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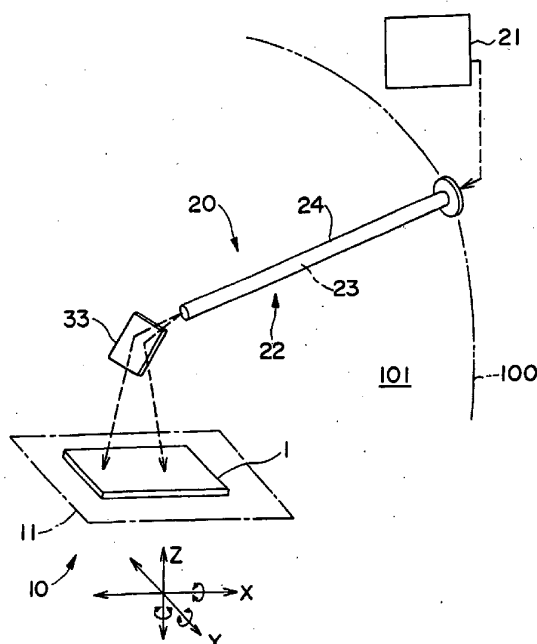
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(54) **LASER HEATER**

(57) A laser heating apparatus (20) for heating a thin film forming substrate (1) in a thin film manufacturing process is disclosed. The substrate (1) set in position in a vacuum chamber (101) of a film forming apparatus (100) is irradiated with a laser light and is thereby heated to a desired temperature. The laser light is guided to a region of the substrate (1) by means of an optical fiber

(23), and the laser beams emanating from the outlet end of the optical fiber (23) is incident directly or indirectly via a reflecting mirror (33) on the substrate (1). The optical fiber (23) is sheathed with a jacket tube (24) whose interior is vacuum drawn. Using a laser light enables the arrangement to be used even in an oxidizing atmosphere and even an insulating substrate to be heated.

FIG. 1



DescriptionTechnical Field

[0001] This invention relates to a laser heating apparatus for heating a thin film forming substrate to an elevated temperature in a thin film manufacturing process.

Background Art

[0002] In the case of forming a thin film on a semiconductor wafer and, inter alia, forming an oxide film on a substrate in a vacuum film forming apparatus designed to cause such a thin film to epitaxially grow, oxygen gas is introduced into a vacuum chamber of the film forming apparatus and is brought under a pressure of 10^{-2} to 10^{-4} Torr. Also by heating the substrate to an elevated temperature, adjustment is made of film forming conditions.

[0003] To precisely position the substrate while heating it in such vacuum film forming apparatus in a manner as mentioned above, it has been the conventional practice that a small, electrically energizable heater is placed in a substrate setting area on a specimen precision mounting table (such as goniometer). Then, by energizing the heater with electric current to cause it to emit heat, the substrate is indirectly heated with heat so emitted.

[0004] As an alternative, a method has also been known that draws electric current directly through the substrate fixed on the specimen mounting table, thereby causing the substrate itself to emit heat.

[0005] In such conventional apparatus, however, especially of the type using the small heater, the maximum attainable heating temperature is limited up to as low as 800°C . Then, efficient heating cannot be achieved, and it is not necessarily easy to establish desired film forming conditions. In addition, there always exists the likelihood for the heater to burn off, making its use in an oxidizing atmosphere impossible. Also, the method of flowing current through the specimen substrate is only applicable to those substrates such as silicon substrates that can carry electric current, and must therefore have limited applicability.

[0006] Moreover, both of these methods or apparatus mentioned above requires heating by direct or indirect application of an electric current, which necessarily causes a magnetic field to build up. Such occurrence of a magnetic field gives rise to problems, when using an analysis that involves an analysis by using a low energy ion or electron beam, such as of affecting the precision of analysis by the magnetic field causing the traveling beam to deflect.

[0007] It is accordingly an object of the present invention to provide a laser heating apparatus that is capable of efficiently and properly heating a specimen substrate in a vacuum apparatus.

Disclosure of the Invention

[0008] In order to achieve the object mentioned above, there is provided in accordance with the present invention, a laser heating arrangement or apparatus for heating a thin film forming substrate, characterized in that a thin film forming substrate set in position in a vacuum chamber of a film forming apparatus is irradiated with a laser light so as to be heated to a predetermined temperature.

[0009] The apparatus mentioned above allows a substrate to be heated to and at a high temperature in an extremely short period of time. Further, using a laser light as means for heating the substrate permits the apparatus to be used even in an oxidizing atmosphere and also even an insulating substrate to be effectively heated. Also, freeing a heat source in a region of the substrate from current passage prevents generation of a magnetic noise and allows analysis using a low energy charged particle beam to be conducted properly.

[0010] Also, in a preferred form of embodiment of the laser heating apparatus according to the present invention, the laser light is guided by means of an optical fiber to a region of the substrate, and the substrate is irradiated directly or indirectly with the laser light arriving from an outlet end of the said optical fiber.

[0011] This specific arrangement permits only the substrate to be selectively heated.

[0012] Also, in a further preferred form of the laser heating apparatus according to the present invention, the said optical fiber is sheathed with a jacket tube whose interior is vacuum drawn or evacuated.

[0013] So constructed, the laser heating apparatus of the present invention can be used with a high vacuum apparatus.

[0014] Further, in another preferred form of the laser heating apparatus according to the present invention, the laser light from the outlet end of the said optical fiber is radiated via a reflecting mirror onto the substrate.

[0015] This specific arrangement permits the position of irradiation with the laser beam to be altered.

[0016] Also, in another preferred form of embodiment of the laser heating apparatus according to the present invention, the laser light is a Nd:YAG laser light.

[0017] This specific arrangement allows the substrate to be heated to and at a high temperature in an extremely short period of time.

[0018] Further, in another specific form of embodiment of the laser heating apparatus, there is included a substrate holder for holding a substrate, the substrate holder having slit orifices formed so as to surround the substrate supported thereby.

[0019] This specific arrangement permits the substrate to be heated efficiently by preventing diffusion of heat and increasing temperature uniformity.

[0020] Also, in another preferred specific form of embodiment of the laser heating apparatus according to the present invention, there is included a substrate holder

for holding a substrate, the substrate holder having an area on which the laser light is incident, and which area is composed of a material that is high in laser light absorbing power.

[0021] This specific arrangement permits the substrate to efficiently absorb the laser light.

[0022] Further, in another preferred specific form of embodiment of the laser heating apparatus according to the present invention, there is included a substrate holder for holding the substrate, the substrate holder having an area on which said laser light is incident, and which area is coated with a material that is a metal oxide or ceramic.

[0023] This specific arrangement makes the substrate holder light in weight and yet causes it to absorb the laser light efficiently to heat the substrate.

[0024] Also, in another preferred specific form of embodiment of the laser heating apparatus according to the present invention, there is included a substrate holder for holding the substrate, the substrate holder having an area on which the laser light is incident, and which area is formed with a thin film that is composed of a material that is high in laser light absorptivity.

[0025] This specific arrangement makes the substrate holder light in weight and yet causes it to absorb the laser light efficiently to heat the substrate.

[0026] Further, in yet another specific form of embodiment of the laser heating apparatus according to the present invention, the said coating or thin film material so that it may not be vaporized is protected by a transparent material.

[0027] This specific arrangement prevents the material that absorbs the laser light from depletion or degradation.

Brief Description of the Drawings

[0028] The present invention will better be understood from the following detailed description and the drawings attached hereto showing certain illustrative forms of embodiment of the present invention. In this connection, it should be noted that such forms of embodiment illustrated in the accompanying drawings hereof are intended in no way to limit the present invention but to facilitate an explanation and understanding thereof.

Fig. 1 is a perspective view diagrammatically illustrating the make-up of a certain form of embodiment of the laser heating apparatus according to the present invention;

Fig. 2 is a cross sectional view illustrating the make-up of an exemplary laser light guidance and radiating means for use in a laser heating arrangement of the present invention;

Fig. 3 is a cross sectional view illustrating a region of the forward end of the laser light guidance and radiating means of the present invention;

Figs. 4A and 4B show one form of embodiment of

the substrate holder according to the present invention in a perspective view of appearance and in a cross sectional view, respectively;

Figs. 5A and 5B show a substrate holder formed with slit orifices in a perspective view of appearance and a cross sectional view, respectively; and

Figs. 6A and 6B show another form of embodiment of the substrate holder in a perspective view of appearance and in a cross sectional view, respectively.

Best Modes for Carrying Out the Invention

[0029] Hereinafter, the present invention will be described in detail with reference to suitable forms of embodiment thereof illustrated in the drawing figures. While the present invention will hereinafter be set forth with respect to certain illustrative forms of embodiments thereof, it will readily be appreciated to be obvious to a person skilled in the art that many alternations thereof, omissions therefrom and additions thereto can be made without departing from the essences of scope of the present invention. Accordingly, it should be understood that the invention is not intended to be limited to the specific forms of embodiment thereof set forth below, but to include all possible forms of embodiment thereof that can be made within the scope with respect to the features specifically set forth in the appended claims and encompasses all the equivalents thereof.

[0030] A detailed description will first be given in respect of a typical form of embodiment of the laser heating arrangement according to the present invention with reference to the drawing figures.

[0031] In this form of embodiment, as illustrated in Fig. 1 a substrate 1 is supported at a preselected location by a substrate supporting mechanism 10, for example in a vacuum chamber 101 of a vacuum film forming apparatus 100. Included in the vacuum film forming apparatus 100 is a laser heater or heating arrangement 20 according to the present invention for high-temperature heating the substrate 1. Also included in the vacuum film forming apparatus is a reactive gas control mechanism (not shown) for introducing an oxygen gas into the vacuum chamber 101 and setting and regulating a gaseous pressure thereof at a preselected level.

[0032] According to the present invention, the substrate 1 set in position in the vacuum chamber 101 of the vacuum film forming apparatus is designed to be irradiated with a laser light so that the substrate 1 is heated to a predetermined temperature.

[0033] More specifically, the laser heating arrangement 20 includes a laser generator 21, and a laser light guidance and radiating means 22 that incorporates an optical fiber to be described below. A laser light produced by the laser generator 21 is guided by means of the optical fiber to a region of the substrate 21, and the laser light from the outlet end of the optical fiber is radiated directly or indirectly onto the substrate 1. In this

form of embodiment illustrated, for the laser generator 21 use is made of a ND: YAG laser generator and for the laser light use is made of a laser light produced thereby.

[0034] Here in the laser light guidance and radiating means 22, as shown in Fig. 2 the optical fiber 23 is advantageously sheathed with a jacket tube 24, advantageously made of stainless steel, whose interior is designed to be vacuum drawn or evacuated. In this case, an outer covering 25 that covers both the optical fiber 23 and the jacket tube 24 is formed with a vacuum drawing orifice 26 near or towards the inlet end of the optical fiber 23. Vacuum drawing orifices 27 (see Fig. 3) and 28 are also formed in the jacket tube 24 at suitable areas thereof over the optical fiber 23 towards its outlet end. The interior of the jacket tube 24 is thus vacuum drawn through these orifices 26, 27 and 28.

[0035] The inlet end of the optical fiber 23 is clamped by a fiber chuck 29, and a tube ferrule 30 is fitted in a fitting bore 31a of a flange 31. The flange 31 is fastened in position to the vacuum chamber 101 by means of a bolt or the like. The laser light from the laser generator 21 is introduced into the inlet end of the optical fiber 23 so attached to and assembled with the vacuum chamber 101.

[0036] Also, the jacket tube 24 at the outlet end side of the optical fiber 23 as shown in Fig. 3 is filled with a ceramic or glass base adhesive 32 around the optical fiber 23. The outlet end of the optical fiber 23 is shaped with a curved surface such that the laser light projecting therefrom may impinge with an appropriate spot diameter on the substrate 1.

[0037] Further, in the form of embodiment illustrated, the laser light outgoing from the outlet end of the optical fiber 23 as shown in Fig. 1 passes through a reflecting mirror 33 and then impinges on the substrate 1. It should be noted, however, that the substrate 1 might be irradiated directly with the laser light from the outlet end of the optical fiber 23 without using the reflecting mirror 33.

[0038] The substrate 1 is supported on a substrate holder 11 of the substrate supporting mechanism 10. According to such substrate supporting mechanism 10, the substrate 1 can be positioned, by means of the substrate holder 11, in three orthogonal axial directions along an X-, a Y- and a Z-axis. In this case, the substrate can also be rotationally positioned about each of the three orthogonal axes, and possibly also so-called "U-centrally". This permits the substrate 1 to be positioned with extremely high positioning accuracy.

[0039] According to a laser heating arrangement 20 of the present invention so constructed as mentioned above, a laser light produced at the laser generator 21 is guided through the optical fiber 23 to a region of the substrate 1, and in the form of embodiment illustrated, indirectly through the reflecting mirror 33 to a region of the substrate 1 for impingement thereon. This substrate heating process, especially using a Nd:YAG laser light, permits a substrate 1 to be heated to and at an elevated

temperature in an extremely short period of time.

[0040] Also, using a laser light allows this heating arrangement to be employed in an oxidizing atmosphere in the vacuum chamber 101, and permits even an electrically insulating substrate to be effectively heated by this arrangement that is not designed to pass electric current therethrough. Further, freeing a heat source in a region of the substrate from current passage prevents generation of any magnetic noise and allows analysis to be conducted properly using a low energy charged particle beam or the like. At the same time, a precision specimen table is brought to realization that is excellent in performance characteristics in which the substrate 1 can be accurately positioned as required by the substrate supporting mechanism 10.

[0041] The above being the case, permitting the interior of the jacket tube 24 sheathing the optical fiber 23 to be adjustably vacuum drawn, coupled with the elaborated way of introducing the laser light into the vacuum chamber 101, provides the ability for the atmospheric pressure to be controllable variably from an extremely high vacuum to an atmospheric pressure.

[0042] Mention is next made of a substrate holder.

[0043] In order to well absorb a ND:YAG laser light of wavelength $\lambda = 1.06\mu\text{m}$, it is desirable that the substrate holder be a metal plate composed of a material having good thermal conductivity such as inconel, nickel or chrome and oxidized at a high temperature.

[0044] Figs. 4A and 4B show a substrate holder in perspective view of appearance and cross sectional view, respectively. In Fig. 4A, the side irradiated with a laser light is shown.

[0045] A substrate holder 41 shown in Figs. 4A and 4B is formed on its side irradiated with the laser light, with a layer of a material such as a metal oxide or ceramic that well absorbs the laser light. The layer of such material that is high in athermanous or heat absorbing efficiency may be provided by coating. While the substrate holder is shown in the form of a disk in Figs. 4A and 4B, it should be noted that the holder may be of any other, preferably symmetrical shape.

[0046] A substrate holder 51 shown in Figs. 5A and 5B has slit orifices 53 so formed as to surround a substrate shown in Fig. 4 and also has a metal oxide layer 56 formed on a portion thereof by oxidizing the portion at a high temperature. Both the orifices and the metal oxide are designed to efficiently heat the substrate.

[0047] A substrate holder formed with slit orifices to surround the substrate may be of a material that is poor in thermal conductivity. While in Figs. 5A and 5B a single substrate is shown, a plurality of substrates may be surrounded by slit orifices. In this case, the slit orifices may be formed so as to surround either each of or more than one substrates.

[0048] Such substrate holders provided with slit orifices prevent escape of a quantity of heat applied to heat the substrate and allows the substrate to be heated efficiently and increases temperature uniformity.

[0049] Also, in order to well absorb a Nd:YAG laser light, a metal foil of oxidized inconel, nickel or chrome may be utilized.

[0050] Figs. 6A and 6B show a substrate holder of an alternative form in perspective view of appearance and cross sectional view, respectively. In Fig. 6A, the side is shown that is irradiated with a laser light.

[0051] Referring to Figs. 6A and 6B, the alternative substrate holder 61 has a bore 63 formed with a stepped portion in which a sapphire (disk) 65 is placed in contact therewith. Then, a metal foil 67, for example, of inconel oxidized at a high temperature is sandwiched between the sapphire 65 and a substrate 5, and a fixture 69 is used to fasten the substrate 5 to the substrate holder 61. While in this form of embodiment the sapphire 65 is used to enclose the light accepting surface of the metal foil so it may not be vaporized by the laser light, it may be of any other transparent material that can withstand heating by the laser light.

[0052] A substrate holder so constructed as mentioned is light in weight, can well absorb a laser light and reduces to minimum the amount of heat escaping from the heated metal foil.

[0053] Such a substrate holder therefore permits a substrate to be efficiently heated and increases temperature uniformity.

[0054] In the forms of embodiment described, the laser medium is not limited to a solid state laser such a Nd:YAG laser but may be liquid, gas or semiconductor laser.

Industrial Applicability

[0055] As has been set forth in the foregoing description, a laser heating apparatus according to the present invention is provided in which for heating a substrate in a vacuum chamber, use is made of a laser light. A heating apparatus is therefore provided that can be used in an oxidizing atmosphere and that can be employed to effectively heat even an insulating substrate.

[0056] A heating apparatus is accordingly provided that has an extended range of applications, that is free from creating a magnetic noise and that ensures accurate analysis results.

[0057] A laser heating apparatus of the present invention is accordingly highly useful as means for heating a specimen both efficiently and properly.

Claims

1. A laser heating apparatus for heating thin film forming substrates, characterized in that a thin film forming substrate set in position in a vacuum chamber of a film forming apparatus is irradiated with a laser light so as to be heated to a predetermined temperature.

2. A laser heating apparatus as set forth in claim 1, characterized in that the laser light is guided by means of an optical fiber to a region of said substrate, and said substrate is irradiated directly or indirectly with the laser light arriving from an outlet end of said optical fiber.

3. A laser heating apparatus as set forth in claim 2, characterized in that said optical fiber is sheathed with a jacket tube whose interior is vacuum drawn.

4. A laser heating apparatus as set forth in claim 2 or claim 3, characterized in that the laser light from the outlet end of said optical fiber is radiated via a reflecting mirror onto said substrate.

5. A laser heating apparatus as set forth in any one of claims 1 to 4, characterized in that said laser light is a Nd:YAG laser light.

6. A laser heating apparatus as set forth in any one of claims 1 to 6, characterized in that there is included a substrate holder for holding said substrate, the substrate holder having slit orifices formed so as to surround said substrate supported thereby.

7. A laser heating apparatus as set forth in any one of claims 1 to 6, characterized in that there is included a substrate holder for holding said substrate, the substrate holder having an area on which said laser light is incident, and which area is composed of a material that is high in laser light absorbing power.

8. A laser heating apparatus as set forth in any one of claims 1 to 7, characterized in that there is included a substrate holder for holding said substrate, the substrate holder having an area on which said laser light is incident, and which area is coated with a material that is a metal oxide or ceramic.

9. A laser heating apparatus as set forth in any one of claims 1 to 6, characterized in that there is included a substrate holder for holding said substrate, the substrate holder having an area on which said laser light is incident, and which area is formed with a thin film that is composed of a material that is high in laser light absorptivity.

10. A laser heating apparatus as set forth in any one of claim 8 or claim 9, characterized in that said coating or thin film material so that it may not be vaporized is protected by a transparent material.

Amended claims in accordance with Rule 86(2) EPC.

1. (Amended) A laser heating apparatus for heating thin film forming substrates, characterized in that a

thin film forming substrate set in place on a substrate supporting mechanism in a vacuum chamber of a film forming apparatus is irradiated with a laser light so as to be heated to a predetermined temperature.

2. (Amended) A laser heating apparatus as set forth in claim 1, characterized in that said substrate supporting mechanism is capable of positioning said substrate in three orthogonal axial directions along an X-, a Y- and a Z-axis, and is also capable of U-centric rotation.

3. (Amended) A laser heating apparatus as set forth in claim 1, characterized in that the laser light is guided by means of an optical fiber to a region of said substrate, and said substrate is irradiated directly or indirectly with the laser light arriving from an outlet end of said optical fiber.

4. (Amended) A laser heating apparatus as set forth in claim 3, characterized in that said optical fiber is sheathed with a jacket tube whose interior is vacuum drawn.

5. (Amended) A laser heating apparatus as set forth in claim 3 or claim 4, characterized in that said optical fiber at an end thereof opposite to its outlet end is fastened to said jacket tube by means of a fiber chuck and is fitted in a fitting bore of a flange and fastened thereto by means of a ferrule.

6. (Amended) A laser heating apparatus as set forth in claim 2 or claim 3, characterized in that the laser light from the outlet end of said optical fiber is radiated via a reflecting mirror onto said substrate.

7. (Amended) A laser heating apparatus as set forth in any one of claims 1 to 6, characterized in that said laser light is a Nd:YAG laser light.

8. (Amended) A laser heating apparatus as set forth in claim 1, characterized in that there is included a substrate holder for holding said substrate, the substrate holder having slit orifices formed so as to surround said substrate supported thereby.

9. (Amended) A laser heating apparatus as set forth in claim 1 or claim 8, characterized in that there is included a substrate holder for holding said substrate, the substrate holder having an area on which said laser light is incident, and which area is composed of a material that is high in laser light absorbing power.

10. (Amended) A laser heating apparatus as set forth in claim 1 or claim 8, characterized in that there is included a substrate holder for holding said sub-

strate, the substrate holder having an area on which said laser light is incident, and which area is coated with a material that is a metal oxide or ceramic.

11. (Added) A laser heating apparatus as set forth in claim 1 or claim 6, characterized in that there is included a substrate holder for holding said substrate, the substrate holder having an area on which said laser light is incident, and which area is formed with a thin film that is composed of a material that is high in laser light absorptivity.

12. (Added) A laser heating apparatus as set forth in any one of claims 8 to 11, characterized in that said coating or thin film material so that it may not be vaporized is protected by a transparent material.

FIG. 1

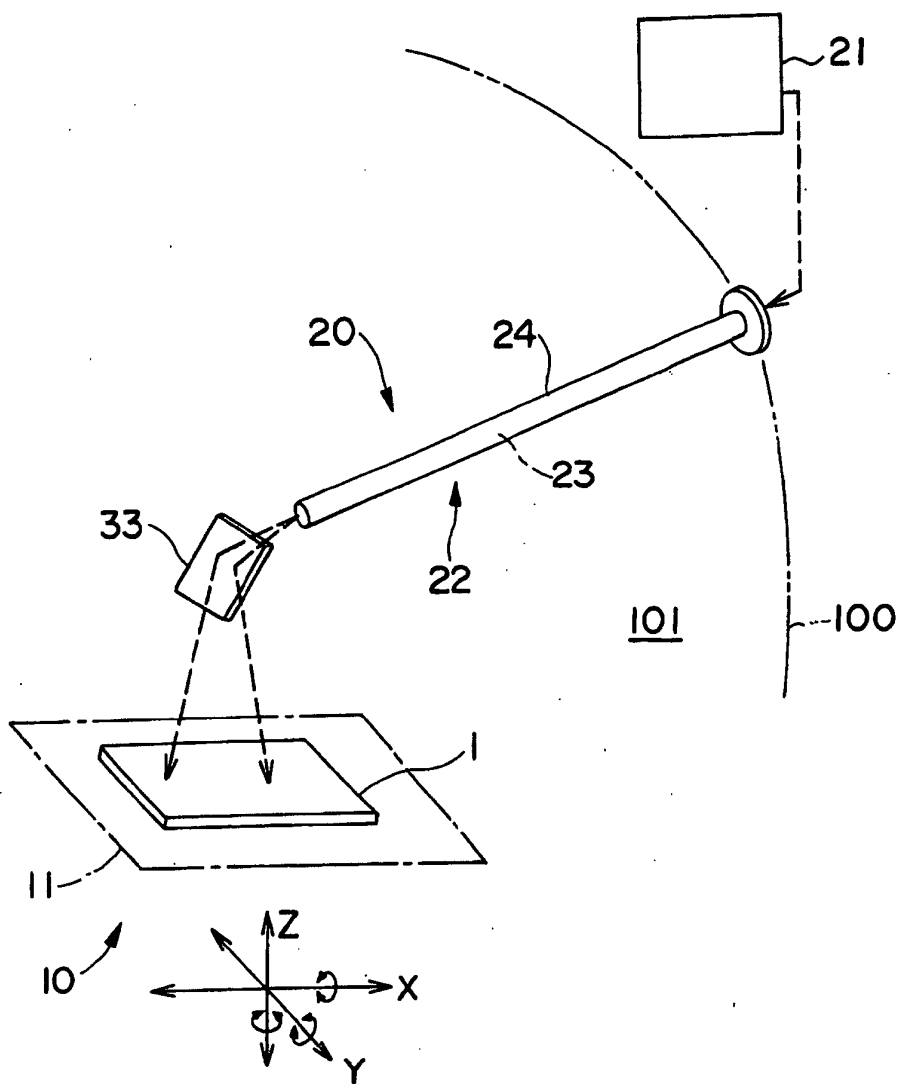


FIG. 2

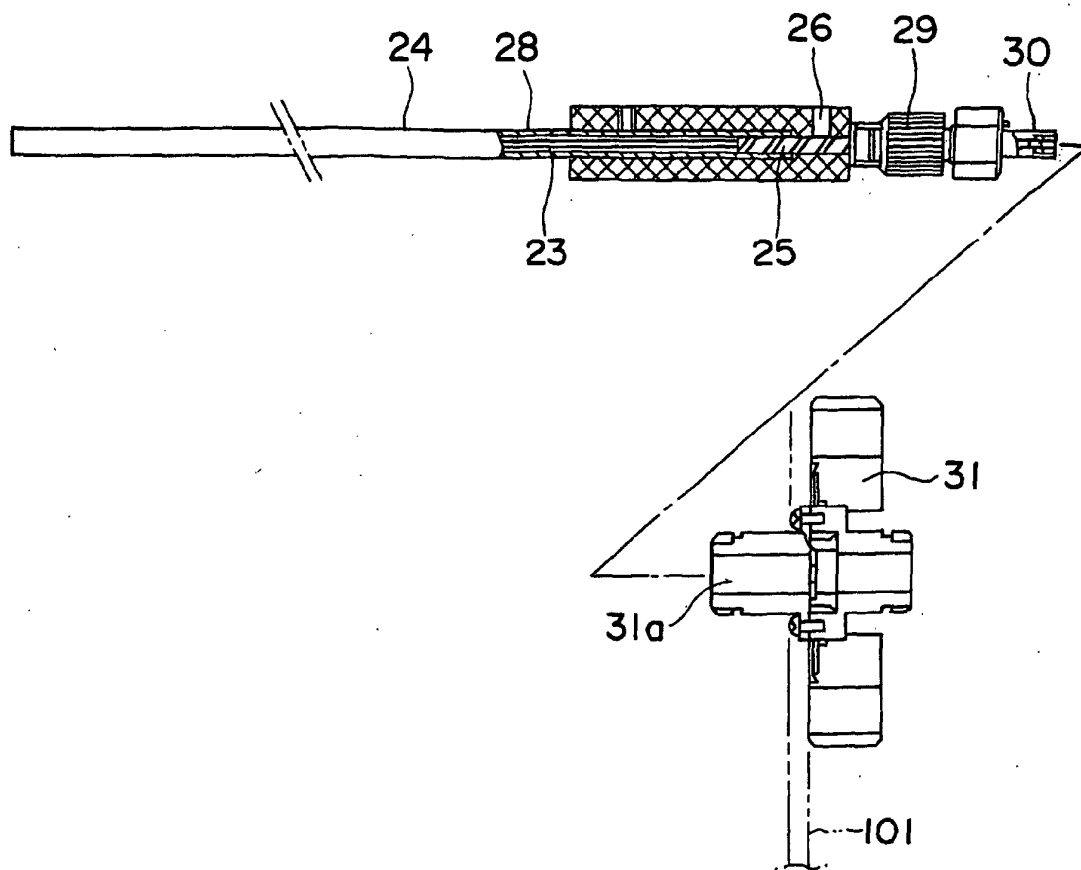


FIG. 3

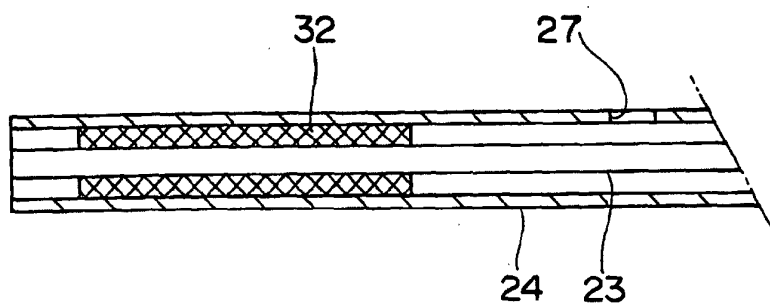


FIG. 4A

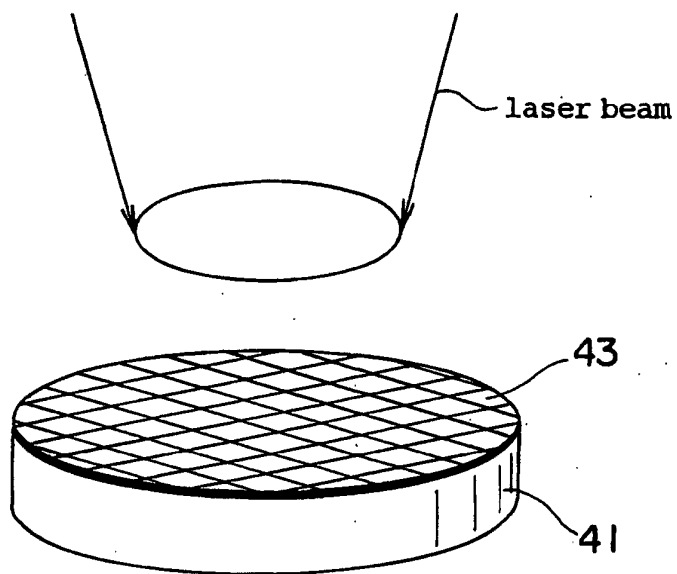


FIG. 4B

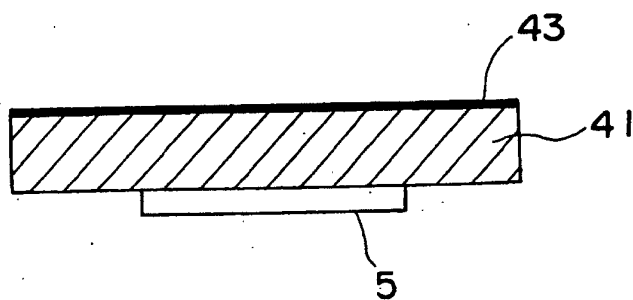


FIG. 5A

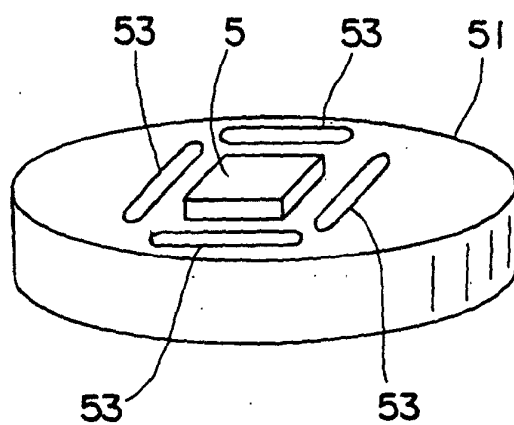


FIG. 5B

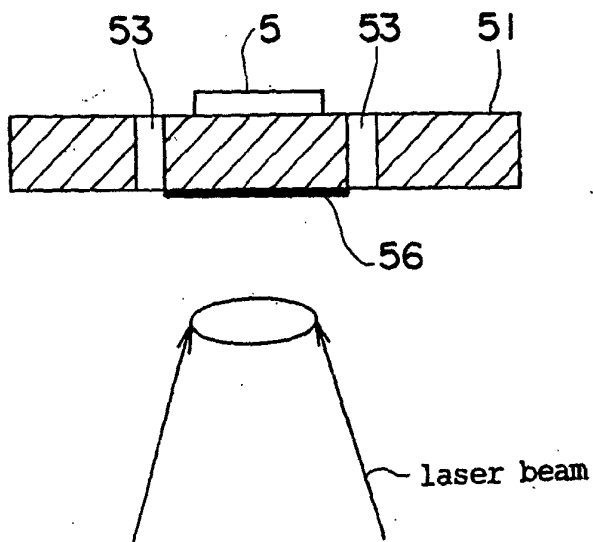


FIG. 6A

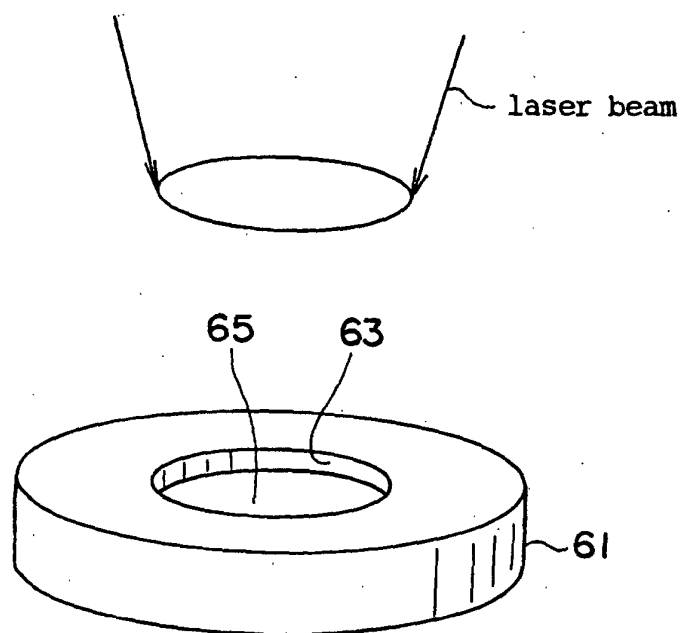
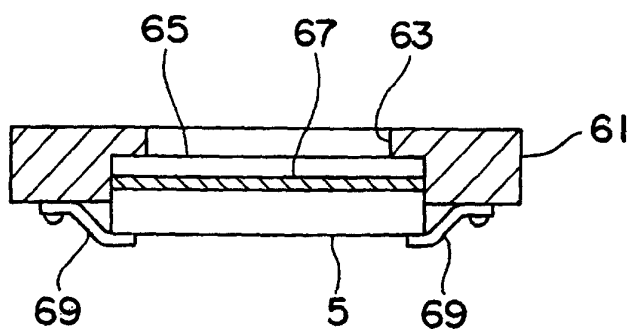


FIG. 6B



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP99/04948

A. CLASSIFICATION OF SUBJECT MATTER Int.Cl. ⁶ C23C14/50		
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) Int.Cl. ⁶ C23C14/00-58, C23C16/00-56, B23K26/00, H01B13/00		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1926-1996 Toroku Jitsuyo Shinan Koho 1994-1999 Kokai Jitsuyo Shinan Koho 1971-1999 Jitsuyo Shinan Toroku Koho 1996-1999		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) JOIS (SUBSTRATE HEATING* [LASER]) WPI/L (C23C-014/50, -014/56)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP, 56-44770, A (Matsushita Electric Ind. Co., Ltd.), 24 April, 1981 (24.04.81) Claim 1, page 3, upper left column, line 19 to upper right column, line 4	1, 5
Y	Page 2, lower left column, lines 1-8 (Family: none)	2-4
X	JP, 8-311651, A (Nisshin Steel Co., Ltd.), 26 November, 1996 (26.11.96) Claims 1, 4,	1, 5
Y	Par. No. [0022] (Family: none)	2-4
X	JP, 2-213075, A (Matsushita Electric Ind. Co., Ltd.) 24 August, 1990 (24.08.90) Claim 1, page 4, lower left column, lines 2-6,	1, 5
Y	Claim 4, page 3, upper left column, lines 10-11 (Family: none)	2-4
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> 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 "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"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 "G" document member of the same patent family	
Date of the actual completion of the international search 07 December, 1999 (07.12.99)	Date of mailing of the international search report 21 December, 1999 (21.12.99)	
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer	
Facsimile No.	Telephone No.	

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP99/04948

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, 3-281074, A (Toshiba Corporation), 11 December, 1991 (11.12.91), Claims (Family: none)	1-10
A	H. Yokoyama, S. Kishida, "Research Material prepared by Study Group on Quantum device of Light, Electricity Society", Vol. OQD-85, No. 65-68 And 70, pages 21-30 (1985)	1-10

Form PCT/ISA/210 (continuation of second sheet) (July 1992)