

APPARATUS AND METHOD FOR THE THERMAL TREATMENT OF
SUBSTRATES

5 The present invention relates to an apparatus and a method for the thermal treatment of substrates, especially semiconductor wafers, including at least one heating device for heating at least one substrate by means of electromagnetic radiation, whereby the heating device includes at least two arc lamps.

10 An apparatus of the aforementioned type is known, for example, from US-A-4,698,486, according to which a semiconductor wafer that is located in a reaction chamber is initially heated by an arrangement of quartz halogen lamps. After the wafer has reached a certain
15 temperature, an additional lamp arrangement, namely a high-power pulsed lamp arrangement, is used for heating the wafer. The pulsed lamp arrangement is used only for a short period of time, whereby the surface temperature of the wafer is raised to a temperature in the vicinity of the melting point of the semiconductor material. Due to the
20 short periods of use of the pulsed lamps, the temperature of the wafer is influenced by the pulsed lamps only in the region of the wafer surface, which leads to a non-homogeneous temperature distribution over the thickness of the wafer. The quartz halogen lamps, as well as the pulsed lamps, are disposed in a highly reflective chamber that

surrounds the reaction chamber and that is built up in the form of a kaleidoscope. In order to achieve a homogeneous temperature distribution on the surface of the wafer in the reaction chamber, it is important with this known apparatus that the spacing between the
5 respective lamps and the surface of the wafer be greater than or at least equal to the diameter of the reflective chamber. The spacing between the respective lamps and the wafer surface, in particular with an apparatus that is suitable for heating both sides of the wafer, leads to a large overall size of the apparatus. With the ever increasing wafer
10 diameters, such as for example 300mm wafers, it is therefore necessary to have a very large reflective chamber, which leads to high manufacturing and maintenance costs of the apparatus.

From US-A-4,398,094 as well as US-A-5,336,641 respective apparatus
15 are known for the thermal treatment of semiconductor wafers, according to which in each case an individual arc lamp having a mirror is used as the heat source. The arc lamps used as the heat source are thereby generally high-power arc lamps having an expensive construction and a complicated cooling device. Due to the use of an
20 individual lamp, it is not possible to achieve a homogeneous thermal treatment of the wafer.

From DD-A-295950 it is furthermore known to use UV radiating systems having varying configurations in combination with glow lamps for the thermal treatment of semiconductor wafers. In this connection, a metallic vapor, low-pressure UV source is used that contributes only insignificantly to the overall radiation density of the heating device. The object of the UV radiation system is not the actual heating of the wafer, but rather the promotion of photochemical reactions in conjunction with thermally activated processes via the UV irradiation.

Most of the presently commercially available apparatus for the thermal treatment of substrates utilize exclusively glow lamps for the thermal treatment of semiconductor wafers. However, these lamps have the drawback that the radiation of the glow lamps is only very slightly absorbed at wafer temperatures below 600°C. This is due to the characteristic spectrum of the glow lamps, which at wave lengths of about 1000nm is at its maximum. The rate of absorption of an Si semiconductor substrate is, however, for wave lengths in this range greatly dependent upon temperature and varies from about 0.1 to 0.7. Only at temperatures of more than 600°C is the rate of absorption in this wave length range nearly independent of wave length. The result of this is that the energy of the glow lamps can be effectively absorbed only at a wafer temperature of greater than about 600°C.

Proceeding from the known apparatus, it is an object of the present invention to provide an apparatus of the aforementioned type that enables an effective economical and homogeneous thermal treatment of substrates.

Pursuant to the present invention, this object is realized with an apparatus of the aforementioned type in that the radiation characteristics for each arc lamp can be individually controlled by a control device, and in that the electromagnetic radiation of the arc lamps contribute substantially to the power density of the electromagnetic radiation of the heating device. The use of arc lamps, which contribute significantly to the power density of the electromagnetic radiation of the heating device, has the advantage that these lamps radiate in a spectral range in which, for example Si wafers, have the highest absorption, and in particular already at room temperature. Thus, as a result of the arc lamps an effective heating in particular of semiconductor wafers is possible even at room temperatures. Due to the possibility of an individual control of the arc lamps, the spatial radiation field of the lamps can be established, which enables a homogeneous radiation distribution and thus a homogeneous temperature distribution upon the wafer surface. Due to

the ability to set the spatial radiation field, the heating device, including the arc lamps can be disposed in the vicinity of the substrate that is to be treated, and it is not necessary to maintain a certain spacing between the heating device and the substrate, which spacing is prescribed by the diameter of the treatment apparatus, in order to be able to carry out a homogeneous substrate treatment. As a result, the overall size of the apparatus, and the cost connected therewith, can be considerably reduced.

For an optimal adaptation of the radiation characteristics of the apparatus to the process conditions, especially to the substrate that is to be treated, the operating mode and/or the lamp current of the arc lamps is advantageously individually controllable. The arc lamps are advantageously controllable in a direct current operation and/or in a pulsed manner as flash or pulsed lamps. For an effective use of the arc lamps, these contribute at least 1/10 to the power density of the heating device. For a good, effective cooling of the arc lamps, these are preferably fluid cooled. As a result of a good cooling of the arc lamps, their life expectancy can be extended considerably.

In order to achieve a good, homogeneous temperature distribution on the substrate that is to be treated, the gas or glow discharge zone of

the arc lamps corresponds essentially to a dimension of the substrate, such as the edge length or the diameter of the substrate. It is preferably longer than the dimension of the substrate. The arc lamps are preferably disposed in the region of the outer periphery of the substrate in order to be able to easily control the temperature distribution in this area. Arc lamps are particularly suitable in this region, because they have a rapid response characteristic.

The heating device preferably has a bank of lamps having at least two rod-shaped lamps that are disposed nearly parallel to one another. In this connection, the lamps of the bank of lamps have, preferably in addition to the arc lamps, glow lamps that enable an economical heating of the substrates. Pursuant to one specific embodiment of the invention, the glow lamps and the arc lamps have essentially the same dimensions so that they can be interchanged in order to be able to specifically adapt the radiation characteristics within the apparatus to the respective substrate or the respective thermal process. The glow lamps and the arc lamps advantageously have essentially the same lamp power, so that the same cooling system can be utilized for the lamps. For an increased effectiveness of the apparatus, the heating device is surrounded by a chamber that at least in sections reflects the electromagnetic radiation, so that radiation of the lamps that is not

directed directly upon the substrate is reflected upon the substrate. In this connection, the spectral reflection coefficient of the chamber is preferably dependent upon position in order to achieve a certain spectral radiation distribution upon the substrate surface. In particular, it is possible to prevent the UV radiation of the arc lamps from being reflected upon certain regions of the substrate that do not face the arc lamps.

In order to reduce the overall size of the apparatus, the spacing of the heating device relative to the surface of the substrate is preferably less than the diameter of a reaction chamber. In this connection, the ratio between spacing and diameter is advantageously less than 0.5.

Pursuant to a particularly preferred specific embodiment of the invention, the radiation characteristics of the electromagnetic radiation of the heating device can be modulated, as a result of which a good possibility of determining the temperature of the wafer is provided. In this connection, it is an advantage of the arc lamps that they can be operated with considerably higher modulation frequencies than is true for halogen lamps. As a result, the temperature of the object, especially during the temperature fluctuations, can be determined more precisely and with simpler evaluation electronics.

The heating device and/or the substrate is advantageously disposed in a nearly homogeneous, adjustable magnetic field, the lines of flux of which, at least in the vicinity of the arc lamp anode have a component that extends essentially parallel to the arc discharge of the arc lamps. A modulation of the lamps can be effected by the magnetic field. Furthermore, by means of the magnetic field a significant influence can be had upon the life expectancy of the arc lamps, since the rate of erosion of the anode can be positively reduced. In this connection, the magnetic flux density of the magnetic field is advantageously between 0.005 and 0.3 tesla.

For a thermal treatment on both sides of the substrate, the apparatus preferably has a second heating device, whereby the substrate is disposed between the heating devices.

The apparatus advantageously has a reaction chamber that essentially surrounds the substrate and is nearly transparent for the electromagnetic radiation of the heating device, the reaction chamber advantageously being provided with quartz glass and/or sapphire. The reaction chamber material advantageously has an absorption coefficient, averaged over the spectrum of the electromagnetic

radiation, between 0.001 per centimeter and 0.1 per centimeter. The thickness of the wall of the reaction chamber is preferably between one millimeter and five centimeters.

5 Pursuant to one preferred specific embodiment of the present invention, the glow lamps at least partially have a helical filament structure with which preferably a predefined geometrical and spectral radiation profile can be achieved. For this purpose, the filament preferably alternatingly has helical and non-helical filament structures.

10 Pursuant to a further, preferred specific embodiment of the invention, at least one glow lamp has at least two individually controllable filaments. Preferably at least one filament of a glow lamp has at least three electrical connections. The density of at least one filament structure preferably varies along the filament.

15 Pursuant to a preferred specific embodiment of the invention, the reaction chamber and/or the lamp bodies form a frequency filter for at least one wave length range of the electromagnetic radiation of the heating device in order to determine within this spectrum the radiation reflected from the wafer and hence to determine the temperature, whereby the lamp
20 is suppressed by the filter effect. Such a frequency filter can be achieved, for example, in that synthetic quartz is

selected for the lamp bulbs and fused quartz is selected for the reaction chamber. The filter effect of such a frequency filter can be additionally influenced by the selection of the temperature of the lamp body. In particular at low temperatures the intrinsic emission of the lamp body is additionally reduced. As a result, approximately at 2700nm the lamp radiation is suppressed, the wafer radiation of 2700nm can, however, be detected through the reaction chamber. In general, such frequency filters can be built up as absorption filters or in the form of interference filters, in other words, by utilizing thin dielectric layers. These advantages can also be advantageously achieved in that at least one of the lamps is at least partially filled with a material that absorbs a specific wave length range of the electromagnetic radiation of the heating device. With the halogen lamps, a suitable additive can, for example, be mixed with the halogen gas of the lamp filling, with such additive absorbing in narrow bands and advantageously emitting only slightly or not at all in the absorption band.

The object of the invention can be realized with a method of the aforementioned type in that the radiation characteristics for each arc lamp are individually controlled, and the electromagnetic radiation of the arc lamps contributes substantially to the power density of the

electromagnetic radiation of the heating device. This results in the advantages already mentioned above.

Pursuant to a particularly preferred specific embodiment of the invention, the substrate is heated in a lower temperature range essentially by means of the arc lamps, since arc lamps give off radiation in a spectral range that, for example, by Si semiconductor wafers, is absorbed better at temperatures below 600°C than is the radiation of glow lamps. The substrate is preferably heated in a lower temperature range exclusively by means of arc lamps. For Si semiconductor wafers, the lower temperature range is preferably between room temperature and approximately 600°C.

The electromagnetic radiation of the heating device is preferably modulated, which pursuant to one specific embodiment of the invention is effected by applying a magnetic field in the region of the substrate and/or the heating device, with the lines of flux of the magnetic field, at least in the region of the arc lamp anode, having a component that extends essentially parallel to the arc discharge.

The invention will be explained in greater detail subsequently with the aid of a preferred specific embodiment and with reference to the drawings; the drawings show:

5 Fig. 1 a schematic cross-sectional view of an apparatus for the thermal treatment of substrates;

 Fig. 2 a schematic cross-sectional view of an alternative specific embodiment taken along the line A-A in Fig. 3;

 Fig. 3 a schematic cross-sectional view of the specific embodiment
10 of Fig. 2 taken along the line B-B in Fig. 2.

Figure 1 shows an apparatus 1 for the thermal treatment of semiconductor wafers 2. The apparatus 1 comprises a housing 4 having an upper wall 5, a lower wall 6, a left side wall 7, a right side wall 8, as well as non-illustrated front and rear walls, to form an
15 essentially closed chamber 10. The surfaces of the walls of the housing 4 that face the chamber 10 are coated in a known manner in order to serve as reflector surfaces, or the walls are made of a material that has a high reflectivity.

20 Provided within the chamber 10, adjacent to the upper wall 5, is a first lamp arrangement 12, and adjacent to the lower wall 6 is a second

lamp arrangement 14. The lamp arrangement 12 comprises five arc lamps 15 as well as five halogen lamps 16, whereby the arrangement can, of course, have a different number of lamps. The lamps 15 and 16 are embodied as rod lamps that extend essentially parallel to the upper wall 5 and perpendicular to the plane of the drawing. The lamps 15 and 16 are held in a suitable manner in the non-illustrated front wall and in the non-illustrated rear wall. The dimensions of the arc lamps 15 correspond essentially to the dimensions of the halogen lamps 16 and they are therefore interchangeable.

The gas or glow discharge zone of the arc lamps 15 corresponds to the diameter of the wafer 2 in order to achieve a uniform radiation distribution upon that wafer surface that is to be heated.

The lamps 15 and 16 of the upper lamp arrangement 12 are respectively individually controllable by means of a non-illustrated control device. In this connection, for example, the arc lamps 15 can be controlled with direct current, or they can be controlled in a pulsed manner, so that they operate in a flash mode. In particular, also the lamp current, and hence the intensity of the radiation given off, can be individually controlled for each lamp. By means of this individual ability to control, not only the spatial but also the spectral radiation profile can

be precisely established within the chamber 10. In so doing, it is possible to achieve over the wafer surface a homogeneity of the temperature distribution of better than 0.5% with a 300mm wafer and a temperature of 1000°C. In particular, it is also possible to control the current density of the arc lamps, whereby the UV portion of the radiation greatly increases at high current densities, so that the arc lamps correspond to a radiating system having a temperature between 8000 and 9000°C. In this connection, the emission spectrum of the radiation has a maximum at approximately 350nm. In this wave length range, the material of the wafer (Si) has a high absorption coefficient that is essentially independent of the temperature of the wafer.

The lower bank of lamps 14 is essentially built up in the same manner from rod-shaped arc lamps and halogen lamps, and will therefore not be described in greater detail. Provided in the lower housing wall 6 is an opening 18 into which a pyrometer 19 is at least partially introduced in order in a known manner to determine the temperature of the wafer 2.

The spacing between the upper and lower banks of lamps 12,14 and the wafer is generally between 1cm and 10cm. Depending upon the diameter of the wafer 2 that is to be handled, and hence the diameter

of the chamber 10, there results a ratio between the spacing and the diameter which is considerably less than 1.0. The ratio is preferably less than 0.5, and preferably even less than 0.15. With a lamp spacing of 1cm and a chamber diameter of 50 cm, a ratio of, for example, 0.02 would result.

The radiation of the lamps 15 and 16 is modulated during the operation of the apparatus in order in a known manner to be able to differentiate the radiation of the lamps from the radiation emitted from the wafer. From the radiation emitted from the wafer it is in turn possible to determine the temperature of the wafer. In this connection, arc lamps have the advantage that they can be operated with a higher modulation frequency than can the halogen lamps. As a result, the temperature of the wafer can be determined more precisely and with simpler evaluation electronics, especially during a heating-up phase with in part rapid temperature variations. The modulation can be effected by modulation of the lamp current or with the arc lamps by applying a magnetic field, as will be described in greater detail subsequently.

Provided within the chamber 10, between the upper and lower lamp arrangements 12,14, is a reaction chamber housing 20 for forming a reaction chamber 22 in which the wafer is accommodated and held in a

known manner. The reaction chamber housing is comprised of a material, for example quartz glass and/or sapphire, that is nearly transparent for the electromagnetic radiation of the lamps. The reaction chamber housing 20, on its left side pursuant to Figure 1, has an inlet conduit 24 that extends through the left side wall 7 of the housing 4 and communicates with a non-illustrated supply of gas. By means of the inlet conduit 24, during the thermal treatment of the wafer 2 a gas is introduced into the reaction chamber 22 in order to provide specific process parameters.

On the right side, the reaction chamber housing 20 has an opening 26 that communicates with an opening 28 in the right side wall 8 of the housing 4. The opening 28 is closed off by a door 30 that can be opened for the introduction into and removal of the wafer 2 from the reaction chamber 22.

In the specific embodiment of the invention illustrated in Figure 1, not only the upper lamp arrangement 12 but also the lower lamp arrangement 14 are provided with arc lamps and halogen lamps. However, when structured wafers are treated, it can be advantageous, for the careful treatment or the preservation of the structures, if no UV light falls on the structures. To prevent this, pursuant to an alternative, non-illustrated

specific embodiment of the invention, for example, the upper bank of lamps 12 has no arc lamps that face the structure of the wafer. Furthermore, the inner walls of the chamber 10 that are disposed above a plane of the wafer are coated with a material, such as gold, that has a very low reflection coefficient for UV light. This prevents UV light from falling directly upon the structure of the wafer, or being reflected thereupon. In contrast, the inner walls of the chamber 10 that are disposed below a plane of the wafer 2 can be coated with a material, such as aluminum, that reflects UV light in order to achieve an efficient irradiation and hence heating of the underside of the wafer, even with UV radiation.

Figure 2 shows an alternative specific embodiment of a thermal treatment apparatus for substrates, whereby in Figure 2 the same reference numerals are used as in Figure 1 in order to designate the same or equivalent components.

Thus, in essentially the same manner as the apparatus of Figure 1, the apparatus of Figure 2 is provided with a housing 4 in which are disposed a reaction chamber housing 20 as well as lamp arrangements 12 and 14.

As can be seen, the section of Figure 2 extends parallel to the lamp arrangements 12 and 14. The housing 4 is partially surrounded by an electromagnet 35. The electromagnet 35 has a ferromagnetic yoke 36 as well as coils 37 for applying a magnetic field. The yoke 36 and the coils 37 are arranged in such a way that they produce a magnetic field that extends essentially parallel to the lamps of the lamp arrangements 12,14, i.e. essentially parallel to the surface of the wafer. By providing auxiliary coils 38, which are similarly provided on the electromagnet 35, the homogeneity of the magnetic field can be set. By means of the magnetic field produced by the electromagnet 35, the geometrical and spectral radiation characteristics of the arc lamps contained in the lamp arrangements 12 and 14 can be established. Furthermore, by means of the magnetic field the life expectancy of the arc lamps can be extended. By modulating the magnetic field, the radiation intensity of the arc lamps can furthermore be modulated, which makes it possible for the pyrometer 19 to determine the wafer temperature.

Instead of, or also in conjunction with the modulation of the lamp radiation, there is also the possibility of providing a frequency filter for at least one wave length range of the electromagnetic radiation of the lamps. This results in an alternative differentiation, at least in one frequency range, between the radiation emitted from the wafer and the

radiation emitted from the lamps. This in turn enables a temperature determination of the wafer. In this connection, for example, the lamp bodies and/or the reaction chamber could form a frequency filter. The filter effect can, for example, be achieved by using synthetic quartz for the lamp bodies and using fused quartz for the reaction chamber. The synthetic quartz suppresses the lamp radiation at about 2700 nm whereas the fused quartz allows the radiation emitted by the wafer in this wave length range to pass through, so that the radiation in this wave length range is detected by the pyrometer and can be used for determining the temperature of the wafer. Such frequency filters can be produced as absorption filters or in the form of interference filters, i.e. by providing thin dielectric layers.

In addition, especially with halogen lamps, there is the possibility of mixing the gas of the lamp filling with a suitable additive that absorbs in a narrow band and in the absorption band emits slightly or even not at all.

Figure 3 shows a cross-sectional view of the apparatus of Figure 2 along the line B-B, whereby in this view one can see a compensation ring 40 that surrounds the wafer 2.

Although the apparatus has been described with the aid of preferred specific embodiments, it should be noted that the invention is not limited to these embodiments. In particular, for example, an apparatus is possible that is provided exclusively with individually controllable arc lamps within the lamp arrangements 12 and 14. Of course, arc lamps can also be used with other than the described halogen lamps within the lamp arrangements. Furthermore, it is also not necessary to provide two separate lamp arrangements 12,14 since under certain circumstances a single lamp arrangement, such as the lamp arrangement 12 would also be adequate for the thermal treatment of the semiconductor wafer 2. Certain of the aforementioned features, such as the provision of frequency filters or the mixing of a gas that absorbs in a narrow band to the lamp filling of heating lamps are independent of the use of certain types of lamps, and in particular are independent of the use of arc lamps.

PATENT CLAIMS

1. Apparatus (1) for the thermal treatment of substrates (2), especially semiconductor wafers, with at least one heating device (12;14) for heating at least one substrate (2) by electromagnetic radiation, whereby the heating device (12;14) includes at least two arc lamps (15) and glow lamps (16),

characterized in that the radiation characteristics for each arc lamp (15) can be individually controlled by a control device, and in that the electromagnetic radiation of the arc lamps (15) contributes substantially to the power density of the electromagnetic radiation of the heating device (12;14), whereby the arc lamps (15) contribute at least 1/10 to the power density of the heating device.

2. Apparatus (1) according to claim 1, characterized in that the operating mode and/or the lamp current can be individually controlled.

3. Apparatus (1) according to claim 1 or 2, characterized in that the arc lamps (15) can be controlled in direct current operation.

4. Apparatus (1) according to one of the claims 1 to 3,
characterized in that the arc lamps (15) can be controlled in
a pulsed manner as flash lamps.

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5. Apparatus (1) according to one of the preceding claims,
characterized in that the arc lamps (15) are fluid cooled.

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6. Apparatus (1) according to one of the preceding claims,
characterized in that the gas discharge zone of the arc lamps
(15) corresponds essentially to a dimension of the substrate
(2).

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7. Apparatus (1) according to one of the preceding claims,
characterized in that the gas discharge zone of the arc lamps
(15) is longer than a dimension of the substrate (2).

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8. Apparatus (1) according to one of the preceding claims,
characterized in that the arc lamps (15) are disposed in the
region of the outer periphery of the substrate (2).

9. Apparatus (1) according to one of the preceding claims, characterized in that the heating device is provided with a bank of lamps with at least two rod-shaped lamps (15;16) disposed nearly parallel to one another.

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10. Apparatus (1) according to one of the preceding claims, characterized in that the glow lamps (16) and the arc lamps (15) essentially have the same dimensions.

11. Apparatus (1) according to one of the preceding claims characterized in that the glow lamps (16) and the arc lamps (15) essentially have the same lamp power.

12. Apparatus (1) according to one of the preceding claims, characterized in that the heating device (12;14) is surrounded by a chamber (4) that is reflective at least in sections stages for the electromagnetic radiation.

13. Apparatus (1) according to claim 12, characterized in that the spectral reflection coefficient of the chamber (4) is dependent upon position.

5 14. Apparatus (1) according to one of the preceding claims, characterized in that the spacing of the heating device (12;14) to a surface of the substrate (2) is less than the diameter of a reaction chamber (22).

10 15. Apparatus (1) according to claim 14, characterized in that the ratio between spacing and diameter is less than 0.5.

15 16. Apparatus (1) according to one of the preceding claims, characterized in that the radiation characteristics of the electromagnetic radiation of the heating device (12;14) can be modulated.

20 17. Apparatus (1) according to one of the preceding claims, characterized in that the heating device (12;14) and/or the substrate (2) is disposed in a nearly homogeneous, adjustable magnetic field, the lines of flux of which, at least in the vicinity of the arc lamp anode have a component that

extends essentially parallel to the arc discharge of the arc lamps (15).

18. Apparatus (1) according to claim 17, characterized in that the magnetic flux density of the magnetic field is between 0.005 and 0.3 tesla.

19. Apparatus (1) according to one of the preceding claims, characterized by a second heating device (12;14), whereby the substrate (2) is disposed between the heating devices (12; 14).

20. Apparatus (1) according to one of the preceding claims, characterized by a reaction chamber (20) that essentially surrounds the substrate (2) and is nearly transparent for the electromagnetic radiation of the heating device (12,14).

21. Apparatus (1) according to claim 20, characterized in that the reaction chamber (20) is provided with quartz glass and/or sapphire.

22. Apparatus (1) according to one of the claims 20 or 21,
characterized in that the reaction chamber material has an
absorption coefficient between 0.001 per cm and 0.1 per cm
averaged over the spectrum of the electromagnetic radiation.

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23. Apparatus (1) according to one of the claims 20 to 22,
characterized in that the reaction chamber (20) has a wall
thickness between 1mm and 5cm.

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24. Apparatus (1) according to one of the preceding claims,
characterized in that the glow lamps (16) have at least in part
a helical filament structure.

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25. Apparatus (1) according to one of the preceding claims,
characterized in that a predefined geometrical and spectral
radiation profile can be achieved by means of the filament
structure of the glow lamps (16).

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26. Apparatus (1) according to one of the preceding claims,
characterized in that the filament of the glow lamps (16) has
alternating helical and non-helical filament structures.

27. Apparatus (1) according to one of the preceding claims,
characterized in that at least one glow lamp (16) has at least
two individually controllable filaments.

5 28. Apparatus (1) according to one of the preceding claims,
characterized in that at least one filament of a glow lamp (16)
has at least three electrical connections.

10 29. Apparatus (1) according to one of the claims 24 to 28,
characterized in that the density thickness of at least one filament
structure varies along the filament.

30. Apparatus (1) according to one of the preceding claims,
characterized in that the glow lamps (16) are halogen lamps.

15 31. Apparatus (1) according one of the preceding claims,
characterized in that a reaction chamber (20) and/or
lamp bodies form a frequency filter for at least one wave
length range of the electromagnetic radiation of the heating
20 device (12;14).

32. Apparatus (1) according to one of the preceding claims,
characterized in that at least one of the lamps (15,16) is filled
at least in part with a material that absorbs a specific wave
length range of the electromagnetic radiation of the heating
device (12; 14).

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33. Apparatus (1) according to one of the preceding claims,
characterized in that the material is essentially non-emitting
in the absorption range.

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34. A method for the thermal treatment of substrates (2), especially
semiconductor wafers, with at least one heating device
(12;14) for heating at least one substrate (2) by
electromagnetic radiation, whereby the heating device
(12;14) includes at least two arc lamps (15) and glow lamps (16),
characterized in that the radiation characteristics for each arc
lamp are individually controlled, and the electromagnetic
radiation of the arc lamps (15) contributes at least 1/10 to the
power density of the electromagnetic radiation of the heating
device (12,14).

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35. Method according to claim 34, characterized in that the operating mode and for the lamp current of the arc lamps (15) is individually controlled.

5 36. Method according to one of the claims 34 or 35, characterized in that the arc lamps (15) are controlled in direct current operation.

10 37. Method according to one of the claims 35 to 37, characterized in that the arc lamps (15) are controlled in a pulsed manner in flash operation.

38. Method according to one of the claims 35 to 39, characterized in that the substrate (2), in a lower temperature range, is heated essentially by means of the arc lamps (15).

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39. Method according to one of the claims 34 to 38, characterized in that the substrate (2), in a lower temperature range, is heated exclusively via the arc lamps (15).

5 40. Method according to one of the claims 38 or 39, characterized in that the lower temperature range is between room temperature and approximately 600° C.

10 41. Method according to one of the claims 34 to 40, characterized in that the electromagnetic radiation of the heating device (12;14) is modulated.

15 42. Method according to one of the claims 34 to 41, characterized by applying a magnetic field in the region of the substrate (2) and/or the heating device (12;14), the lines of flux of the magnetic field, at least in the region of the arc lamp anode, having a component that extends essentially parallel to the arc discharge.

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