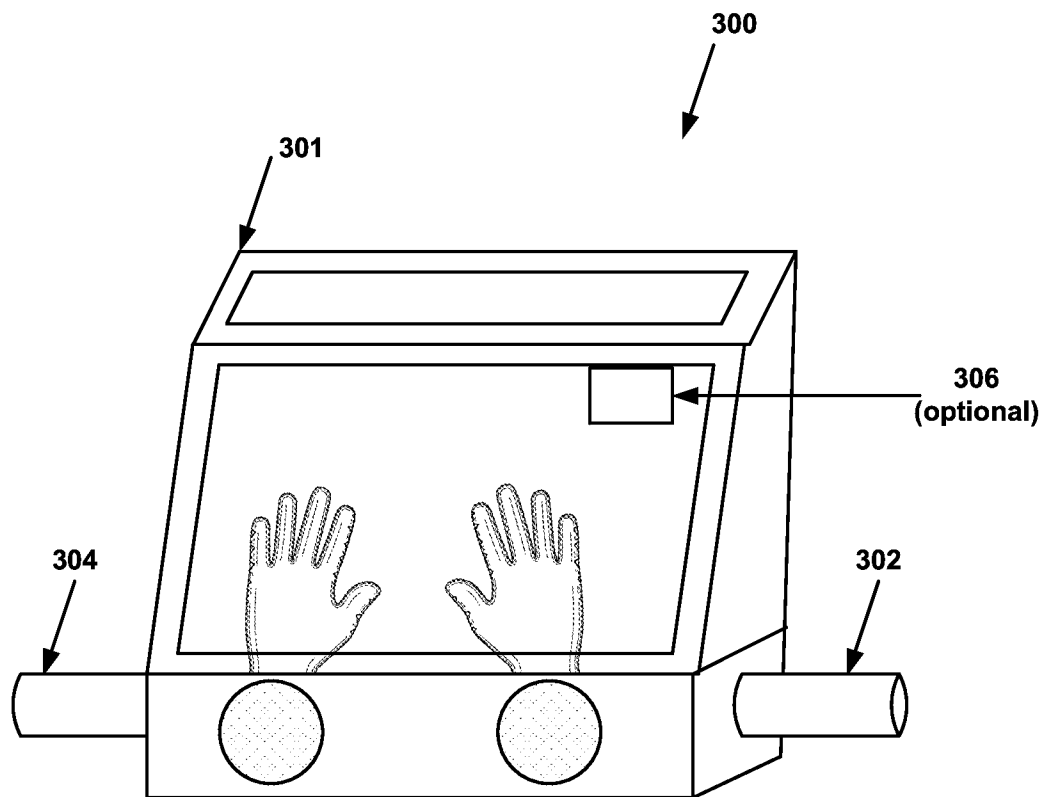


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.
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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 7/20; H01S 3/10; B32B 3/00; B32B 31/00; B32B 3/26; G02B 7/00; G02B 7/02; B32B 9/04; C30B 33/00

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: optical contacting, ambient temperature, control, humidity, inert gas

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2003-075698 A (KONICA CORP.) 12 March 2003 See paragraphs [0022]-[0035] and figures 1(a)-5(b).	1-20
Y	US 2010-0215890 A1 (HUAI-CHUAN LEE et al.) 26 August 2010 See paragraphs [0053], [0056]-[0065] and figure 1.	1-20
A	US 2010-0272964 A1 (NICK TRAGGIS et al.) 28 October 2010 See paragraphs [0028]-[0076] and figures 2-3.	1-20
A	US 5846638 A (HELMUTH E. MEISSNER) 08 December 1998 See column 9, line 27 - column 11, line 41 and figures 1A-1C.	1-20
A	US 2004-0218641 A1 (GREGORY J. MIZELL) 04 November 2004 See paragraphs [0020]-[0023] and figures 1-2.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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