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Anderson et al.

[11] **3,862,397**

[45] **Jan. 21, 1975**

[54] **COOL WALL RADIANTLY HEATED REACTOR**

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[73] Assignee: **Applied Materials Technology, Inc.,** Santa Clara, Calif.

[22] Filed: **Sept. 17, 1973**

[21] Appl. No.: **397,631**

Related U.S. Application Data

[63] Continuation of Ser. No. 237,698, March 24, 1972, abandoned.

[52] **U.S. Cl.** **219/405,** 118/49.5, 219/343, 219/349, 219/354, 219/377, 240/47, 432/31

[51] **Int. Cl.** **H05b 1/00,** F27b 5/14, F21v 29/00

[58] **Field of Search** 219/411, 343, 347–349, 219/354, 377, 405; 240/47; 432/202, 206; 118/49.5; 432/31; 34/4

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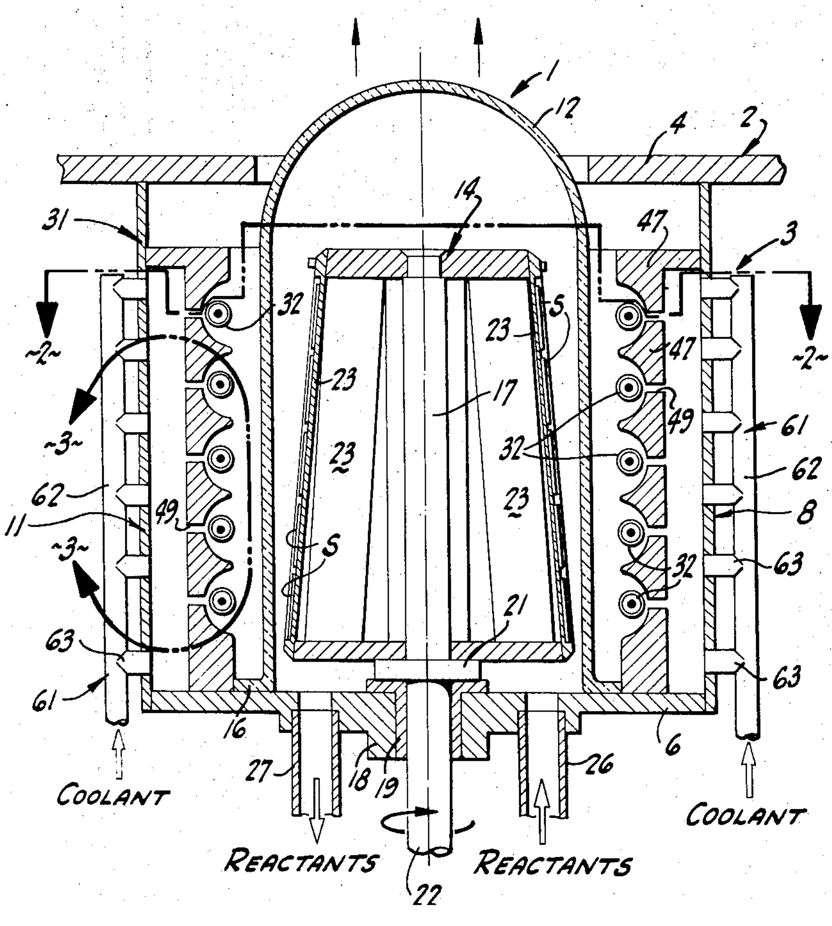
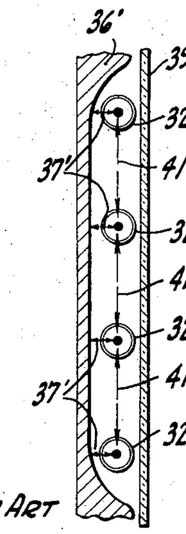
[57] **ABSTRACT**

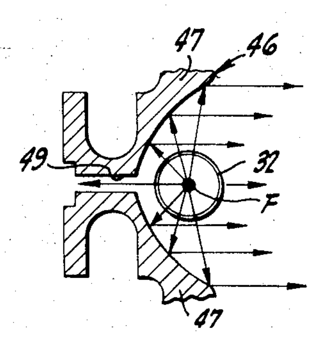
A cool wall radiantly heated chemical vapor deposition reactor includes a plurality of banks of elongated heat lamps surrounding the radiant energy transmissive wall of the reactor for heating the susceptor in the reactor on which the wafer substrates are supported. Each bank of lamps includes a segmented reflector assembly having the reflector segments spaced from each other to provide slots aligned with the lamp filaments for permitting a gaseous coolant to be introduced from a cooling structure into contact with the lamps and with the wall of the reactor and which precludes direct reflection of radiant heat back on the lamp filaments which would cause damage thereto and shorten lamp life. Furthermore, reflector segments are arranged to isolate the individual lamps in each bank from each other to further enhance lamp life by precluding direct filament-to-filament radiation transfer between adjacent lamps. The reflector segments are hollow and the cooling structure is designed to introduce the gaseous coolant directly into the hollow interior of the reflector segments from which the coolant thereafter circulates through the slots and over the lamps. Each reflector segment may also be provided with conduit means through with a liquid coolant is circulated to additionally cool the segments.

5 Claims, 9 Drawing Figures





PRIOR ART



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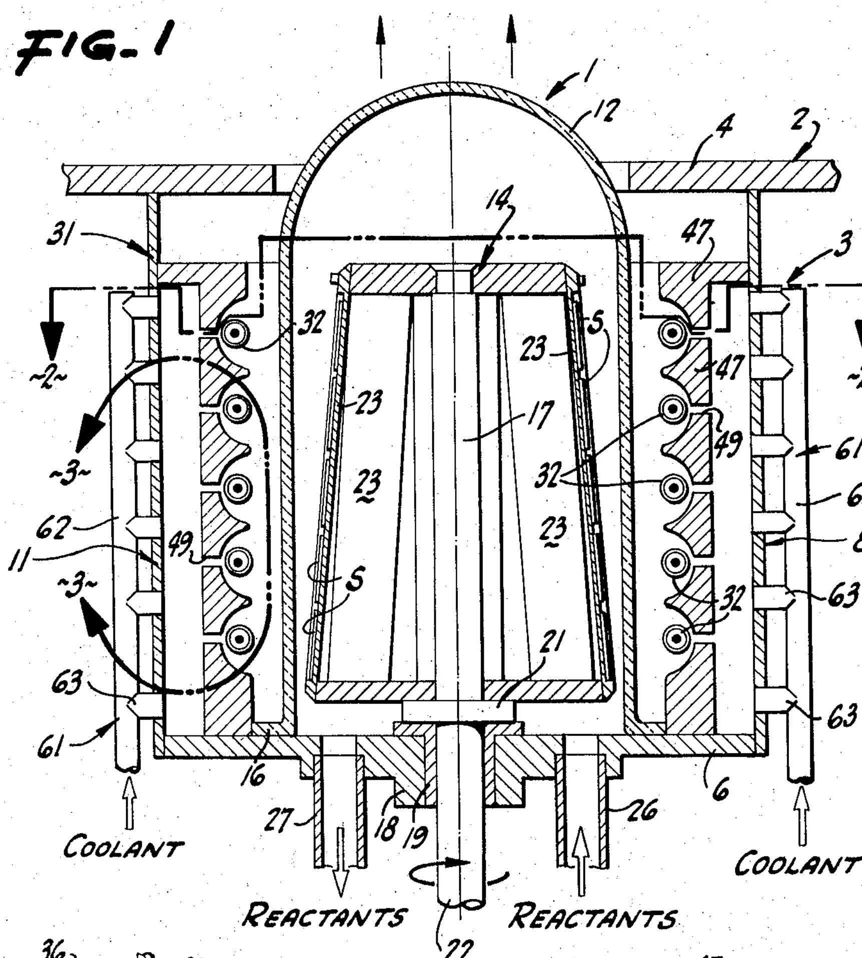
2 Sheets-Sheet 1

FIG. 1



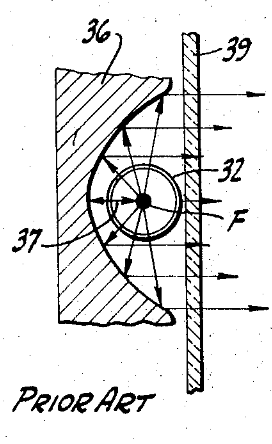


FIG. 4

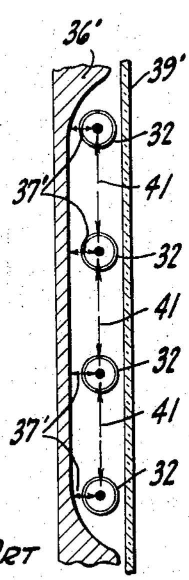


FIG. 5

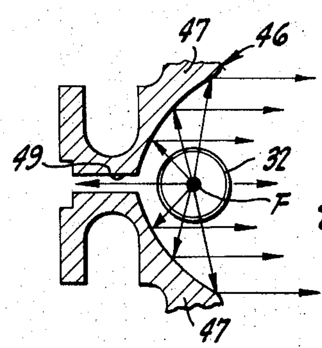


FIG. 6

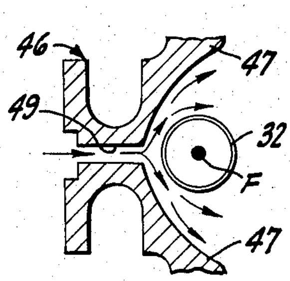


FIG. 7

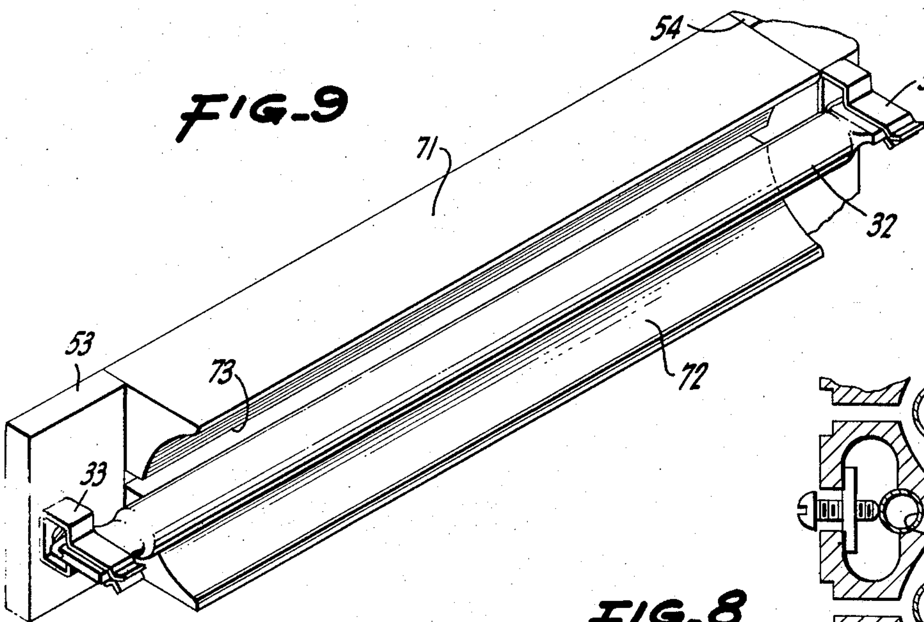


FIG-9

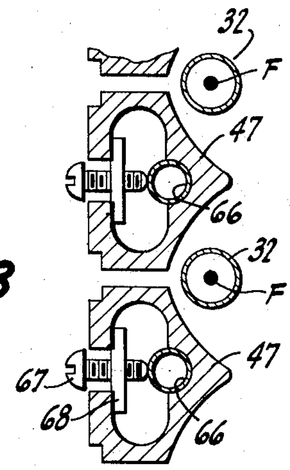


FIG-8

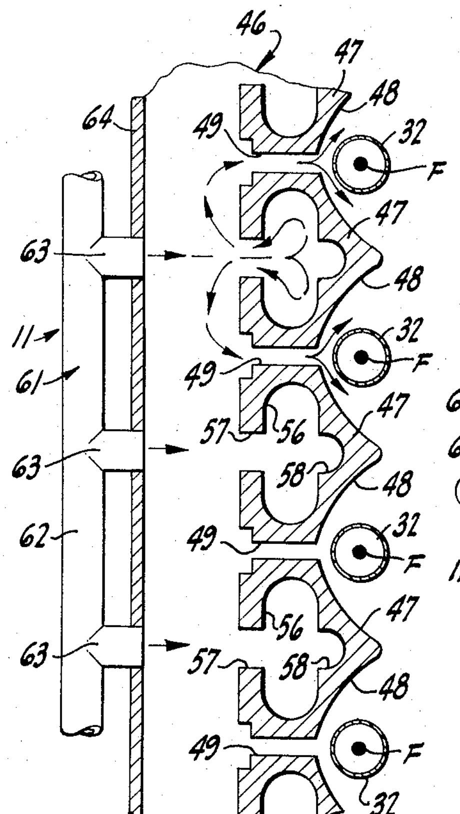


FIG-3

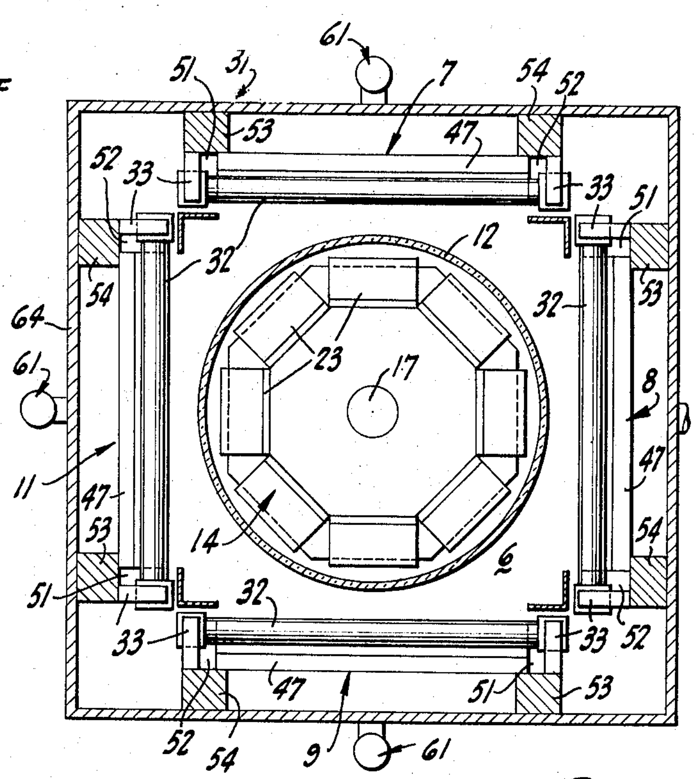


FIG-2

COOL WALL RADIANTLY HEATED REACTOR

This application is a continuation of application Ser. No. 237,698, filed Mar. 24, 1972 and now abandoned.

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to the field of radiant energy assemblies. More particularly, the field of this invention involves radiant energy sources for transmitting heat energy against a surface to be heated thereby. This invention further relates to the field of high temperature radiant heat lamps, and reflectors therefor, such as high intensity lamps capable of producing and transmitting radiant heat energy at short wave lengths, such as approximately one micron.

Still more particularly, this invention relates to the field of utilization of radiant heat energy in the heating of silicon or like wafer substrates used in the production of semiconductor devices while chemical vapor films are deposited on such substrates. This invention further relates to the field of means for cooling high temperature radiant heat sources and for prolonging the useful life of high temperature lamps utilized as radiant heat sources.

Description of the Prior Art

Radiant heat sources comprising one or more radiant heat lamps utilized to heat silicon wafer substrates or susceptors supporting such substrates in the production of semi-conductor devices have been known heretofore. However, so far as is known, the particular reflector assembly and cooling structure embodied in the heat source of the present invention has not been known or utilized heretofore. The reflector assembly of the present invention has been designed to enhance lamp life and efficiency, by facilitating cooling of lamps used as a source of high temperature radiant heat, and by minimizing lamp damage by eliminating reflected radiation which heretofore has been directed back against the lamp by prior known reflector assemblies.

By way of example of one desirable field of use of the present invention, in chemical vapor deposition systems, it is highly desirable to carry out the deposition reaction in a cold wall type reaction chamber. By maintaining the reaction chamber walls in the relatively unheated state, such walls receive little or no film deposition thereon during substrate coating. Cold wall systems are additionally desirable because they insure the deposition of high purity films on the substrates being coated. Impurities can be evolved from or permeate through heated reaction chamber walls. Thus, because such impurities would interfere with and adversely affect the purity of the substrate coating, cold wall reaction chambers preferably are employed.

Cold wall chemical vapor deposition processes have been developed which permit heating of the substrate positioned within a reaction chamber without simultaneously heating the reaction chamber walls. Such processes frequently involve the use of radio frequency (RF) induction heating of a graphite susceptor positioned within a reaction chamber, the walls of which are formed of non-conducting material, such as quartz. However, RF heating of graphite or like susceptors positioned within a quartz reaction chamber has inherent drawbacks which are well known in the art.

As a result, improved cold wall reactors have been devised within recent years to replace the prior known RF reactors used in conjunction with the vapor deposition of oxide, nitride, metal or other similar films on substrates. Such improved reactors and processes overcome the disadvantages of prior known RF induction heated systems by utilizing radiant heat sources which transmit heat energy from a radiant heat lamp positioned outside a transparent reaction chamber. The wave length of the radiated heat energy and of the material from which the reactor walls are formed are selected so that the radiant heat energy is transmitted through the walls of the reaction chamber with minimal absorption so that the walls remain essentially unheated.

The radiant heat source utilized preferably comprises one or more high intensity, high temperature lamps which operate at a filament temperature in the range of 5,000° to 6,000°F., by way of example. Such lamps may be selected from the type which produce radiant heat energy in the short wave length range of, for example, approximately one micron. Radiant heat energy at such short wave length passes through material found suitable for defining the walls of the reaction chamber, of which quartz is preferred. Quartz possesses excellent radiant energy transmission characteristics at the short wave length noted so that minimal radiation is absorbed by the walls, thus insuring the advantages of cool wall reaction systems as noted previously to preclude the deposition of chemical vapor films on the reactor walls during a chemical vapor deposition procedure.

Prior to the subject invention, however, the useful life of lamps utilized to emit radiant heat energy in a chemical vapor deposition reaction or other procedure was shortened because of difficulty in providing adequate coolant in conjunction with the lamp to overcome the high filament temperatures at which such lamps operate. Additionally, because such lamps normally are utilized in conjunction with a highly polished reflector structure to insure maximum heat transfer to the articles being heated, radiant energy emanating from the filaments of the lamps was directed back onto such filament, or onto the filaments of adjacent lamps, which resulted in lamp damage and shortened lamp life.

The present invention relates to an improved radiant heat lamp reflector assembly and cooling structure, particularly as the same is utilizable in conjunction with a chemical vapor deposition reactor. Thus, the advantages of use of radiant heat energy generally recognized as favorable in conjunction with a cool wall reaction chamber is retained while improved lamp life is insured.

In applicants' assignee's McNeilly et al. U.S. Pat. No. 3,623,712, dated Nov. 30, 1971, and in applicants' assignee's pending Rosler application Ser. No. 208,732, filed Dec. 16, 1971, improved cool wall radiation heated systems are disclosed which were designed to replace the RF type and other previously known reaction systems utilized theretofore. In that regard, the subject invention is illustrated and described herein in conjunction with one of the reactor embodiments disclosed in said Rosler application but it should be understood that utility of the present invention is not restricted to such an environment and that the same may be utilized in conjunction with the other reactor construction shown in the Rosler application as well as with the various reactor structures shown in said

McNeilly et al. patent, as well as in other environments.

SUMMARY OF THE INVENTION

This invention relates generally to an improved heat source. More particularly, this invention relates to an improved radiant energy heat source well suited for use in conjunction with a chemical vapor deposition apparatus, or other apparatus requiring a heat source in conjunction therewith. Still more particularly, this invention relates to an improved radiant lamp assembly, and associated cooling structure, well suited for use in conjunction with a cool wall chemical vapor deposition reactor, and to improved reflector means which permits lamp coolant to be effectively circulated relative to the lamp assembly and reaction chamber associated therewith, and which precludes the reflection back of radiant energy onto the filaments of the lamps or onto the filaments of adjacent lamps.

While this invention is disclosed herein in conjunction with a chemical vapor deposition reactor, it should be understood that its utility is not so limited and that the same is applicable in any apparatus or system requiring radiant energy transmission and the reflection and focusing of such energy onto an object to be heated. That is, while this invention has particular utility in conjunction with a chemical vapor deposition system for coating substrates with various types of known films, including epitaxial, polycrystalline and amorphous films, its utility is not so limited. Similarly, while this invention is disclosed herein in conjunction with a particular type of chemical vapor deposition reactor, it should be understood that utility of this invention in conjunction with other types and constructions of reactors also is contemplated.

To prolong the life of each lamp utilized as a heat source in the manner noted, the reflector of this invention which is associated with such a lamp is provided with improved means which defines a slotted base structure through which a suitable coolant, such as air, may be introduced along the length of the lamp. With tubular radiant heat lamps of the type commonly utilized for the noted purpose, such coolant introduction along the length of the lamp is particularly important. Heretofore, coolant, such as air, necessarily was introduced and passed longitudinally of the tubular lamps; such coolant circulation along the length of the lamp was less than fully effective.

Additionally, with prior known lamp reflector assemblies not possessing the slotted base structure of the present invention, radiant energy emanating from the filament of the lamp was reflected directly back onto the lamp, resulting in damage, due to overheating, to the transparent quartz envelope surrounding the lamp filament and to the seals at the lamp ends, with attendant shortened lamp life and lowered lamp efficiency. With the subject invention, the slotted base structure of the reflector also provides an exit passage for radiant heat energy emanating from the filament so that damaging reflection of radiant energy back to the lamp is precluded.

In a modified embodiment, a suitable liquid, such as water, may be introduced into the reflector assembly to further assist in cooling the same.

From the foregoing, it should be understood that objects of this invention include the provision of an improved radiant heat lamp source; the provision of means for prolonging the effective life of a radiant heat lamp source; the provision of an improved reflector assembly and associated cooling structure for a radiant heat lamp source and reaction chamber associated therewith; and the provision of an improved reflector assembly for a radiant heat lamp comprising slotted base means which permits a coolant to be effectively introduced into contact with the lamp and which permits the selective escape of radiant heat energy through the reflector assembly.

These and other objects of this invention will become apparent from a study of the following description in which reference is directed to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a generally schematic vertical sectional view through a chemical vapor deposition reactor showing the subject invention positioned to heat a susceptor positioned therein;

FIG. **2** is a horizontal sectional view through the reactor of FIG. **1** taken in the plane of line **2—2** of FIG. **1**;

FIG. **3** is a partial vertical sectional view, on an enlarged scale, taken generally in the area defined by line **3—3** of FIG. **1**;

FIGS. **4** and **5** are sectional views of prior art conventional radiant heat lamp and reflector assemblies;

FIGS. **6** and **7** are sectional views of a portion of a reflector assembly having the improved construction of the present invention;

FIG. **8** is a view corresponding generally to a portion of FIG. **3** showing additional cooling means provided in conjunction with the reflector assembly thereof;

FIG. **9** is an isometric illustration of a modified embodiment of the subject invention utilized in conjunction with a single lamp rather than a bank of lamps.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of radiant heat source reflectors and cooling structures are disclosed herein in conjunction with one exemplary embodiment of a chemical vapor deposition reactor of the type disclosed in the above identified Rosler application. However, full structural details of such reactor and its mode of operation are not described in detail herein. For a full understanding of the construction and operation of a radiant heated reactor of the type illustrated herein, reference is directed to the aforementioned Rosler et al. application and to the aforementioned McNeilly et al. U.S. Pat. No. 3,623,712. The chemical vapor deposition procedure effected within the reaction chamber of the illustrated reactor is fully described in said McNeilly et al. patent.

Generally, it should be understood that the reactor with which the subject radiant heat source is illustrated is designed to produce various chemical reactions and/or thermal pyrolysis reactions to deposit a variety of films on silicon wafers or like substrates. Such films include various types of epitaxial, polycrystalline or amorphous films, such as silicon, aluminum oxide, silicon nitride and silicon dioxide, as well as metal films such as molybdenum, titanium, zirconium, and tungsten, depositable in accordance with known chemical vapor deposition reactions in the presence of heat.

In that regard, the heat source illustrated desirably comprises one or more tungsten filament lamps, such as tungsten filament quartz-halogen high intensity lamps of which quartz-iodine and quartz-bromide are exemplary. Such lamps are commercially available as described in said McNeilly et al. patent. Such lamps are capable of producing high filament temperatures in the range of 5,000° to 6,000°F. The lamps chosen desirably are selected from the type which produces maximum radiant heat energy in the short wave length, preferably approximately one micron. Radiant heat energy in such short wave length passes through material found suitable for defining the walls of a chemical vapor deposition reaction chamber, of which quartz is preferred.

Reactors of the type described briefly herein have been effectively used heretofore for producing films of the type identified with film thickness uniformity of plus or minus 5 percent from substrate to substrate within a given run. Highly effective results are insured because operating temperatures can be controlled closely and uniformly with the radiant heat source described. Such operating temperature uniformity can now be even more closely controlled, and heat source life extended, by utilizing a reflector assembly and cooling structure of the present invention.

Referring first to the showing of FIGS. 1 and 2 in which an exemplary barrel type chemical vapor deposition reactor system is shown, it should be understood that the reactor structure is intended to be enclosed within a surrounding cabinet (not shown) in and on which the necessary gaseous reactant flow controls, electrical power sources and other attendant mechanisms are to be housed and mounted. For purposes of understanding the subject invention, only those portions of the reactor necessary to illustrate the environment in which the improved radiant lamp and reflector assembly is utilized have been illustrated. It should be understood that those portions of the reactor illustrated are intended to be supported within the aforementioned cabinet in any suitable fashion and that suitable power supply sources are provided for energizing the lamps shown.

The reactor illustrated in FIG. **1**, generally designated **1**, is defined by an enclosure, generally designated **2**, within which the subject heat source, generally designated **3**, is positioned. The enclosure **2** is defined by a pair of opposed upper and lower plates, **4** and **6**, the upper one of which is apertured for the purpose to become apparent.

Heat source **3**, as will be described in greater detail hereinafter, is defined by a plurality of banks of high intensity lamps capable of producing and transmitting radiant heat energy at the short wave length noted previously. As seen from FIG. **2**, heat source **3** is defined by a plurality of four banks of radiant lamps designated **7, 8, 9** and **11**, respectively. Such banks of lamps are positioned at right angles to each other to surround the reaction chamber of the reactor, which in the embodiment shown in FIG. **1**, is defined by a quartz bell jar **12** which is transparent to heat energy emanating from the heat source at the wave length noted.

The bell jar surrounds the susceptor structure **14** of the reactor which corresponds in construction to that shown in the aforementioned Rosler application. At its lower end, the bell jar is provided with a circular peripheral flange **16** which is supported upon the lower plate **6** of the enclosure **2**.

Susceptor **14** includes a vertically extending shaft **17** which extends upwardly through a boss **18** provided in lower plate **6** and through a bearing **19** positioned in the boss as seen in FIG. **1**. Within the reaction chamber, shaft **17** is provided with an enlarged retaining ring **21** which supports the susceptor for rotation within the reaction chamber. In that regard, the lower portion **22** of the shaft is operatively connectable with suitable means for rotating the same (not shown) so that the entire susceptor is rotatable within the reaction chamber in the presence of radiant heat energy emanating from the banks of radiant heat lamps surrounding the chamber.

The susceptor further comprises a plurality of graphite or like susceptor slabs, designated **23**, each of which carries a plurality of wafer substrates S to be chemically vapor deposition coated in the known manner. In that regard, each of such slabs is separable from the supporting framework of the susceptor when the bell jar is removed from around the susceptor by raising the same in the direction of the arrows shown at the top of FIG. **1**.

Suitable chemical vapor reactants are introducible into the reaction chamber through a conduit **26** for contacting the substrates to be coated in the presence of heat emanating from the radiant heat source. The spent gaseous reactants are withdrawable from the reaction chamber through a conduit **27** after the reactants have been maintained in contact with the substrates for a suitable period of time to effect the desired chemical coating reaction.

During introduction of gaseous reactants into the reaction chamber, the susceptor structure **14** preferably is rotated by the means noted previously to insure uniform heating of all substrates to be coated. While such rotation is not required under all circumstances, relatively slow rotation in the range of approximately **10-15** revolutions per minute has been found effective to insure uniform heating of the susceptor slabs **23** and substrates carried thereby.

It will be noted from FIG. **2** that each of the lamp banks **7, 8, 9** and **11** is supported by lower plate **6** and is enclosed within a vertical framework, generally designated **31**, which extends between the upper and lower plates **4** and **6** of the enclosure **2**. The lamp banks, as seen in FIG. **1**, are generally coextensive with the susceptor to insure effective heating thereof.

In that regard, each bank of lamps comprises a plurality of vertically spaced radiant heat lamps **32** of the aforementioned type; five such lamps are illustrated in each bank in the reactor embodiment shown. It should be noted further from FIG. **2** that each of the lamps **32** is tubular in construction and elongated in configuration to extend substantially the full width of one side of the reactor enclosure. Each such lamp has a transparent envelope surrounding an elongated filament F extending longitudinally thereof which produces the infrared radiant heat energy emanating therefrom.

The combined four lamp banks, as seen in FIG. **2**, completely surround the reaction chamber to insure effective heating of the susceptor **14** positioned therein as noted. It will be noted that each lamp envelope at each of its opposite ends is sealed around a metal electrical contact which in turn is received in and clamped by a metal contact clamp, each designated **33.** Such contact clamps are operatively connected with a suitable electrical source (not shown) in known fashion. Thus, to replace a lamp it is merely necessary to slip the same from its associated pair of electrical contact clamps and substitute a new lamp therefor, as may be required.

Heretofore the life of such lamps has been unnecessarily shortened because of the inability to effectively cool the same, and furthermore because of the contact of radiant energy with the lamp which is reflected from the lamp itself or emanates from an adjacent lamp in a bank of lamps. The present invention obviates the cooling problem noted, as well as the radiant energy problem noted by including in the lamp assembly an improved reflector assembly and cooling structure.

Before describing the preferred embodiment of the improved reflector assembly and cooling structure of this invention, reference is directed to FIGS. **4** and **5** which illustrate the problems encountered in the prior art constructions. FIG. **4** shows a standard highly polished parabolic metal reflector of the type commonly used and readily available on the market in conjunction with lamps of the type noted. Such reflector, designated **36,** is formed from any suitable reflective temperature-resistant material. A lamp **32** is positioned to extend generally longitudinally through the focal point of the reflector so that the parabolic configuration of the reflector base will direct radiant energy emanating from the filament F of the lamp back towards the body to be heated. In that regard, it will be noted by arrow **37** in FIG. **4** that a portion of the radiant energy emanating from the filament F of the lamp will strike the base of the parabolic reflector surface and will be directed thereby back onto the filament. Such reflective energy traveling back to the lamp filament tends to shorten the filament life and, accordingly, the lamp life. Also, such reflective energy causes overheating of the transparent quartz envelope surrounding the filament, which produces softening of the envelope and attendant expansion or bubbling thereof. Such reflected energy also creates oxidation of the electrical contacts at the lamp end due to overheating thereof. Thus, such conditions appreciably shorten lamp life and efficiency.

FIG. **4** also illustrates the standard procedure for cooling such radiant heat lamps, namely the utilization therewith of a coolant barrier, designated **39,** which extends longitudinally of the lamp. Such a coolant barrier comprises a transparent sheet, such as a sheet of quartz, which extends longitudinally of the reflector **36** and the lamp **32.** The purpose of such barrier sheet is to retain cooling air in contact with the lamp during operation thereof. Such cooling air is introduced longitudinally of the lamp at one end of the reflector and exits from the other end thereof. However, such longitudinal coolant flow is not fully effective and does not produce uniform lamp cooling. Additionally, the requirement for a quartz or like air barrier complicates the construction of the lamp assembly unnecessarily.

In FIG. **5** a further prior art arrangement is illustrated, which possesses the inherent disadvantages noted previously, in conjunction with a bank of lamps. As illustrated by the arrows **37′** in such figure, the problem of reflected energy from the base of the reflector **36′** onto the filaments of the respective lamps **32** is encountered. Additionally, as illustrated by arrows **41,** the embodiment of FIG. **5** has the further disadvantage in that radiant heat energy may pass directly from the filament of one lamp onto another which further shortens the lamp filament and envelope effectiveness and life as above noted. The requirement for a quartz or like for barrier **39′** with its inherent disadvantages and ineffective cooling similarly is encountered in the prior art bank of lamps shown in FIG. **5.**

In the schematic showings of FIGS. **6** and **7,** the improved features of the present invention are illustrated. Such features comprise a simple yet highly effective modification of the base of the reflector structure utilized in conjunction with a radiant heat lamp so that more effective coolant circulation around the lamps and reaction chamber **12** may be effected and so that reflected radiant energy back onto the filament of the lamp is precluded. The schematic showings of FIGS. **6** and **7** should be taken in conjunction with the detailed showing of the reflector assembly of this invention, generally designated **46** in FIG. **3.**

In the embodiment of FIG. **3,** the reflector assembly **46** comprises a reflector structure defined by a series of adjacent reflector elements designated **47** adjacent which the respective lamps **32** are positioned. The reflector assembly illustrated in FIGS. **1** through **3** is defined by a plurality of said reflector segments **47** mounted closely adjacent each other but in vertically spaced orientation relative to adjacent segments. Thus, two adjacent reflector segments **47** cooperate as seen in FIG. **3** to define a single parabolic reflector surface, designated **48,** adjacent which the respective lamps **32** are positioned.

In that regard, each reflector segment **47** is formed with a generally triangular tip portion comprising a peak lying between a pair of highly polished concave reflecting surfaces, the contour of which is designed to define the parabolic reflecting surface **48** mentioned previously when such reflector segment is positioned adjacent a similarly contoured reflector segment. However, because of the vertical spacing of adjacent reflector segments, the base of each parabolic reflector surface is provided with a discontinuous or open structure which extends the full length of the reflector. Each such discontinuous base includes a longitudinal opening or slot **49** extending therealong as seen in FIG. **3** and illustrated generally schematically in FIGS. **6** and **7.**

As noted in those latter figures, the purpose of each slot **49** is two-fold, namely to permit the introduction of coolant through the reflector assembly to pass over and around a lamp to cool the same so that the temperature thereof may be effectively controlled, and, secondly, to permit the selective escape of radiant energy emanating from the filament F of the lamp in the manner seen in FIG. **7** so that such energy is not reflected directly back onto the lamp in the manner characteristic of prior known reflector assemblies so that envelope, end seal and filament damage are obviated. Thus, efficiency and lamp life are enhanced. Also, as noted from FIGS. **1** and **2,** after the coolant passes over the lamps **32,** it contacts the wall of the reaction chamber **12,** and passes thereover prior to exiting through the apertured top of the reactor. Thus, cool wall deposition reactions as discussed hereinabove are further enhanced.

Each reflector segment **47** is mounted in its operative position by securing opposite ends **51** and **52** thereof in any suitable fashion (by bolting or bonding) to mounting blocks **53** and **54** which extend vertically of the framework **31** within which the lamp and reflector assemblies are positioned. The mounting blocks **53** and **54** may be of any suitable insulating material to preclude unwanted transmission of heat from the reflector assembly to the framework.

Each reflector segment **47** is formed from any known reflective material used in the art heretofore. The various parabolic respective reflecting surfaces **48** preferably are gold plated and are highly polished for most effective radiant heat energy transmission. The actual material from which the reflector segments are formed may be chosen from a list of ceramics or metals which are known to be capable of withstanding the substantial heat to which the segments are subjected.

As noted from FIG. **3**, each reflector segment in the embodiment illustrated preferably is hollow in construction and includes a main recess **56** extending its full length which is in communication with an open longitudinal slot **57** provided opposite from the peak between the two curved reflecting surfaces of each segment. Additionally, a generally semi-spherical extension of the main recess **56**, designated **58**, is provided in the tip portion of each reflector segment for the purpose to be described.

The hollow interior thus provided in the respective reflector segments is provided therein to admit a coolant fluid into the interior of the segments to maintain the temperature thereof at a workable level during operation of the lamp bank assembly. In that regard, provided in conjunction with the reflector assembly is a coolant manifold, generally designated **61**, defined by a main conduit **62** which is positioned in operative communication with a source of coolant fluid (not shown), such as a supply of cool air under pressure. Branching from the main conduit **62** are a series of vertically spaced branch conduits **63**, each of which is positioned to extend through openings provided in the side walls **64** of the framework **31** surrounding the lamp assembly, each such side wall forming a baffle plate positioned behind the respective reflector assemblies.

Thus, cooling fluid such as air introduced through the respective conduits **63** passes into the opening behind the reflector assembly and such cooling fluid enters the respective hollow interiors of the reflector segments **47**, circulates therein, and passes out therefrom to subsequently pass between the respective segments through the slots **49** to pass over the lamps **32**. As a result, the temperature of the reflector segments and of the lamps may be maintained below the critical level. Additionally, such cooling fluid also passes over the wall of the reaction chamber **12** to enhance the cool wall deposition reaction capability carried out in that chamber as discussed previously herein.

It will be noted that the branch conduits **63** are positioned generally in line with the slots **57** provided in the respective reflector segments to insure direct introduction of coolant into the hollow interiors of the segments for most effective cooling thereof. With the arrangement illustrated, a cooling fluid may be introduced into contact with the reflector assembly in a manner unknown heretofore to cool the reflector segments as well as to pass therefrom into contact with the high temperature lamps **32** to maintain the temperature of such lamps at a workable level also.

FIG. **8** shows a modified arrangement for the cooling structure of the reflector assembly shown in FIG. **3** which includes additional means for introducing coolant into contact with the respective segments **47**. In that regard, each such segment is provided with a fluid conduit, such as a length of copper tubing, designated **66**, positioned in the semi-spherical extension **58** of the hollowed out interior of each reflector segment. Each such conduit extends longitudinally for the full length of its associated reflector segment and such conduit is maintained in position within the segment by means of a threaded wedge bolt **67** which passes through a threaded plate member **68** positioned within the hollow interior of each segment **47**. The wedge bolt **67** urges a conduit **66** against the bottom of extension **58** and holds the same in operative position within the respective reflector segments.

The conduits **66** may be positioned in the segments during any stage of production thereof. It should be understood that the respective conduits in turn are operatively connected with a fluid manifold (not shown) at each of the opposite ends of the respective reflector assemblies. The manifold at one end of the assembly introduces cooling fluid, such as water, through the respective conduits **66** and the manifold at the other end removes the fluid from the respective segments after the fluid has passed longitudinally the length of the respective segments.

With the arrangement shown in FIG. **8**, a gaseous coolant such as air may be introduced into contact with the reflector segments and lamps **32** in the manner described previously with respect to FIG. **3** and additionally a liquid coolant may be passed longitudinally of the respective reflector segments to further effectively cool the same.

It should be understood from the foregoing description that with the subject arrangement a reflector assembly may be fabricated to any desired size, depending upon the nature of the work piece or susceptor to be heated, merely by adding or subtracting reflector units and lamps from the assembly. In that regard, suitable fasteners, such as bolts, or other means such as bonding adhesive, may be utilized to position the reflector segments in place in the manner seen in FIG. **2.**

It should also be noted from FIGS. **3** and **8** that the peaked center portions of adjacent reflector segments **47** provide shields which prevent direct radiation from passing between adjacent lamps of the lamp bank, thereby prolonging lamp life in a fashion not possible with the prior art arrangement of FIG. **5.**

Reference is now directed to FIG. **9** for an illustration of a modified arrangement of the subject reflector structure. In the FIG. **9** embodiment, the lamp **32** is held in place in opposed clip members **33** in the manner described previously, such clip members being secured to suitable mounting plates corresponding to the mounting plates **53** and **54** described previously. Such mounting plates **53** and **54** also provide means for mounting segments of a reflector in the manner shown. In that regard, the single lamp reflector illustrated in FIG. **9** comprises a pair of spaced opposed reflector segments **71** and **72** which define a slot **73** for the passage of coolant therebetween in the manner described previously. It will be noted that each of the segments **71** and **72** forms essentially one-half of a segment of the type described previously. Additionally, each such segment is generally solid, that is, it does not include recess portions **56, 57** and **58** described previously with respect to segments **47.** However, the respective segments **71** and **72** each includes a portion of a curved reflective surface of the type noted previously with the portions of the two segments cooperating to define a parabolic reflecting surface of the type described previously. Such parabolic surface is continuous except for the slotted opening **73** passing therethrough to permit coolant to be circulated around the lamp **32** as previously noted.

With the arrangement shown in FIG. **9**, a single lamp heating unit may be employed, or a plurality of reflector units of the type shown in FIG. **9** may be positioned adjacent each other to form a composite reflector assembly useable with a bank of lamps in an arrangement similar to that shown in FIGS. **1** through **3.**

It should be understood that the slots **49** in the reflector assembly of FIG. **3** and the slot **73** in the modified arrangement of FIG. **9** may vary in width to meet particular needs. However, each such slot should have a width which is at least equal to the thickness of the filament F of the lamp with which the reflector is to be used so that radiant energy emanating from the filament and directed towards the base of an associated parabolic reflecting surface will pass through the slot and none of such energy will be reflected directly back to the lamp filament and its surrounding quartz envelope.

While the subject invention has been illustrated in conjunction with an upright reactor utilizing a generally barrel shaped susceptor of the type shown in the aforementioned Rosler et al. application, it should be understood that reflector assemblies of this invention may be utilized with horizontal reactors of the type shown in the aforementioned McNeilly et al. patent. Similarly, as previously noted, the improved reflector assembly and cooling structure illustrated herein may be utilized in conjunction with the heating or other radiant energy treatment of various other structures in addition to susceptors or substrates used in chemical vapor deposition reactors as illustrated and described herein. Furthermore, while this invention has been illustrated herein in conjunction with an elongated tubular lamp, it should be understood that the principles disclosed herein are also applicable for use in effectively cooling other high temperature lamps having configurations and sizes different from those of the lamp shown.

Having thus made a full disclosure of this invention, reference is directed to the appended claims for the scope of protection to be afforded thereto.

We claim:

1. A cool wall radiantly heated chemical vapor deposition reactor comprising in combination a plurality of banks of elongated radiant energy heat lamps for heating substrates to be treated in said reactor, each of said lamps including an elongated filament therein; a radiant energy transmissive cool wall reaction chamber in which said substrates are to be treated, said banks of lamps being oriented to generally surround said reaction chamber to transmit radiant energy through the wall thereof; a reflector assembly; for each bank comprising a plurality of adjacently disposed reflector segments; and cooling structure in conjunction with said reaction chamber and each of said lamp banks, said lamps of each bank being spaced from each other and from the wall of said reaction chamber with portions of adjacent segments of each reflector assembly being interposed between adjacent lamps to prevent direct transmission of radiant energy between the filaments of such adjacent lamps; each reflector assembly having the plurality of said reflector segments spaced from each other so that elongated generally slot shaped openings are provided between adjacent reflector segments, each of said lamps being positioned so that its elongated filament lies generally in line with one of said elongated openings, said openings being at least as wide as the width of said filaments and at least as long as the lenght of said filaments aligned therewith so that radiant energy passing in one direction from each said filament may exit length an adjacent opening so that reflection of said energy back toward said lamp filament is precluded; said cooling structure comprising dual purpose conduit means associated with each reflector assembly for introducing a coolant through said slot shaped openings of each reflector assembly, such coolant upon passing through such openings passing over each of said lamps in said bank positioned in line therewith to effect cooling of such lamps, and further passing over the wall of said reaction chamber to assist in maintaining such chamber wall cool during treatment of substrates in said reactor.

2. The combination of claim **1** in which at least some of said reflector segments are hollow and have a coolant entrance so that coolant from said cooling structure may enter said segments to cool the same internally.

3. The combination of claim **2** in which said conduit means comprises an air manifold defined by a plurality of conduit sections, each of said conduit sections being aligned with the coolant entrance extending into a hollow reflector segment, whereby coolant may be introduced directly into said reflector segments and thereafter may circulate from such segments into and through said slot shaped openings over said lamps.

4. The combination of claim **1** in which said cooling structure further includes elongated conduits positioned within at least some of said reflector segments, said conduits being operatively connected with means for introducing a coolant into said conduits for circulation therethrough and through said segments.

5. The combination of claim **1** in which said conduit means comprises an air manifold defined by a plurality of conduit sections arranged to direct air over and between said segments of each reflector assembly.

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