United States Patent

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[54] **INTERNALLY VIEWABLE MICROWAVE INDUCTION HEATER**
6 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** **219/10.55,** 219/10.43, 219/10.49
[51] **Int. Cl.** **H05b 9/06,** H05b 5/00
[50] **Field of Search** 219/10.55, 10.43, 10.49

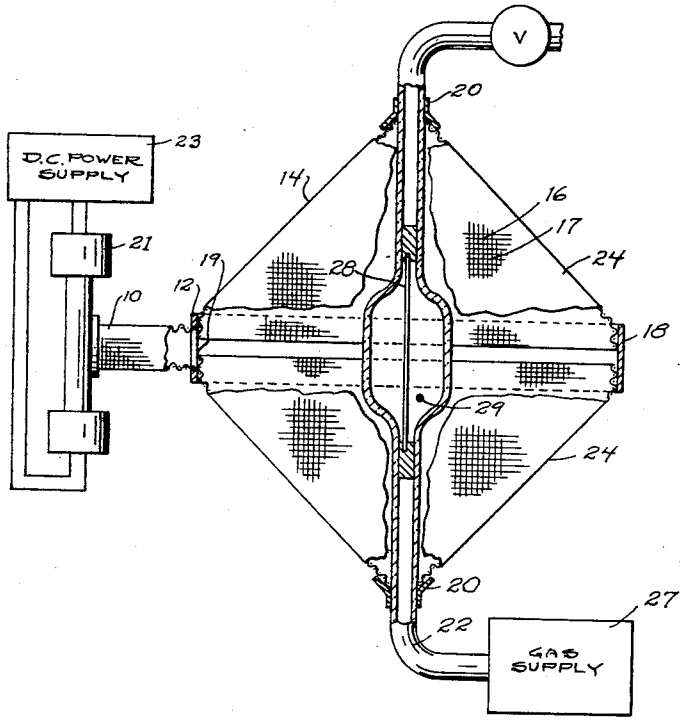
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ABSTRACT: The present invention relates to an internally viewable microwave induction heater comprised of conductive screen, the width and height of whose meshes are small compared to the wavelength of selected microwaves within said internally viewable microwave induction heater. The selected microwaves do not pass through said meshes but remain contained within the interior of said internally viewable microwave induction heater. A microwave susceptible material within said internally viewable microwave induction heater can be visually observed while it is being inductively heated.



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SHEET 1 OF 2

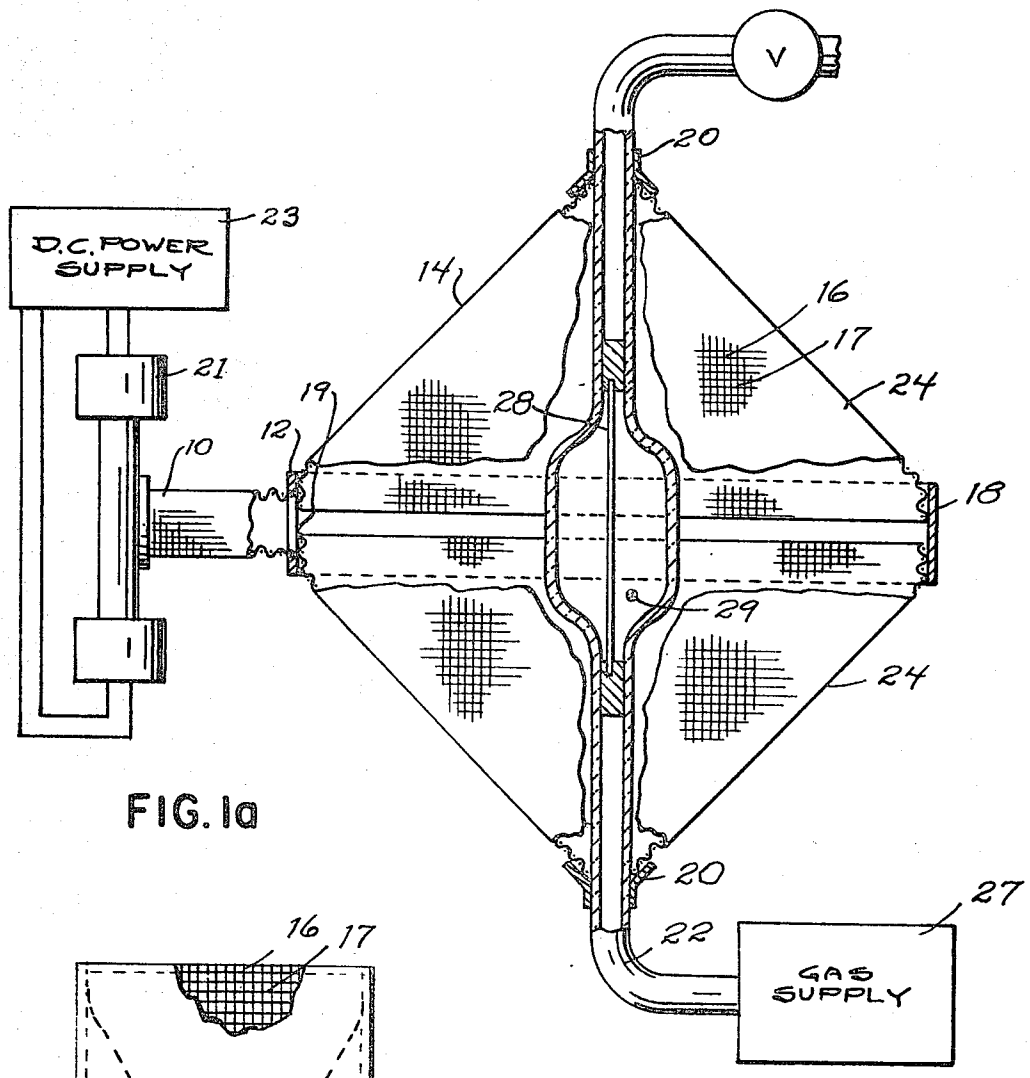


FIG. 1a

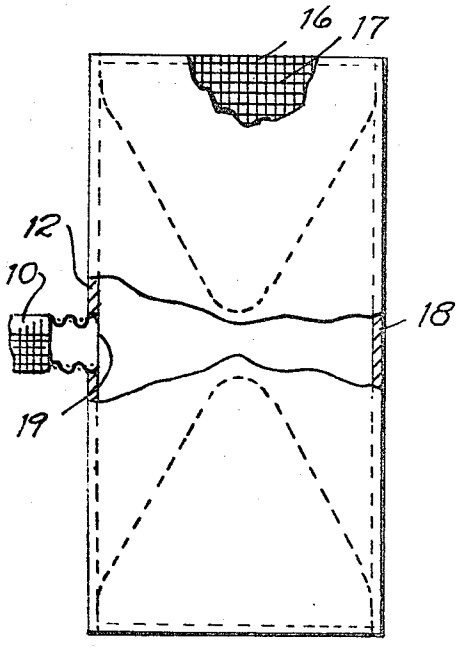


FIG. 1b

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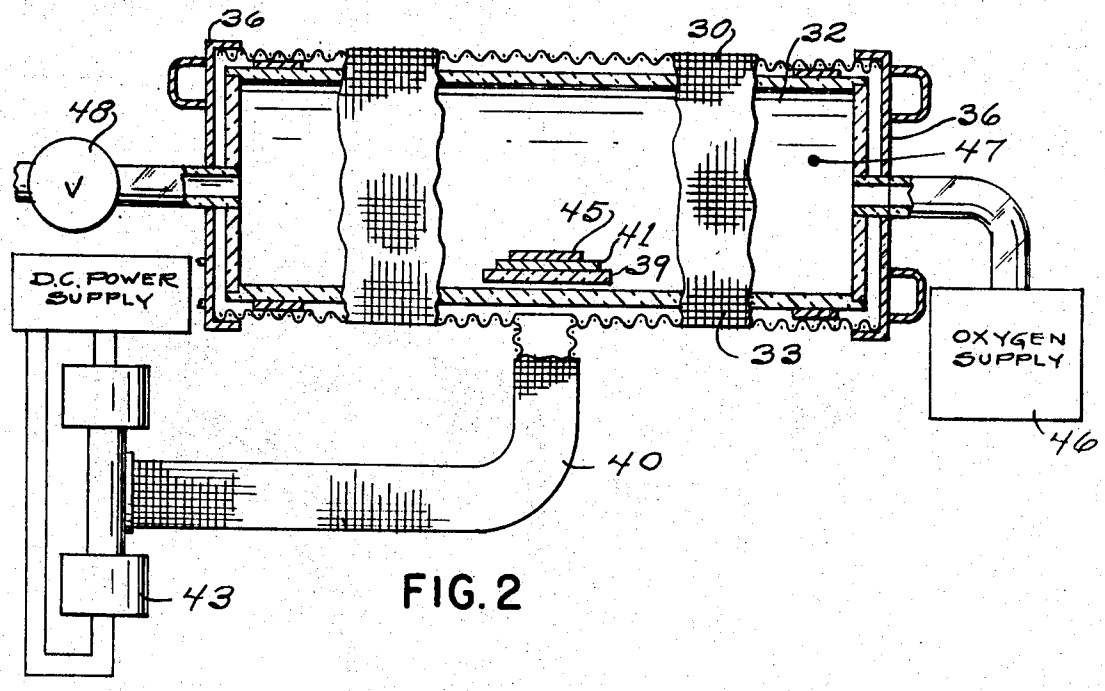


FIG. 2

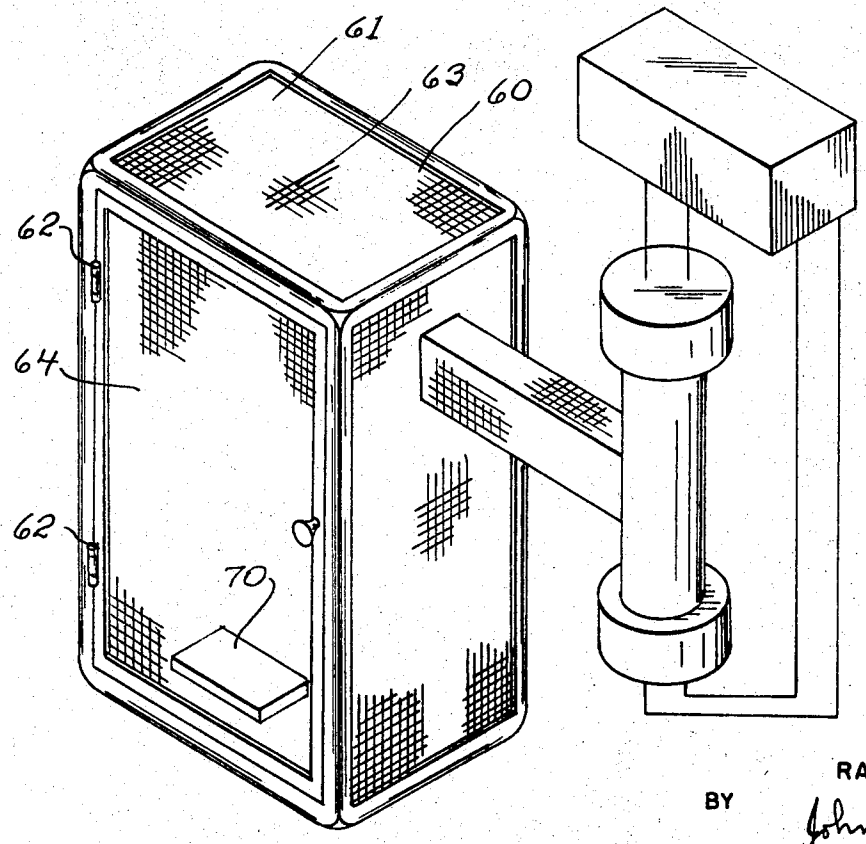


FIG. 3

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INTERNALLY VIEWABLE MICROWAVE INDUCTION HEATER

BACKGROUND OF THE INVENTION

In the prior art is disclosed a microwave cavity which is composed of a solid material which does not have closely spaced meshes therein. Such a microwave cavity is not internally viewable and easy to fabricate. Such a microwave cavity has not been used very successfully as an induction heater due to its opaqueness, difficulty to fabricate, and difficulty of operation.

The internally viewable microwave induction heater of the present invention is easily fabricated, internally viewable, and amenable of various easily designed configurations. The internally viewable cavity is fabricated from conductive screen, the width and height of whose meshes is small compared to the wavelength of selected microwaves within said internally viewable microwave induction heater. A microwave source is connected to the internally viewable microwave induction heater to allow selected microwaves to inductively heat a susceptor therein.

SUMMARY OF THE INVENTION

The present invention relates to an internally viewable microwave induction heater comprising a three-dimensionally closed, conductive screen having a microwave entrance therein, for accepting and holding microwaves within the interior of said three-dimensionally closed, conductive screen, the width and length of the meshes of the conductive screen being less than one-thirtieth of the wavelength of the selected microwaves to be within the interior of said three-dimensionally closed, conductive screen.

Accordingly, it is an object of the present invention to provide a new microwave induction heater furnace system which is capable of achieving very high specimen temperatures.

Yet another object of the present invention is to provide a new microwave induction heater which is amenable to economy of fabrication.

Still another object of the present invention is to provide a microwave induction heater which is easily placed around a desired processing space, and which may be removed with equal ease.

Still another object of the present invention is to provide a microwave induction heater which permits visibility of a specimen during its heating.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a plan view of a double-conically shaped internally viewable microwave induction heater furnace system.

FIG. **2** is a perspective view of a cylindrically shaped internally viewable microwave induction heater furnace system.

FIG. **3** is a perspective view of a rectangularly shaped internally viewable microwave induction heater furnace system for heating food.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. **1***a*, a waveguide **10**, with flanges **12** therein, is connected to a 26.5-inch long double-conically shaped internally viewable microwave induction heater **14**. The internally viewable microwave cavity **14** is comprised of conductive screen **16**, which has 1-mm. wide square meshes **17**, spaced 0.1-mm. apart by 0.1-mm. copper wire. The internally viewable double-conically shaped microwave cavity **14** is made semirigid by supporting each 12-inch long copper screen cone **24** by means of a 2.5-inch long and 4-inch in diameter brass cylinder **18**. The brass cylinder **18** has a microwave window looking into the waveguide **10** and of the same dimensions as the waveguide. Load matching is conveniently accomplished by inductive shunts, sidewall hybrid junctions, or other conventional tuning methods well known to the art. Each conductive screen cone **24** of the internally viewable microwave induction heater **14** ends in a 2-inch long and 0.25-inch internal diameter hollow copper tip **20**. A quartz furnace tube **22** passes through the hollow copper tips **20** of the internally viewable microwave cavity **14**.

Microwaves, of nominal 120-mm. wavelength, are sent from a magnetron or klystron **21** into said internally viewable microwave induction heater **14**. The power level, from a DC power supply **23** into klystron **21**, is maintained at approximately 50 watts.

The microwaves, which have a wavelength of nominally 120 mm., enter into the internally viewable microwave cavity **14** through microwave window **19** and do not escape through meshes **17**. The microwaves remain in the internally viewable microwave cavity **14** to inductively heat a 0.001-inch diameter carbon filament **28** within said quartz furnace tube **22** with radiant energy. The quartz tube **22** does not reach a temperature of over 400° C., but the carbon filament **28** is inductively raised to a temperature of 2,000° C. No appreciable amount of microwave energy is absorbed by the quartz furnace tube **22** since the quartz furnace tube is not susceptible, and it is not in the region of maximum field within the cavity. The carbon filament **28** is susceptible and is also located in the focused energy of the microwave field. No appreciable microwave energy is absorbed by the conductive screen **16** of the internally viewable microwave cavity **14**, which remains near room temperature, due to the high electrical conductivity of the copper screen **16**. However, energy is absorbed by a conductive filament such as carbon filament **28**.

Ethyl iodide doped ethylene **29** from gas supply **27** is passed through the quartz furnace tube at 200-ml. per minute. During the inductive heating of the carbon filament **28** to 2,000° c., one may observe its being coated with more carbon through the meshes **17** within the internally viewable microwave cavity **14** due to the decomposition of ethylene **29** at the site of the hot carbon filament **28**. After 5 minutes of processing, the carbon filament **28** has a large tensile strength of 140,000 p.s.i. due to it being coated with additional carbon.

When a poor conductor such as carbon is placed within the quartz furnace tube **22**, microwaves entering into the internally viewable microwave inductive heater **14** will be absorbed by said conductor so as to inductively heat said conductor. The conductor, such as a carbon filament, may be inductively heated to a temperature of over 2000° c. by means of the internally viewable microwave induction heater of the present invention.

Such an internally viewable microwave induction heater **14** may be used to grow quartz whiskers on a 0.002-inch diameter tungsten wire by passing vapors of ethyl-o-silicate gas through the quartz furnace tube **22** for 10 minutes. The inductively heated tungsten wire in the quartz furnace tube **22** may be visually inspected during the growing process within the internally viewable microwave induction heater **14**. That is, a single-crystalline material may be grown within quartz furnace tube **22**.

The preferred embodiment of FIG. **1***a* may be extended for utilization in chemical processing of gaseous or liquid streams. Thus, the tube may be extended lengthwise to become a conduit in a processing assembly. A stream of gas or liquid confined therein and flowing axially is subject to the influence of the microwave field confined to the volume bounded by the screened surfaces. Viewpoints along the conduit are so arranged that the reaction site is observable through the screened surfaces. The conic screens may also be inverted as shown in FIG. **1***b* to increase the high-voltage component of the microwave field to enhance ionization and other plasma effects which are used to advantage in the conversion of O_2 and O_3 and for other chemical processing.

FIG. **2** shows a cylindrically shaped internally viewable microwave induction heater **30** comprised of conductive screen having 1-mm. wide square meshes **33**. The internally viewable microwave induction heater **30** is built upon a quartz tube **32**. The cylindrically shaped internally viewable

microwave induction heater **30** has conductive screen caps **36**, which are attached to the ends of said internally viewable microwave induction heater **30** so as to allow a carbon susceptor **39** which can be inductively heated to be placed within the quartz furnace tube **32**. An internally viewable waveguide **40** is connected at the longitudinal center of the cylindrically shaped internally viewable microwave induction heater **30**. A silicon semiconductor wafer **41** is placed within the quartz furnace tube **32**. Microwaves having a nominal 120-mm. wavelength are entered into aid cylindrically shaped microwave induction heater **30** from a klystron **43** so as to heat the silicon semiconductor **41** to a temperature of approximately 1,100° C. Oxygen gas **47** from oxygen supply **46** is passed through the quartz furnace tube **32** at 1-liter per minute. The oxygen gas **47** passes out of said quartz furnace tube **32** through valve **48**. One can visually observe the growing of a silicon dioxide layer **45** upon the silicon semiconductor wafer **41** within the cylindrically shaped microwave induction heater **30**.

FIG. **3** shows a parallelepiped shaped internally viewable microwave induction heater **60**. The microwave induction heater **60** is comprised of conductive screen **61** having 1-mm. wide and 1-mm. high meshes **63**. The microwave induction heater has hinges **62** thereon, which support a conductive screen port **64**, so as to allow access to the interior of said internally viewable microwave induction heater **60**. A specimen **70** to be heated, such as food, can be placed within the interior of said internally viewable microwave induction heater **60**. The food **70** is heated in the microwave induction heater **60** by interaction of the food **70** and the microwave field.

I claim:

1. An internally viewable microwave induction heater comprising: a three-dimensionally closed, meshed conductive wire screen having a microwave entrance therein, for accepting and holding elected microwaves within the interior of said three-dimensionally closed, meshed conductive wire screen, the width and length of the meshes of the meshed conductive wire screen being less than one-thirtieth of the wavelength of the selected microwaves to be held within the interior of said three-dimensionally closed, meshed conductive wire screen, the thickness of the wire of the meshed conductive wire screen being approximately 0.1 mm..

2. An internally viewable microwave induction heater system, comprising:

a. A source means for supplying microwaves of a selected wave length;

b. Waveguide means connected to said source means for transferring microwaves; and

c. A three-dimensionally closed meshed conductive wire screen, microwave cavity the width and length of whose meshes are small compared to the wavelength of the selected microwaves, connected to said waveguide means to allow microwaves to enter from said waveguide means and remain therein, the thickness of the wire of the meshed conductive wire screen being approximately 0.1 mm..

3. An internally viewable microwave induction heater system comprising:

a. A source means for supplying microwaves of a selected wavelength;

b. Waveguide means connected to said source means for transferring microwaves;

c. A three-dimensionally closed meshed conductive wire screen, microwave cavity the width and length of whose meshes are small compared to the wavelength of the selected microwaves, connected to said waveguide means to allow microwaves to enter from said waveguide means and remain therein, the thickness of the wire of the meshed conductive wire screen being approximately 0.1 mm.; and

d. Susceptor means for holding a specimen thereon within said internally viewable microwave cavity, the susceptor means to be inductively heated by microwaves within said internally viewable microwave induction heater in order to heat the specimen on the inductively heated susceptor means.

4. The internally viewable microwave induction heater system of claim **3** wherein the three-dimensionally closed meshed conductive wire screen, microwave cavity is a double-conically shaped meshed conductive wire screen microwave cavity.

5. The internally viewable microwave induction heater system of claim **3** wherein the three-dimensionally closed meshed conductive wire screen, microwave cavity is a cylindrically shaped meshed conductive wire screen, microwave cavity.

6. The internally viewable microwave induction heater system of claim **3** wherein the three-dimensionally closed, meshed conductive wire screen, microwave cavity are conic surfaces held to the interior of a long tubular conduit and so arranged with vertices opposed or adjacent as to provide microwave field voltage components suitable for producting chemical or physical effects upon a process steam flowing axially therein.