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(54) **COOLING TECHNIQUE**

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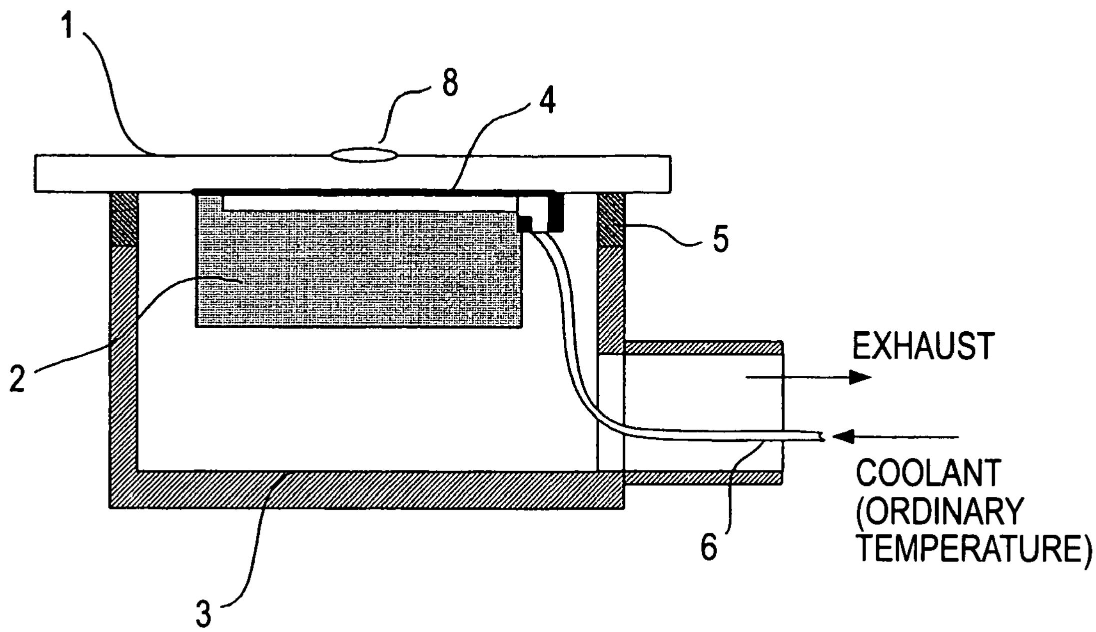
(57) **ABSTRACT**

Disclosed is a positioning apparatus, including a positioning unit, and a temperature adjusting unit which adjusts a temperature of at least a portion of the positioning unit, the temperature adjusting unit including a cooling mechanism based on vaporization heat of a liquid Also disclosed is a cooling apparatus, including a container, a supplying unit which supplies a liquid to the container, and an exhaust unit which exhausts the container.



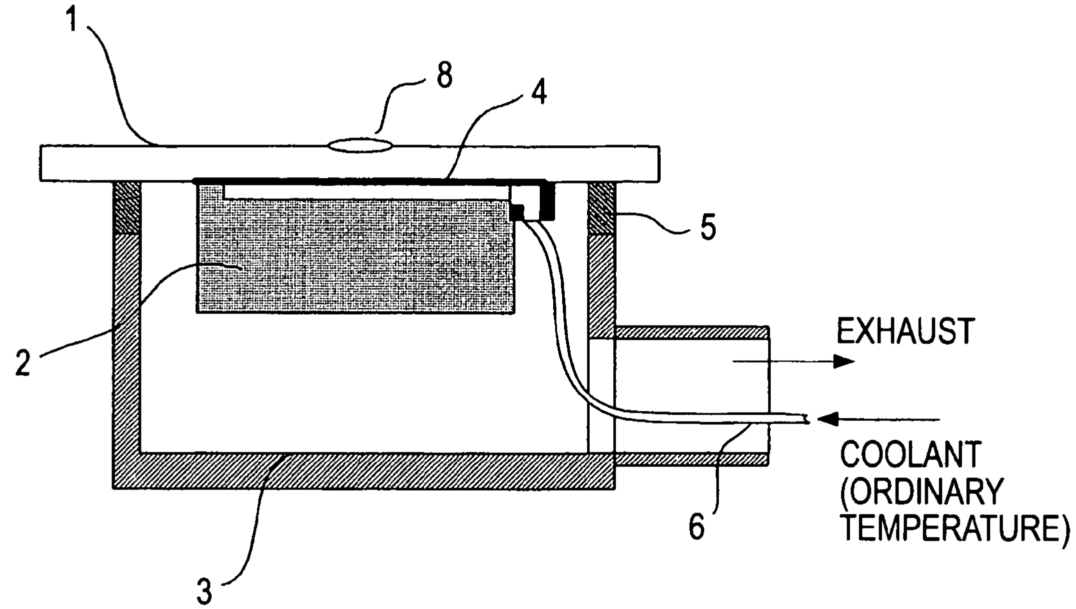
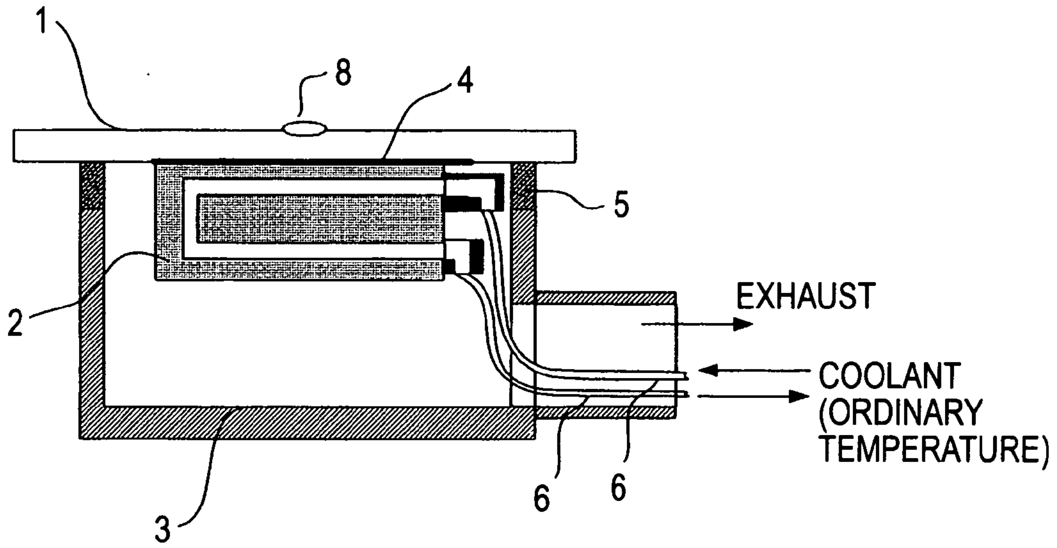

1
8
4
5
EXHAUST
2
COOLANT
(ORDINARY
TEMPERATURE)
6
3

FIG. 1


1
8
4
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EXHAUST
2
COOLANT
(ORDINARY
TEMPERATURE)
6
6
3

FIG. 2

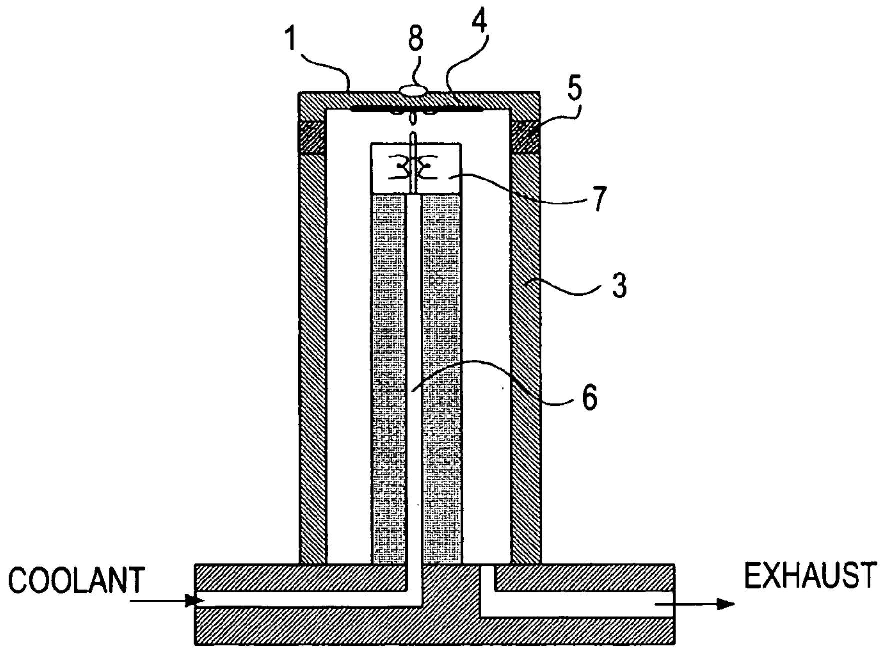
1
8
4
5
7
3
6
COOLANT
EXHAUST

FIG. 3

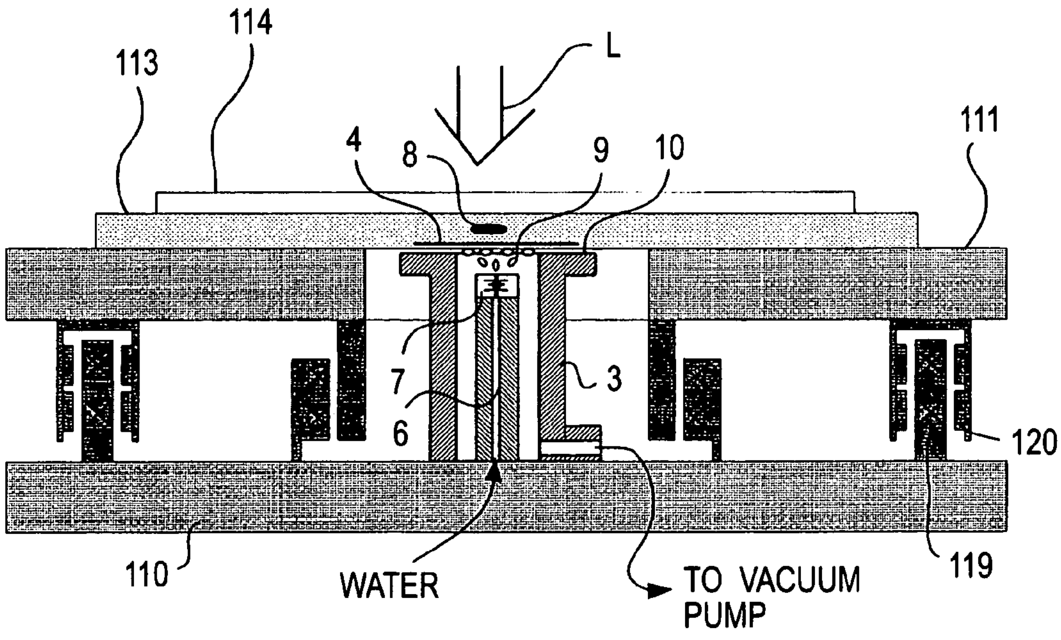
114
113
L
111
4
8
9
10
7
3
7
6
6
120
110
WATER
TO VACUUM
PUMP
119

FIG. 4

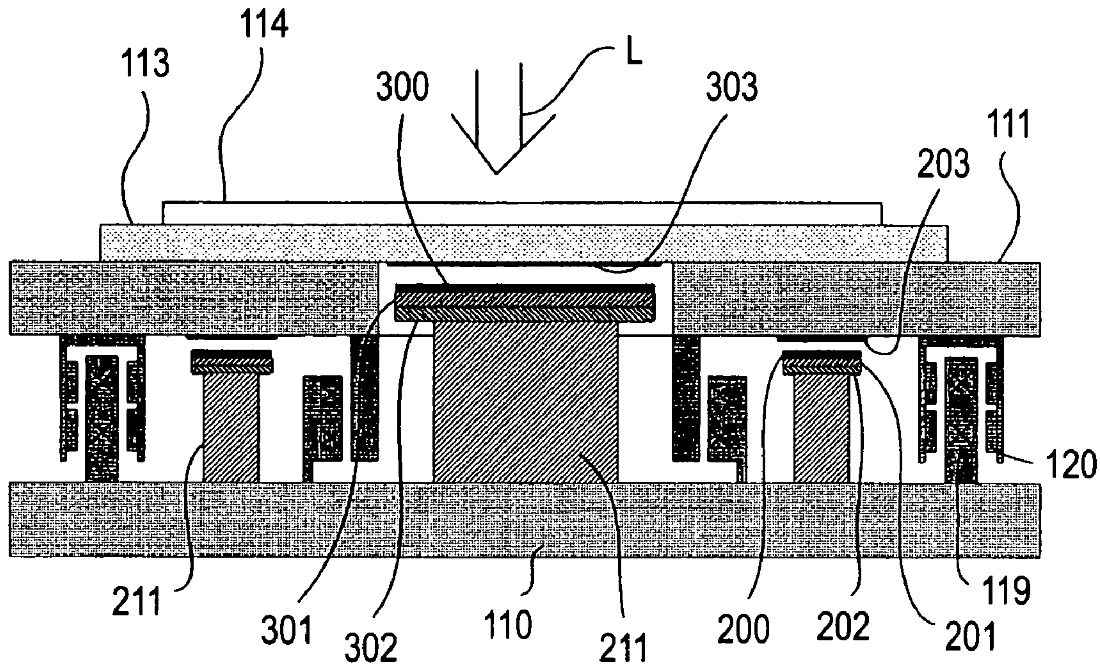
114
113
L
300
303
111
203
120
211
301
302
110
211
200
202
201
119

FIG.5

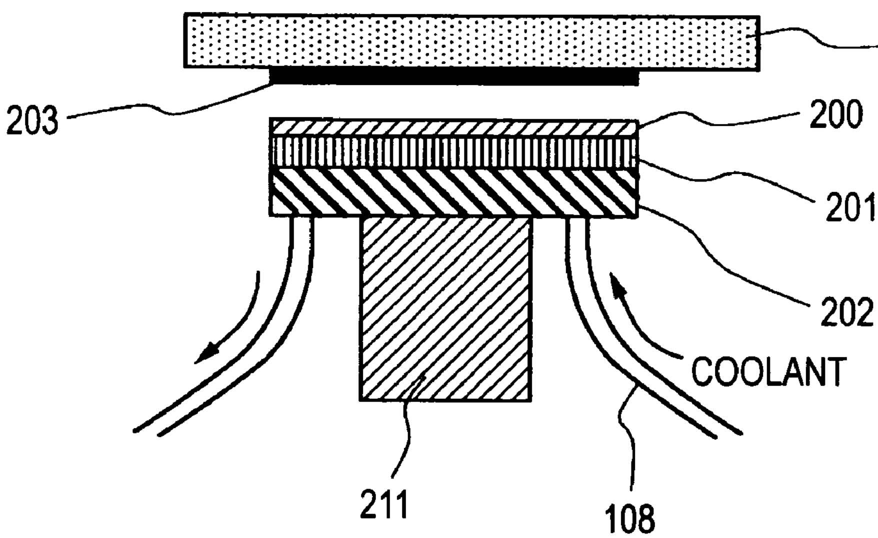
111
203
200
201
202
COOLANT
211
108

FIG.6

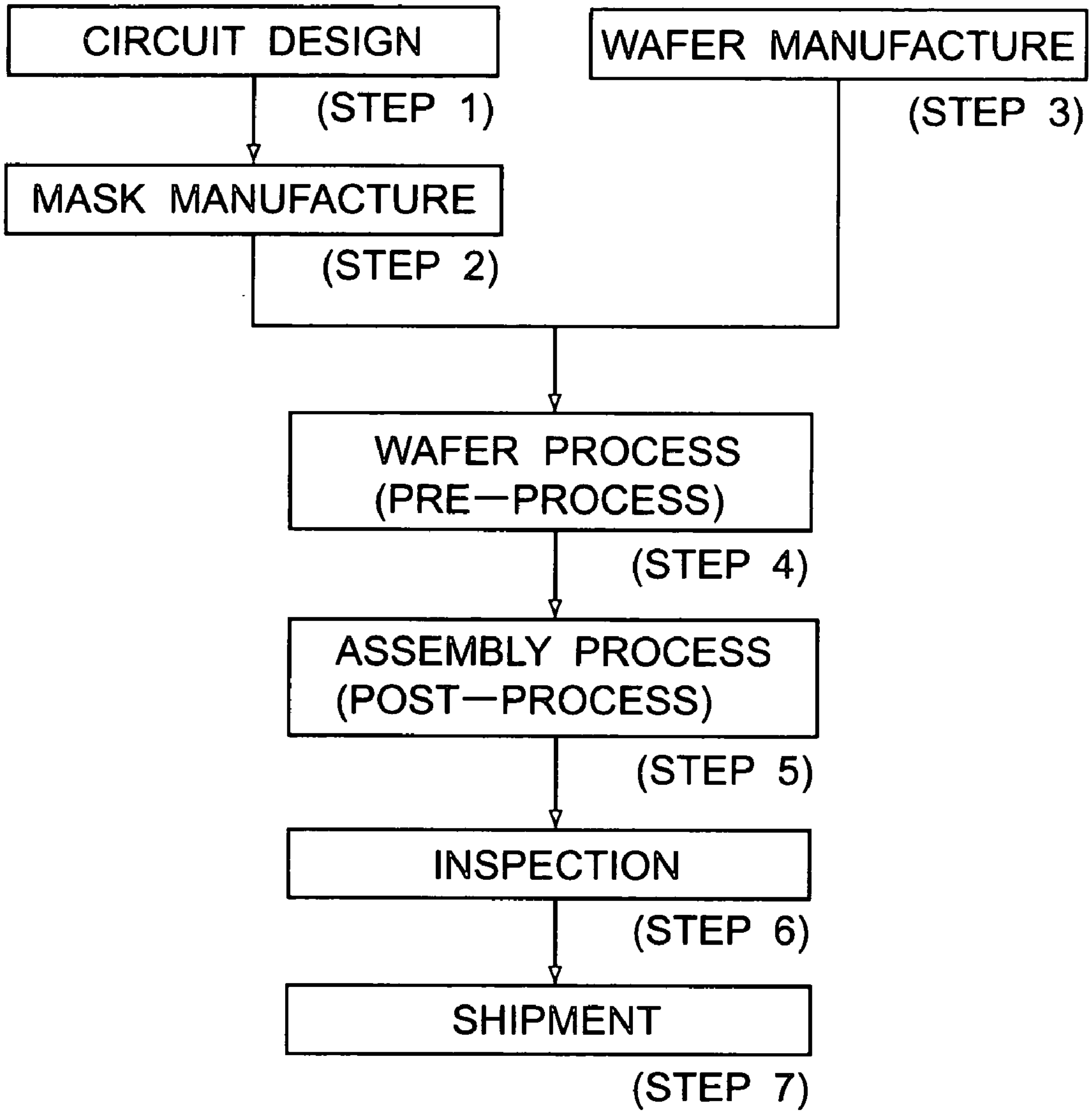
CIRCUIT DESIGN
(STEP 1)
MASK MANUFACTURE
(STEP 2)
WAFER MANUFACTURE
(STEP 3)
WAFER PROCESS
(PRE—PROCESS)
(STEP 4)
ASSEMBLY PROCESS
(POST—PROCESS)
(STEP 5)
INSPECTION
(STEP 6)
SHIPMENT
(STEP 7)

FIG. 7

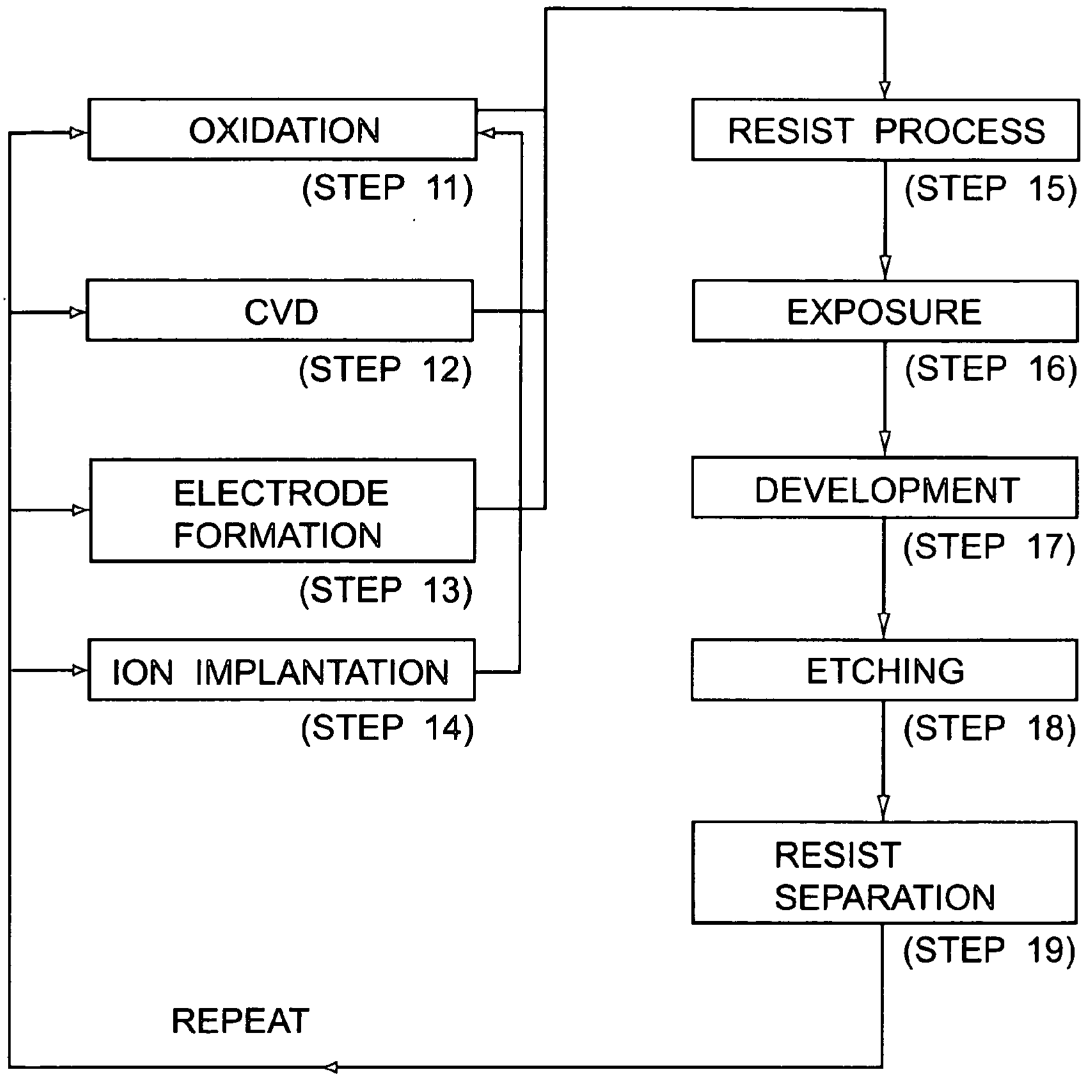
OXIDATION
(STEP 11)
CVD
(STEP 12)
ELECTRODE FORMATION
(STEP 13)
ION IMPLANTATION
(STEP 14)
RESIST PROCESS
(STEP 15)
EXPOSURE
(STEP 16)
DEVELOPMENT
(STEP 17)
ETCHING
(STEP 18)
RESIST SEPARATION
(STEP 19)
REPEAT

FIG. 8

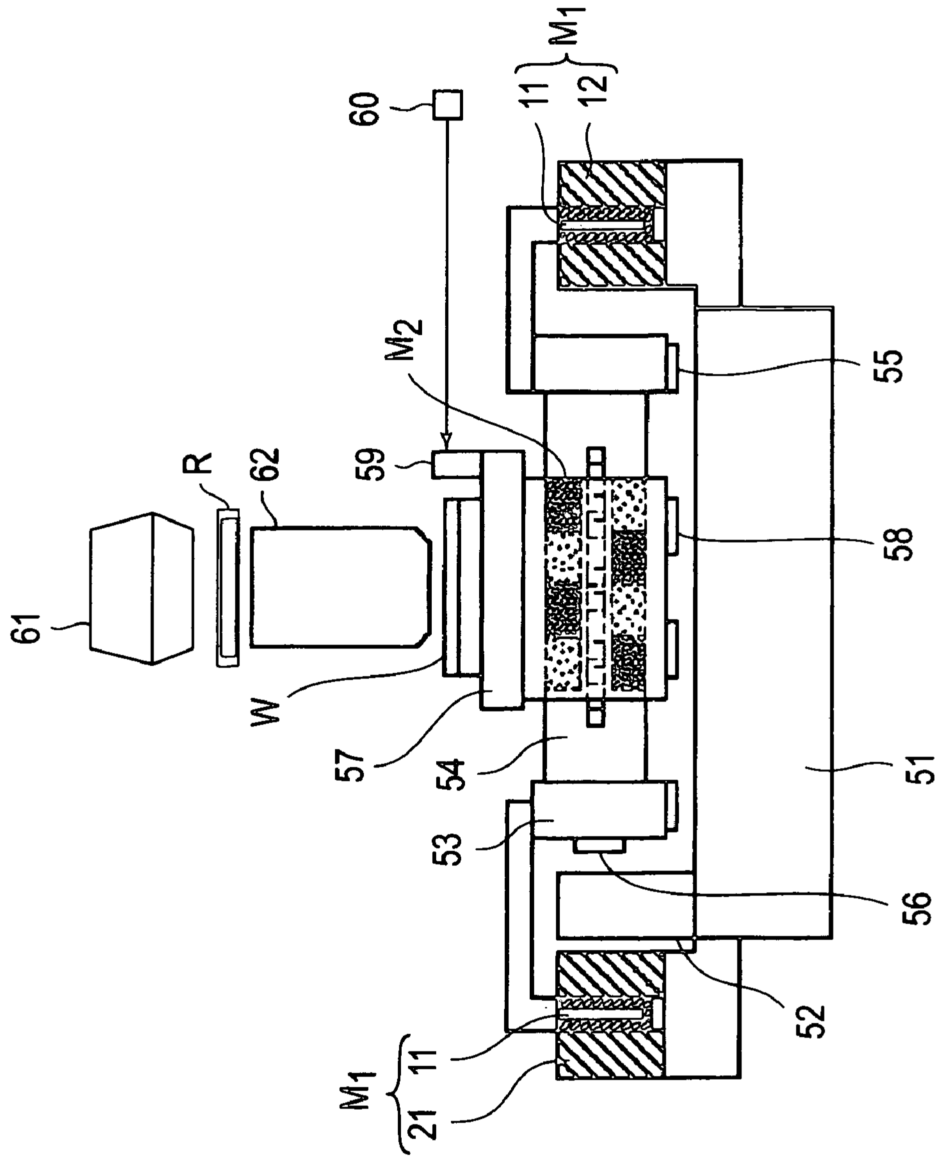

FIG. 9

COOLING TECHNIQUE

FIELD OF THE INVENTION AND RELATED ART

[0001] This invention relates to a cooling technique suitably usable to an exposure apparatus for manufacture of devices such as semiconductor devices having a fine pattern, or to precision measuring devices, for example.

[0002] Referring to **FIGS. 5 and 6**, a structure of a positing device such as disclosed in Japanese Laid-Open Patent Application, Publication No. 2003-58258 will be explained. **FIG. 5** illustrates a positioning device disposed in a vacuum ambience, for performing high-precision positioning, as well as a cooling mechanism therefor. **FIG. 6** shows details of the cooling mechanism.

[0003] In **FIG. 5**, a substrate **114** such as a semiconductor wafer is placed on a chuck **113** which is supported by a top plate **111**. The top plate **111** is floated by non-contact self-weight compensating mechanism (not shown) whose spring characteristic can be almost disregarded. Also, the top plate **111** is positioned without contact, by means of a linear motor (**119**, **120**). With this arrangement, approximately complete vibration insulation is achieved, and high precision positioning is enabled.

[0004] On the other hand, since the substrate **114**, the chuck **113** and the top plate **111** are completely floated in vacuum, there is no escape for exposure heat L flowing into the substrate **114** or for heat generated in the chuck **113**. Thus, use of a cooling mechanism is inevitable. To this end, and in order to cool the chuck **113** and the top plate **111** while keeping the advantages of vibration insulation and of the non-contact supporting drive, radiation plates **300** and **200** being temperature controlled to about 0 to 10° C. are disposed opposed to the respective subjects of cooling (i.e., a heat dissipating plate **303** intimately contacted to the chuck **113**, and a heat dissipating plate **203** intimately contacted the top plate **111**). This enables cooling of the chuck **113** and top plate **111** without contact thereto. The radiation plates **200** are controlled at a low temperature by means of Peltier device **201** as shown in **FIG. 6**, and also the radiation plate **300** is controlled similarly at a low temperature by means of a Peltier device **301** The back faces of the Peltier devices **201** and **301** are cooled by a coolant of a temperature of about 23° C. which is the same temperature of the positioning device structure **110** and **211**.

[0005] With the cooling based on radiation, if the temperature difference between the subject of cooling and the radiation plate is not large, a desired cooling rate is not obtainable. Therefore. usually, a temperature difference of about 10 to 20° C. should be set. Thus, if the cooling subject is 23° C., the radiation plate has to be made 10° C. or less. Furthermore, while the foregoing example uses Peltier devices, in some cases it is difficult to use such Peltier device. For example, if an electric current is applied to the Peltier device to actuate the same, a magnetic field change attributable to a change in electric current inside the device may occur. Therefore, if it is incorporated into an EB (electron beam) exposure apparatus, the exposure precision may be adversely affected thereby. In such case, Peltier devices can not be used.

[0006] The temperature of the radiation plate may be directly controlled by use of a coolant of 10° C. or less. However, since in that case the temperature of piping structure extending from the coolant temperature adjusting device up to the radiation plate is also lowered, and thus the temperature of the structure of the positioning device as a whole changes. This causes thermal deformation and degradation of the positioning precision.

[0007] It is therefore desirable to develop cooling means by which, except Peltier device, a radiation plate can be controlled at a low temperature without adversely affecting the positioning precision.

SUMMARY OF THE INVENTION

[0008] It is accordingly an object of the present invention to provide a cooling technique by which at least one of the inconveniences described above can be solved.

[0009] In accordance with an aspect of the present invention, to achieve the above object, there is provided a positioning apparatus, comprising: a positioning unit; and a temperature adjusting unit which adjusts a temperature of at least a portion of said positioning unit, said temperature adjusting unit including a cooling mechanism based on vaporization heat of a liquid.

[0010] In accordance with another aspect of the present invention, there is provided a cooling apparatus, comprising: a container; a supplying unit which supplies a liquid to said container; and an exhaust unit which exhausts said container.

[0011] In accordance with a further aspect of the present invention, there is provided a positioning apparatus, comprising: a holding unit which holds an object: a positioning unit which positions said holding unit; and a cooling unit which cools said holding unit, wherein said cooling unit includes (a) a container, (b) a supplying unit which supplies a liquid to said container, and (c) an exhaust unit which exhausts said container.

[0012] In accordance with a yet further aspect of the present invention, there is provided an exposure apparatus for exposing a substrate to a pattern, said apparatus comprising: a cooling unit which cools an object, wherein said cooling unit includes (a) a container, (b) a supplying unit which supplies a liquid to said container, and (c) an exhaust unit which exhausts said container.

[0013] In accordance with a still further aspect of the present invention, there is provided a device manufacturing method, comprising the steps of: exposing a substrate to a pattern by use of an exposure apparatus, and developing the exposed substrate, wherein said exposure apparatus has a cooling unit for cooling an object, which cooling unit includes (a) a container, (b) a supplying unit which supplies a liquid to said container, and (c) an exhaust unit which exhausts said container.

[0014] In Accordance with the present invention, the necessity of applying an electric current in the vicinity of a subject of cooling as in the case using a Peltier device is removed, and also adverse influence on anything other than the subject of cooling, from cooling pipes, can be reduced.

[0015] These and other objects, features and advantages of the present invention will become more apparent upon a consideration of the following description of the preferred embodiments of the present invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] **FIG. 1** is a schematic view of a structure of a cooling mechanism according to a first embodiment of the present invention.

[0017] **FIG. 2** is a schematic view of a structure of a cooling mechanism according to a second embodiment of the present invention.

[0018] **FIG. 3** is a schematic view of a structure of a cooling mechanism according to a third embodiment of the present invention.

[0019] **FIG. 4** is a schematic view of a structure of a cooling mechanism according to a fourth embodiment of the present invention.

[0020] **FIG. 5** is a schematic view of a known example of positioning device, to which a radiation cooling mechanism according to the present invention can be applied.

[0021] **FIG. 6** is a schematic view for explaining details of the radiation cooling mechanism of **FIG. 5**.

[0022] **FIG. 7** is a flow chart for explaining sequence of device manufacturing processes.

[0023] **FIG. 8** is a flow chart for explaining details of a wafer process included in the procedure of **FIG. 7**.

[0024] **FIG. 9** is a schematic view of an exposure apparatus of device manufacture, according to an embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0025] Preferred embodiments of the present invention will now be described with reference to the attached drawings.

[0026] [First Embodiment]

[0027] **FIG. 1** shows a cooling mechanism according to a first embodiment of the present invention. **FIG. 1** illustrates the structure for controlling a radiation plate temperature on the basis of heat of vaporization of water. Water which is temperature controlled to about the same temperature of the structure **110** and **211** (**FIG. 5**) which constitutes a positioning device, that is, usually about 23° C., is supplied to a porous material member **2** through a flowpassage **6**. The porous material member **2** is disposed inside a container **3** which is vacuum exhausted by means of a vacuum pump, for example. The water supplied therein is dispersed within the porous material member **2** and, when a vapor pressure (or steam pressure) or lower pressure is reached, vaporization occurs. For example, the vapor pressure of water at 0° C. is 610 Pa and, therefore, by keeping the inside pressure of the container **3** at about 100 Pa, the water can be well vaporized even if the temperature of the porous material member **2** comes near to 0° C. When vaporized, the water deprives vaporization heat from the porous material member **2** by 2440 J per 1 g. As a result, the temperature of the porous material member **2** gradually decreases and, thus, the temperature of a radiation plate **1** connected thereto is lowered. Therefore, even if the temperature of the water to be supplied is at an ordinary temperature, it is possible to decrease the temperature of the radiation plate to about 0° C.

[0028] Theoretically, if the inside pressure of the container **3** is so controlled that the vapor pressure of the water is reached therein at the set temperature of the radiation plate **1**, it enables such control cycle that, as the temperature of the radiation plate is lowered and it reaches the set temperature, vaporization of water stops, whereas when the temperature of the radiation plate **1** increases beyond the set temperature, vaporization of water resumes, whereby the temperature of the radiation plate **1** is automatically controlled at the set temperature.

[0029] Practically, however, the temperature precision of the radiation plate **1** or the response of temperature control is taken into account, the Inside pressure of the container **3** is made sufficient small (not greater than 100 Pa) and, for the temperature control of the radiation plate **1**, heating means such as a heater, for example, provided for the radiation plate **1** is used. For example, on the basis of an output of a temperature sensor **8**, energization (on/off control or applied voltage) of a heater **4** disposed adjacent the radiation plate (at the back of radiation plate in the illustrated example) may be controlled. Here, if this cooling mechanism is used in an electron beam exposure apparatus, for example, a change in magnetic field due to variation of the electric current flowing through the heater may have an adverse influence. In consideration of this, the heater is made of a strand structure of high resistance wire material so that the magnetic field produced from the electric current flowing through the wire material can be cancelled. Furthermore, in order to prevent overcooling of peripheral components by the radiation plate **1**, an insulating material **5** is provided between the radiation plate **1** and the peripheral structure to thereby suppress the heat transfer.

[0030] While this embodiment has been described with reference to an example wherein water having large vaporization heat is used as a coolant, any other coolant may be chosen from the standpoint of desired temperature, cooling rate, convenience in usage, for example. For example, if the radiation plate **1** should be controlled at 0° C., ammonia may be used as a coolant. When the set temperature of the radiation plate **1** is not higher than 0° C., if water is chosen as the coolant, the water may be solidified in the flowpassage **6** inside the porous material member **2** This can be avoided by using ammonia having low solidification temperature. The steam pressure of ammonia. namely, the pressure of vaporization, is higher than that of water, and it is 4.3 atm at 0° C. and 8.5 atm at 20° C. Therefore, by supplying ammonia up to the porous material member at a very high supply pressure of 10 atm and by opening the container to the atmosphere (without exhausting it even to vacuum) to hold a pressure of about 1 atm, vaporization phenomenon well occurs and the cooling of the radiation plate is enabled. This means that the inside pressure of the container is not always negative, and it may be a positive pressure. Anyway, it should be maintained not greater than the steam pressure of the coolant at the set temperature.

[0031] Where the cooling mechanism described above is applied to the positioning device of **FIG. 5**, the temperature of the radiation plate can be held at low temperature, like the case where a Peltier device **201** is used. Therefore, even in an environment wherein any Peltier device is unusable for any magnetic factor or the like, a cooling mechanism having a similar cooling effect can be incorporated into the positioning device. Therefore, radiation cooling even for an electron beam exposure apparatus, for example, can be achieved.

[0032] In this example, a radiation plate is taken as a subject of cooling. However, any other cooling subject may be taken. Furthermore, the subject of application of this cooling mechanism is not limited to a positioning device as described above.

[0033] A heat pipe is an example using vaporization heat, and Japanese Patent No. 2975089 proposes an exposure apparatus using such mechanism. However, the heat pipe is such structure that a coolant confined in a closed space is vaporized, for cooling, in a higher-temperature region A of the container surface (usually, it is adjacent the subject of cooling) and then it is liquefied in a lower-temperature region (usually, it is a region cooled by a coolant) to emit heat. Thus, the heat pipe itself is not a cooling mechanism, but rather it is a mechanism for efficiently transmitting heat from the region A to the region B. If therefore such heat pipe is applied to the positioning device of **FIG. 5**, although the radiation plate **1** may be cooled to a low temperature 10° C. due to the vaporization heat effect in the region A, it is still necessary to cool the region B to a temperature much lower than 10° C. Furthermore, since the heat pipe has merely a large apparent heat conductivity, it is necessary to set a large temperature difference between the regions A and B in proportion to the physical length between the regions A and B. It is therefore practically difficult to separate the regions A and B by a large distance. In the structure according to this embodiment of the present invention, on the other hand, there is no portion corresponding to the "region B". Even if the exhaust means and the liquid supplying means are disposed far away from the portion corresponding to the "region A" within the limit allowed by the piping arrangement or the like, the cooling effect to the "region A" is unchanged. Thus, the cooling mechanism of this embodiment is definitely distinct from the heat pipe.

[0034] [Second Embodiment]

[0035] **FIG. 2** shows a second embodiment of the present invention. This embodiment differs from the first embodiment in that water (coolant) is circulated through a porous material member **2** and that a portion of the circulated water is vaporized through the porous material member **2**. Usually, a positioning device may be equipped with circulation of water for cooling. Thus, a portion of such circulation water may be bypassed toward the porous material member **2**. In that occasion, there are advantages that the liquid pressure control is easy, and that the liquid is not easily solidified within the flowpassage **6** even if the set radiation plate temperature is low.

[0036] [Third Embodiment]

[0037] **FIG. 3** shows a third embodiment of the present invention. In the cooling mechanism of **FIG. 3**, a liquid is directly applied against the back of a radiation plate. More specifically, water being supplied through a flowpassage **6** is applied (or discharged) from a nozzle **7** directly against the back of a radiation plate **1**. Since the inside pressure of a vacuum container **3** is held by means of a vacuum pump (not shown), for example, at a pressure sufficiently smaller than the steam pressure of the water, the discharged water is vaporized while depriving, from the radiation plate, a heat quantity corresponding to the vaporization heat. With this arrangement, the radiation plate **1** can be cooled, and the temperature thereof can be reduced to about 0° C. As described with reference to the first embodiment, the temperature control for the radiation plate may be carried out by controlling energization of a heater **4** provided adjacent the radiation plate (at the back of the radiation plate, in the illustrated example), on the basis of an output of a temperature sensor **8**. Furthermore, if it is desired to change the cooling rate based on evaporation heat cooling, it may be effective to intentionally change the amount of discharge of water from the nozzle **7**. In order to prevent thermal external disturbance to the radiation plate, an insulating material **5** is provided between the radiation plate and the peripheral structure. Here, as regards the water to be supplied to the nozzle **7**, it is not specifically necessary to keep the same at low temperature. It may be at the same temperature (usually, about 23° C.) of the peripheral structure. Thus, without changing the structure temperature, the radiation plate can be maintained at low temperature, and so degradation of positioning precision due to thermal deformation is not a problem to be cared.

[0038] The required function of the nozzle **7** is just to discharge a coolant against the subject of cooling. It does not need a particular structure. A simple nozzle which uses a pressure difference between the flowpassage **6** and the Inside of the container **3**, may be used or, alternatively, a nozzle having an inside heat generating element for boiling the water to thereby discharge the same, may be used. As a further alternative, a nozzle having an inside piezoelectric device or the like for discharging water, may be used.

[0039] [Fourth Embodiment]

[0040] **FIG. 4** shows a fourth embodiment of the present invention. While this embodiment has a basic stage structure similar to the **FIG. 5** structure, the cooling mechanism does not use radiation cooling but it is arranged to directly cool a chuck **113** by using vaporization heat. More specifically, water discharged from a nozzle **7** is directly applied against a chuck **113** which is the subject of cooling, and by vaporization of the water **9** adhered to the chuck surface, the chuck **113** is cooled. The inside pressure of a container **3** is exhausted and maintained by means of a vacuum pump (not shown), for example, at a pressure (about 100 Pa) corresponding to the steam pressure of the water. The chuck **113** functions as a portion of the vacuum container **3**, and it is disposed opposed to a non-contact seal member **10** provided on the container body, **3** with a small clearance intervening therebetween. With this arrangement, vibration or heat of a rough-motion stage **110** is prevented from being transmitted to the chuck. Additionally, because of vacuum seal effect of the small clearance, there occurs almost no leakage of a gas inside the container **3** to the vacuum ambience around the stage. For facilitating the temperature control of the chuck **113**, while the required cooling rate is controlled by this cooling mechanism to some extent, additional temperature control may be made by use of chuck heating means **14** such as a heater, for example, on the basis of an output of a temperature sensor **8** provided to the chuck **113**. Furthermore, if necessary, the cooling rate may be controlled by controlling the amount of water discharge from the nozzle **7**.

[0041] In accordance with the embodiments described above, a cooling mechanism using vaporization heat of coolant can be applied to a positioning device, with substantially the same cooling effect as attainable with Peltier device. It is therefore possible to meet electron beam exposure apparatus or the like wherein use of Peltier device is difficult. When the cooling mechanism is incorporated into a positioning device in an electron beam exposure apparatus or the like, high precision positioning and thus high precision exposure as well are assured.

[0042] [Fifth Embodiment]

[0043] Next, referring to **FIGS. 7 and 8**, an embodiment of a device manufacturing method which uses an exposure apparatus described above, will be explained.

[0044] **FIG. 7** is a flow chart for explaining the procedure of manufacturing various microdevices such as semiconductor chips (e.g., ICs or LSIs), liquid crystal panels, CCDs, thin film magnetic heads or micro-machines, for example. Step **1** is a design process for designing a circuit of a semiconductor device. Step **2** is a process for making a mask on the basis of the circuit pattern design. Step **3** is a process for preparing a wafer by using a material such as silicon. Step **4** is a wafer process which is called a pre-process wherein, by using the thus prepared mask and wafer, a circuit is formed on the wafer in practice, in accordance with lithography. Step **5** subsequent to this is an assembling step which is called a post-process wherein the wafer having been processed at step **4** is formed into semiconductor chips. This step includes an assembling (dicing and bonding) process and a packaging (chip sealing) process. Step **6** is an inspection step wherein an operation check, a durability check an so on, for the semiconductor devices produced by step **5**, are carried out. With these processes, semiconductor devices are produced, and they are shipped (step **7**).

[0045] **FIG. 8** is a flow chart for explaining details of the wafer process. Step **11** is an oxidation process for oxidizing the surface of a wafer. Step **12** is a CVD process for forming an insulating film on the wafer surface. Step **13** is an electrode forming process for forming electrodes upon the wafer by vapor deposition. Step **14** is an ion implanting process for implanting ions to the wafer. Step **15** is a resist process for applying a resist (photosensitive material) to the wafer. Step **16** is an exposure process for printing, by exposure, the circuit pattern of the mask on the wafer through the exposure apparatus described above. Step **17** is a developing process for developing the exposed wafer. Step **18** is an etching process for removing portions other than the developed resist image. Step **19** is a resist separation process for separating the resist material remaining on the wafer after being subjected to the etching process. By repeating these processes, circuit patterns are superposedly formed on the wafer.

[0046] With these processes, high density microdevices can be manufactured.

[0047] [Sixth Embodiment]

[0048] **FIG. 9** shows a semiconductor device manufacturing exposure apparatus in which a positioning device as described hereinbefore is incorporated as a wafer stage.

[0049] This exposure apparatus is to be used for manufacture of microdevices having a fine pattern formed thereon, such as semiconductor devices (semiconductor integrated circuits, for example), micromachines, or thin-film magnetic heads, for example. In this exposure apparatus, exposure light (which may include visible light, ultraviolet light, EUV light, X-ray, electron beam, and charged particle beam, for example) as an exposure energy supplied from a light source **61** illuminates a reticle R (original), and light from the reticle R is projected onto a semiconductor wafer W (substrate) through a projection system having a projection lens **62** (which may include refractive lens, reflective lens, catadioptric lens system, and charged particle lens, for example), whereby a desired pattern is produced on the substrate.

[0050] The exposure apparatus includes a base table **51** having a guide **52** and a linear motor stator **21** fixed thereto. The linear motor stator **21** has a multiple-phase electromagnetic coil, while a linear motor movable element **11** includes a permanent magnet group. The linear motor movable portion **11** is connected as a movable portion **53** to a movable guide **54** (stage), and through the drive of the linear motor M**1**, the movable guide **54** can be moved in a direction of a normal to the sheet of the drawing. The movable portion **53** is supported by a static bearing **55**, taking the upper surface of the base table **51** as a reference, and also by a static bearing **56**, taking the side surface of the guide **52** as a reference

[0051] A movable stage **57** which is a stage member disposed to straddle the movable guide **54** is supported by a static bearing **58**. This movable stage **57** is driven by a similar linear motor M**2**, so that the movable stage **57** moves leftwardly and rightwardly as viewed in the drawing, while taking the movable guide **54** as a reference. The motion of the movable stage **57** is measured by means of an interferometer **60** and a mirror **59** which is fixed to the movable stage **59**.

[0052] A wafer (substrate) W is held on a chuck which is mounted on the movable stage **57**, and a pattern of the reticle R is transferred in a reduced scale onto different regions on the wafer W by means of the light source **61** and the projection optical system **62**, in accordance with a step-and-repeat method or a step-and-scan method.

[0053] It should be noted that the positioning device described hereinbefore can be similarly applied also to an exposure apparatus in which, without using a mask, a circuit pattern is directly drawn on a semiconductor wafer to expose a resist thereon.

[0054] The present invention can be embodied in various aspects, and examples are as follows.

[0055] (1) A positioning device having temperature adjusting means, characterized in that said temperature adjusting means includes a cooling mechanism based on vaporization heat of liquid. Since vaporization heat of liquid is used, there is no necessity of applying a relatively large electric current in the vicinity of a subject of cooling as in the case where a Peltier device is used. Therefore, even in an exposure apparatus using a charged particle beam such as electron beam, exposure precision is not adversely affected. Furthermore, even in a case where a radiation plate is disposed opposed to the subject of cooling and, by cooling the radiation plate, the cooling subject is cooled through radiation cooling, there is no necessity that the liquid for cooling the radiation plate has a large temperature difference with a coolant used to cool the structure of the positioning device. Moreover, as compared with a case wherein cooling pipes are stretched, factors which adversely affect the positioning precision can be removed. As a result, higher precision positioning is assured and, when the positioning device of this aspect of the present invention is incorporated into an exposure apparatus, higher precision exposure can be accomplished.

[0056] (2) A positioning device according to Item (1), characterized in that said cooling mechanism includes means for applying liquid to a portion to be cooled. A cooling mechanism based on vaporization heat is used in air conditioner, refrigerator, freezer, or the like. However, they are all arranged to discharge a liquid into an inside space of a heat exchanger. To the inside wall of the heat exchanger, the coolant is applied as a gas. As compared, in the structure according this aspect of the present invention, liquid coolant is directly applied to the portion to be cooled, such that vaporization heat is directly deprived from the portion to be cooled. The cooling efficiency can be therefore improved.

[0057] (3) A positioning device according to Item (2), wherein said cooling mechanism uses vaporization heat of liquid to cool the portion to be cooled at a temperature not higher than the temperature of the liquid applied to the portion to be cooled.

[0058] (4) A positioning device according to Item (2) or (3), wherein said cooling mechanism includes means for setting an ambience contacting to the portion to be cooled, at a pressure not higher than a steam pressure of the liquid at a set target temperature of the portion to be cooled.

[0059] (5) A positioning device according to any one of Items (2)-(4), wherein said ambience setting means includes a container for surrounding the ambience and means for exhausting the container.

[0060] (6) A positioning device according to Item (5), wherein the container comprises a subject of cooling or a cooling member, including said portion to be cooled, and a surrounding member disposed opposed to the cooling subject or cooling member with a small clearance intervening therebetween.

[0061] (7) A positioning device according to any one of Items (2)-(6), wherein said liquid applying means comprise means for discharging a liquid against the portion to be cooled. As regards the liquid, a liquid such as water which is kept in a liquid state at ordinary temperature and ordinary pressure, may be used. In that occasion, the cooling mechanism may preferably arranged so that the ambience contacting the portion to be cooled is held at vacuum of about 100 Pa while a liquid is discharged against the portion to be cooled. The portion to be cooled may be provided on a subject of cooling, or it may be provided on a cooling member disposed in contact wit or opposed to the cooling subject

[0062] (8) A positioning device according to any one of Items (2)-(6), wherein said liquid applying means comprises a liquid flowpassage provided inside a cooling member which includes the portion to be cooled and which is disposed in contact with or opposed to a subject of cooling, means for supplying a liquid to said liquid flowpassage, and means for communicating said flowpassage to an ambience contacting the portion to be cooled.

[0063] (9) A positioning device according to Item (8), wherein said liquid supplying means circulates the liquid through said liquid flowpassage.

[0064] (10) A positioning device according to Item (8) or (9), wherein said cooling member includes a porous material member which is the member to be cooled, and wherein said communicating means comprises a communication bore formed in said porous material member.

[0065] (11) A positioning device according to any one of Items (6) and (8)-(10), wherein the cooling member is made of a material having high heat conductivity and small thermal resistance with a subject of cooling. The cooling mechanism may have a structure that a liquid is supplied through a cooling member which is connected to a cooling subject and yet is in contact with vacuum, and also that the liquid flowpassage in the cooling member is communicated with the vacuum. Also, the cooling member may preferably be made of a porous material for facilitating vaporization and improved cooling efficiency.

[0066] (12) A positioning device according to any one of Items (1)-(11), wherein said temperature adjusting means includes heating means.

[0067] (13) A positioning device according to Item (12), wherein said heating means comprises a strand structure of high resistance wire materials. When the temperature adjusting means comprises a structure having a heater, the temperature control of the cooling subject becomes easier. Where the heater has a stranded wire structure, variation of magnetic field produced from the current flowing through the heat is reduced.

[0068] (14) A positioning device according to any one of Items (1-(13), wherein the liquid commonly used also as a coolant for cooling the structure of said positioning device, or it is controlled at substantially the same temperature as of that coolant.

[0069] (15) A cooling device characterized by a container, supplying means for supplying a liquid into said container, and means for exhausting said container.

[0070] (16) A cooling device according to Item (15), characterized by a porous material member disposed in said container, for keeping the liquid therein.

[0071] (17) A cooling device according to Item (15) or (16), characterized by collecting means for collecting the liquid from said container.

[0072] (18) A cooling device according to any one of Items (15)-(17), wherein a subject of cooling functions as at least a portion of said container.

[0073] (19) A cooling device according to any one of Items (15)-(18), wherein the subject of cooling is one of a radiation plate and a positioning device.

[0074] (20) A cooling device according to any one of Items (15)-(19), wherein said supplying means includes a nozzle for discharging the liquid into said container.

[0075] (21) A positioning device, characterized by a holding member for holding an object, positioning means for positioning said holding member, and a cooling device as recited in any one of Items (15)-(20), wherein said holding member is a subject of cooling of said cooling device.

[0076] (22) An exposure apparatus characterized by including a cooling device as recited in any one of Items (15)-(20).

[0077] (23) An exposure apparatus characterized by including a positioning device as recited in any one of Items (1)-(14).

[0078] (24) An exposure apparatus according to Item (23), wherein a substrate to be exposed is disposed in a vacuum, and wherein exposure is carried out by projecting an electron beam to the substrate to be exposed.

[0079] (25) A device manufacturing method, characterized in that a device is manufactured by use of an exposure apparatus as recited in any one of Items (22)-(24).

[0080] A subject of cooling and/or a cooling member may be provided inside a container or it may be structured as a portion of the container (Item (5) above) and, by vacuum exhausting the container, a cooling device (Item (18) above) can be provided. The container may not be completely closed, and it may include a portion which is defined by a structure having members opposed to each other with a small clearance intervening therebetween. Because of seal effect of the small clearance, the function as a container can still be kept, and also since the physical connection between the members is disconnected, thermal insulation and vibration insulation are achieved. When the cooling mechanism is applied to a radiation plate for performing radiation cooling, this advantage of cooling mechanism is best made use of. Particularly, this cooling mechanism is suited to an electron beam exposure apparatus.

[0081] While the invention has been described with reference to the structures disclosed herein, it is not confined to the details set forth and this application is intended to cover such modifications or changes as may come within the purposes of the improvements or the scope of the following claims.

[0082] This application claims priority from Japanese Patent Application No. 2003-344012 filed Oct. 2, 2003, for which is hereby incorporated by reference.

What is claimed is:

1. A positioning apparatus, comprising:

a positioning unit; and

a temperature adjusting unit which adjusts a temperature of at least a portion of said positioning unit, said temperature adjusting unit including a cooling mechanism based on vaporization heat of a liquid.

2. An apparatus according to claim 1, wherein said cooling mechanism includes a liquid applying unit for applying a liquid to a particular member to be cooled.

3. An apparatus according to claim 1, wherein said cooling mechanism cools a particular member to be cooled, to a temperature not higher than the temperature of the liquid.

4. An apparatus according to claim 1, wherein said cooling mechanism includes a pressure adjusting unit for adjusting a pressure of an ambience contacting a particular member to be cooled, to a pressure not higher than a vapor pressure of the liquid at a target temperature of the particular member to be cooled.

5. An Apparatus according to claim 4, wherein said pressure adjusting unit includes a container for surrounding the ambience, and an exhaust unit for exhausting said container.

6. An apparatus according to claim 5, wherein said container includes a surrounding member disposed opposed to the particular member to be cooled, with a clearance intervening therebetween.

7. An apparatus according to claim 2, wherein said liquid applying unit discharges a liquid against the particular member to be cooled.

8. An apparatus according to claim 2, wherein said liquid applying unit includes a flowpassage formed inside the particular member to be cooled, a supplying unit for supplying a liquid to said flowpassage, and a connecting member for connecting the flowpassage and an ambience contacting the particular member to be cooled.

9. An apparatus according to claim 8, wherein said supplying unit circulates the liquid through said flowpassage.

10. An apparatus according to claim 8, wherein said connecting member is made of a porous material.

11. An apparatus according to claim 8, wherein the particular member to be cooled is a member having high heat conductivity and having small thermal resistance with a subject of cooling.

12. An apparatus according to claim 1, wherein said temperature adjusting unit includes a heater.

13. An apparatus according to claim 12, wherein said heater includes a strand structure of resistance wire material.

14. A cooling apparatus, comprising:

a container;

a supplying unit which supplies a liquid to said container; and

an exhaust unit which exhausts said container.

15. An apparatus according to claim 14, further comprising a porous material member disposed in said container, for keeping the liquid therein.

16. An apparatus according to claim 14, further comprising a collecting unit for collecting the liquid from said container.

17. An apparatus according to claim 14, wherein at least a portion of said container constitutes a subject of cooling.

18. An apparatus according to claim 14, wherein a subject of cooling is one of a radiation plate and a positioning apparatus.

19. An apparatus according to claim 14, wherein said supplying unit includes a nozzle for discharging the liquid into said container.

20. A positioning apparatus, comprising:

a holding unit which holds an object;

a positioning unit which positions said holding unit; and

a cooling unit which cools said holding unit;

wherein said cooling unit includes (a) a container, (b) a supplying unit which supplies a liquid to said container, and (c) an exhaust unit which exhausts said container.

21. An exposure apparatus for exposing a substrate to a pattern, said apparatus comprising:

a cooling unit which cools an object,

wherein said cooling unit includes (a) a container, (b) a supplying unit which supplies a liquid to said container, and (c) an exhaust unit which exhausts said container.

22. An apparatus according to claim 21, wherein the object is one of a chuck which holds the substrate, and a radiation plate.

23. An apparatus according to claim 21, wherein the substrate is exposed in a vacuum ambience.

24. A device manufacturing method, comprising the steps of:

exposing a substrate to a pattern by use of an exposure apparatus; and p**1** developing the exposed substrate, p**1** wherein said exposure apparatus has a cooling unit for cooling an object, which cooling unit includes (a) a container, (b) a supplying unit which supplies a liquid to said container, and (c) an exhaust unit which exhausts said container.

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