(12) UK Patent Application (19) GB (11) 2 081 559 A

(21) Application No **8124008**
(22) Date of filing **6 Aug 1981**
(30) Priority data
(31) **55/108664**
55/163751
55/178332
56/050799
56/050798
(32) **6 Aug 1980**
19 Nov 1980
16 Dec 1980
3 Apr 1981
3 Apr 1981
(33) **Japan (JP)**
(43) Application published **17 Feb 1982**
(51) **INT CL³ H05B 6/72 6/76 //6/80**
(52) Domestic classification **H5H 2M 3S H1Q KA**
(56) Documents cited **GB 1546114 GB 1207511**
(58) Field of search **H5H**

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(72) and (74) continued overleaf

(54) **Microwave heating apparatus**

(57) Microwave heating apparatus comprises a microstripline 10 receiving microwaves from a coaxial line 20. The microstripline 10 comprises a center conductor 12 formed on a dielectric base plate 11, the rear surface of which is formed with a ground conductor 15, wherein a plurality of slits 14 are arranged distributed in the propagating direction of the microwaves on the center conductor12 or ground conductor 15, thereby to form a ladder circuit portion 13. A material being heated such as a paper sheet 40 is transferred on the ladder circuit portion 13, and is heated by the microwaves leaked through the slits 14. The impedances of the microstripline 10 and coaxial line 20 may be matched by adjustment, adjacent the junction therebetween, of the width of the center conductor 12, the thickness of the dielectric base plate 11 or the diameter of the central conductor 21 of the coaxial line 20; a plurality of dielectric members of different dielectric constants or one shaped dielectric member may be included between the conductors 21, 22 of the coaxial line 20. The heating area may be enclosed, dielectric resonators being provided to prevent microwave leakage.

FIG.2

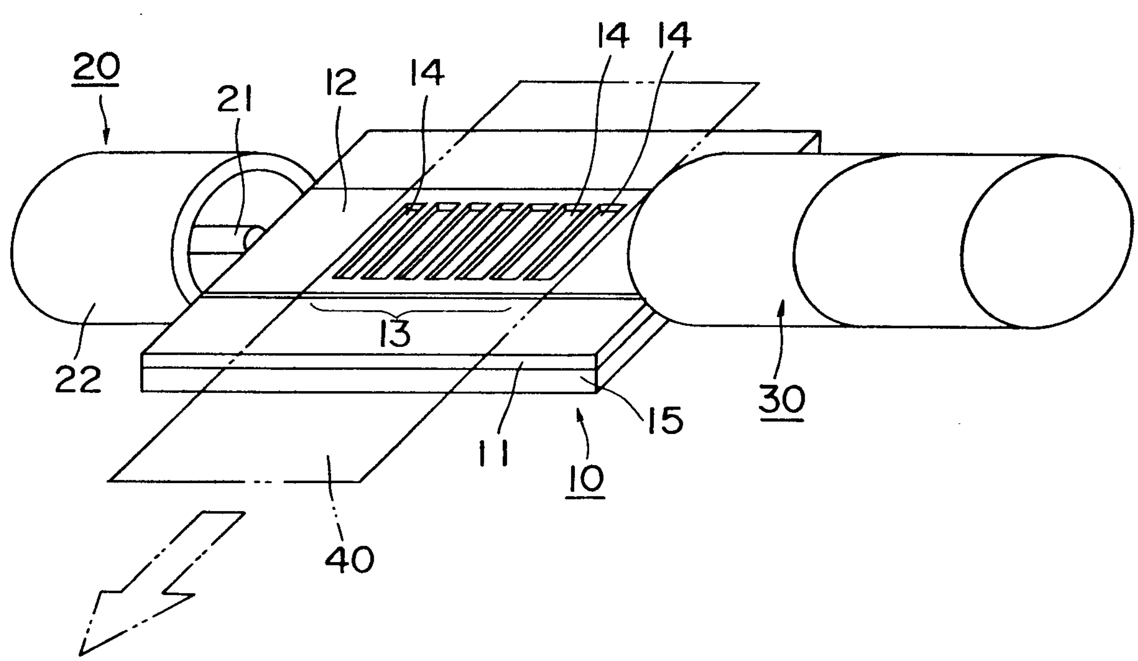

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FIG.1

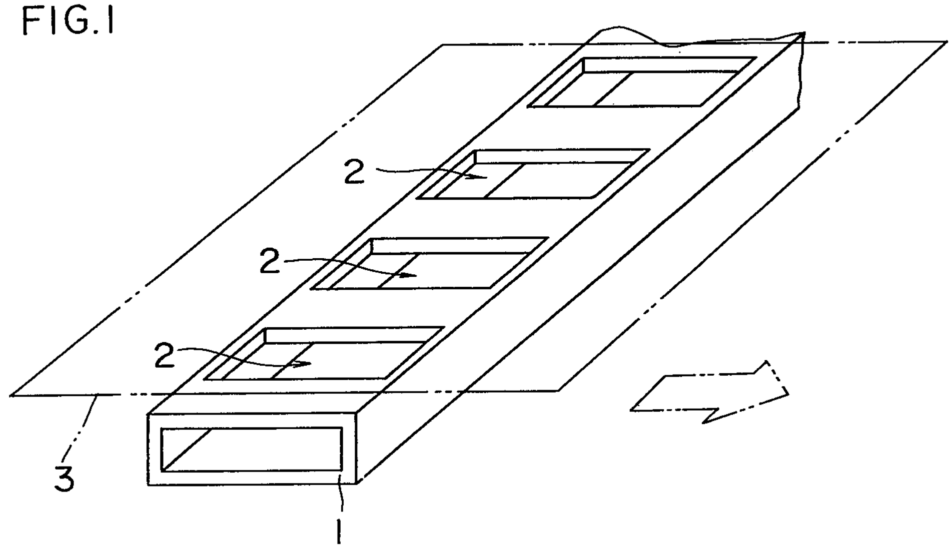


FIG.2

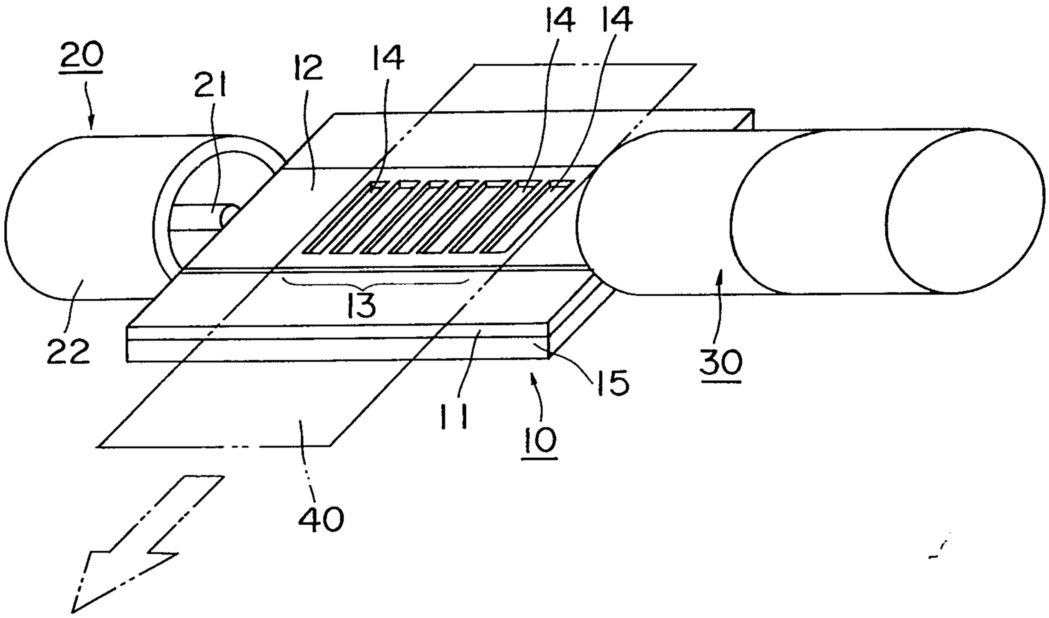


FIG.3

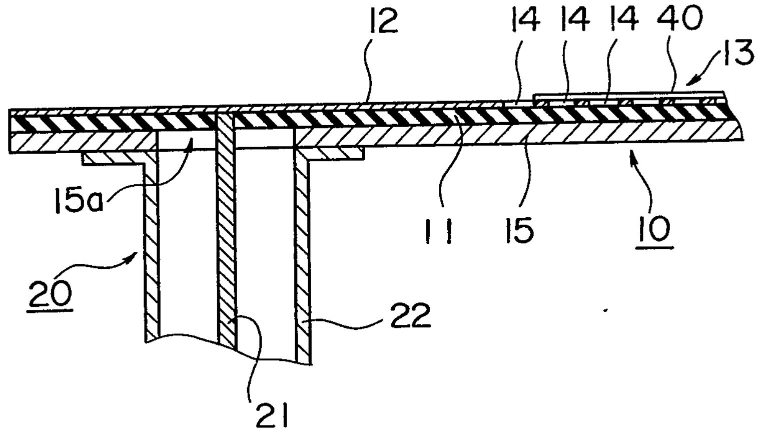


FIG.4

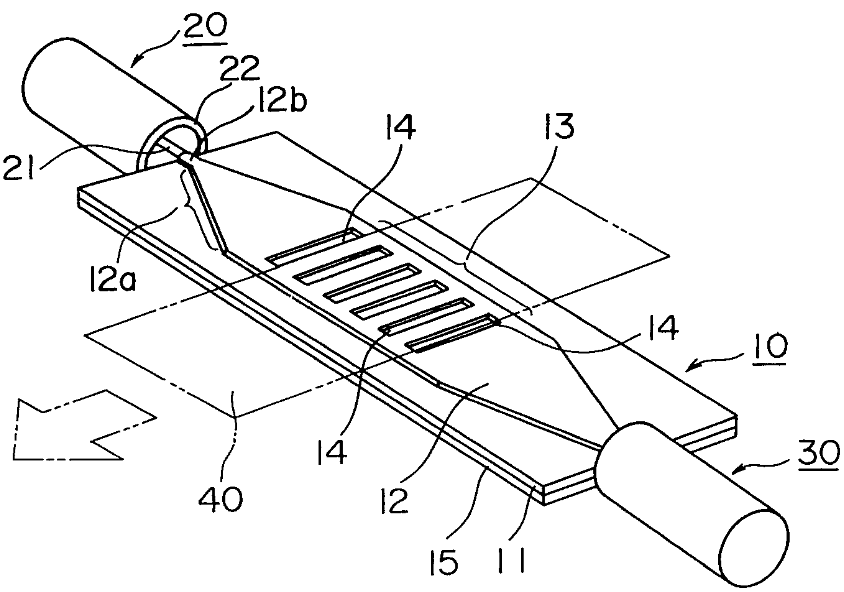


FIG.5

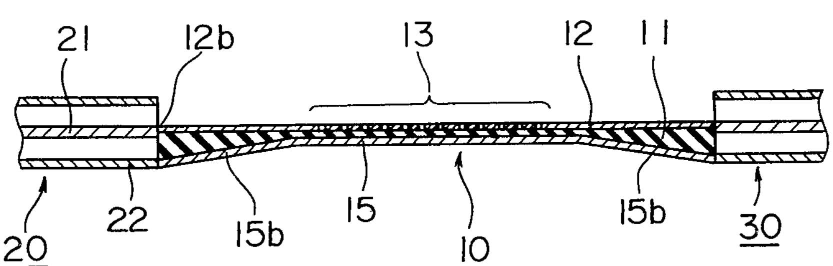


FIG.6

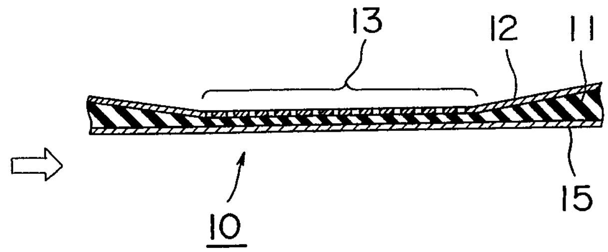


FIG.7

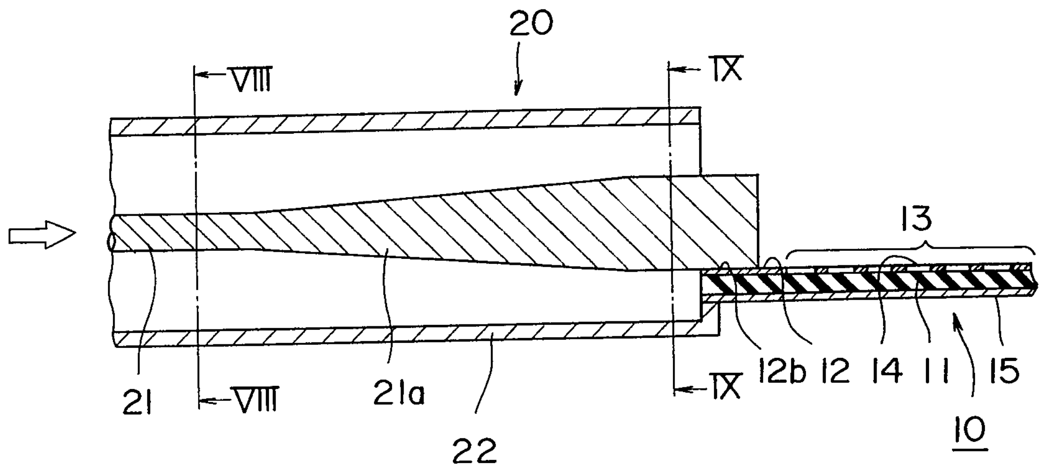


FIG.8

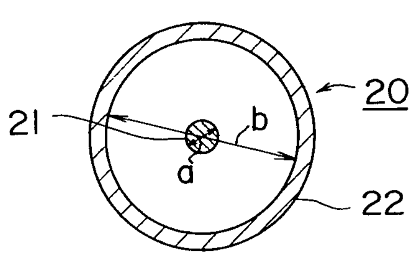


FIG.9

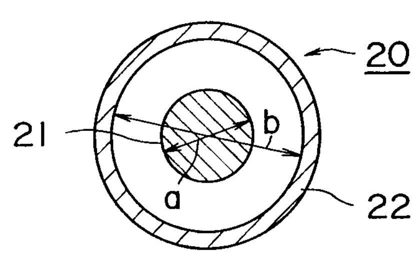


FIG.10

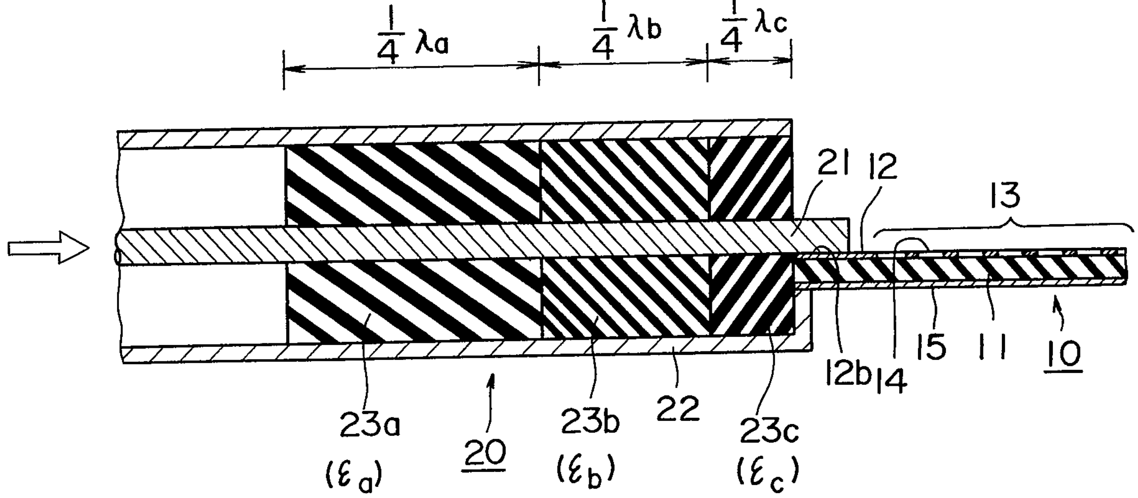


FIG.11

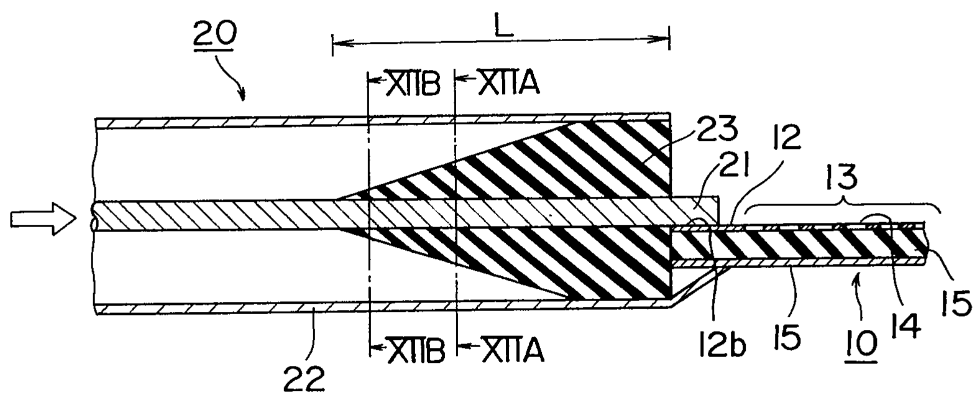


FIG.12A

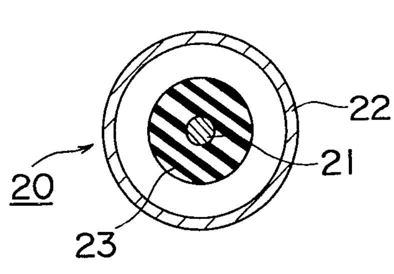


FIG.12B

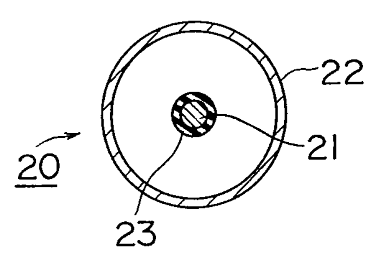
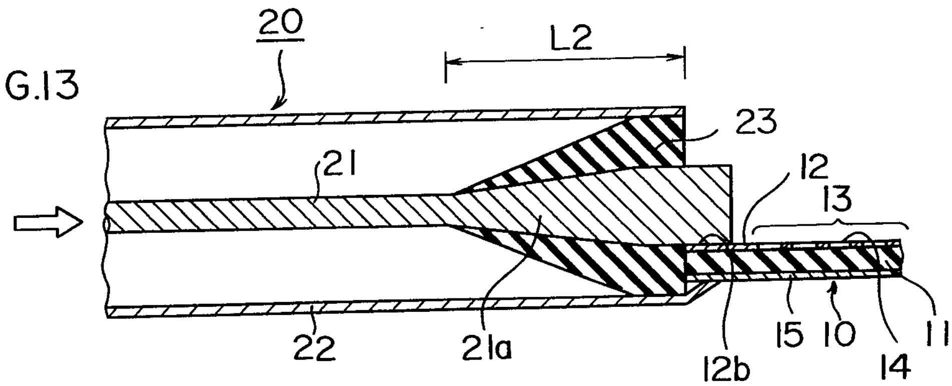


FIG.13



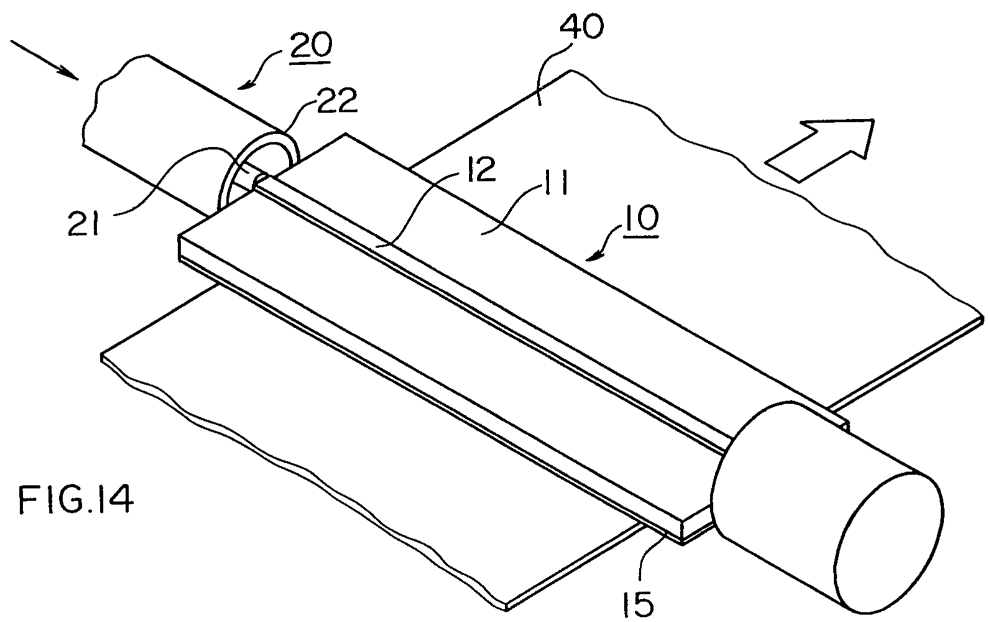


FIG.14

FIG.15

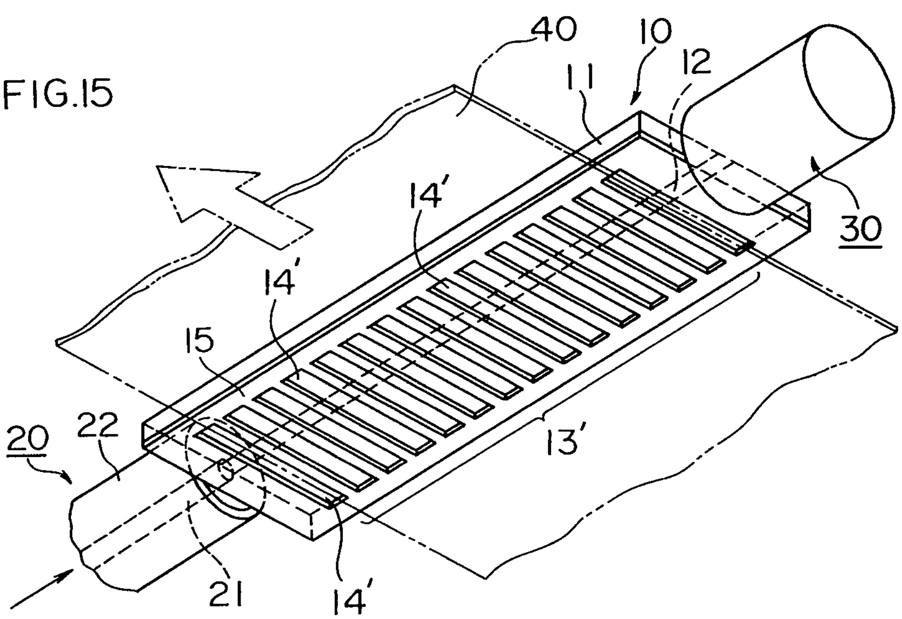


FIG.16

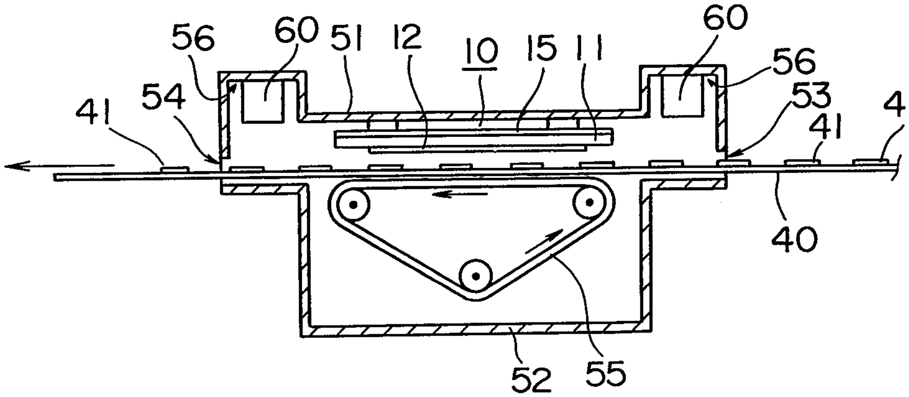

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FIG.17

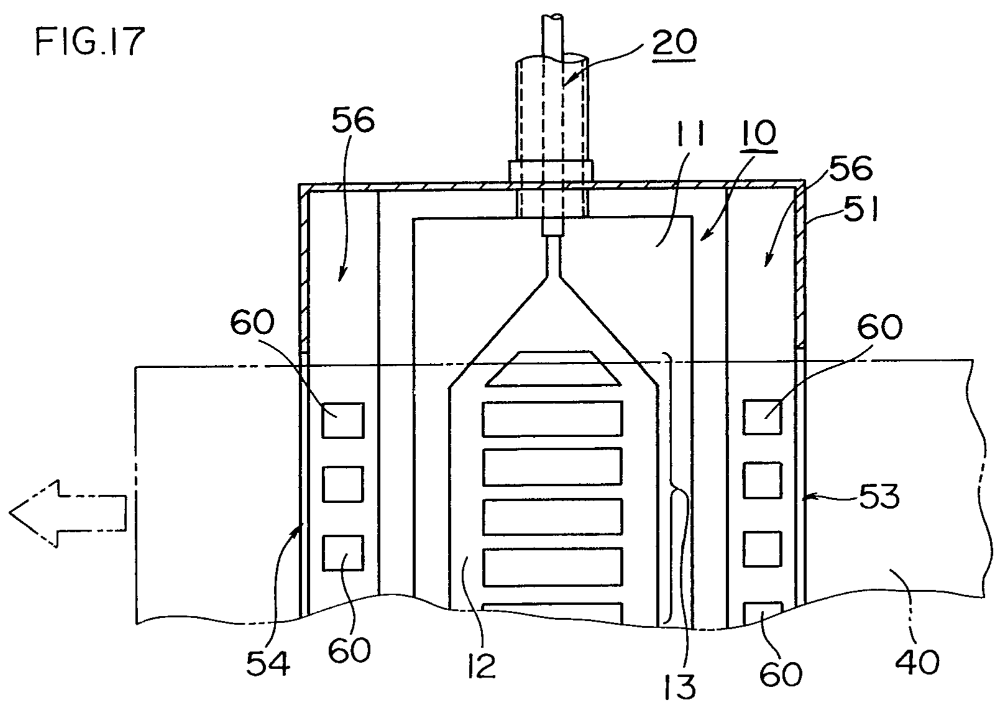
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FIG.18

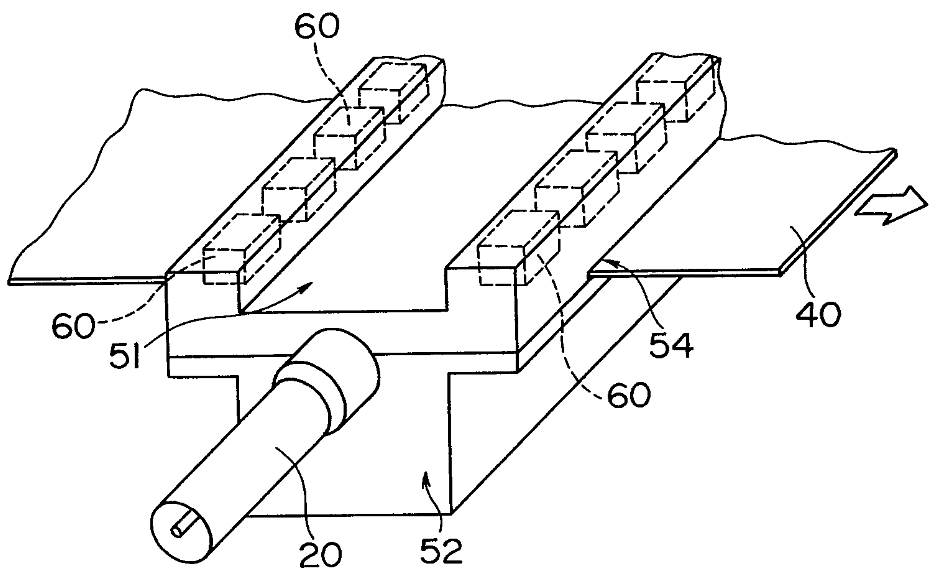
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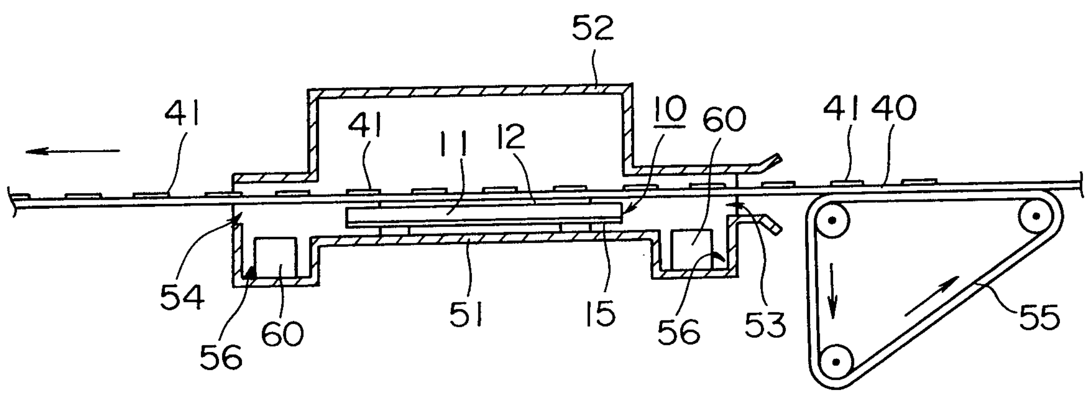
FIG.19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SPECIFICATION

Microwave heating apparatus

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention generally relates to a microwave heating apparatus. More specifically, the present invention relates to a microwave heating apparatus adapted for uniformly heating a sheet-like material such as a paper sheet and the surface of other type of a material being heated.

Description of the Prior Art

Conventionally it has been well-known that a material being heated is heated by a microwave. However, in heating a material being heated having a large surface area as compared with the volume thereof, such as a paper sheet, by the use of a conventional microwave heating apparatus, a heating efficiency is decreased and hence an electric field strength of the microwave need be increased. Accordingly, it was hardly possible to heat effectively and uniformly a sheet-like material being heated, such as a paper sheet, by the use of a conventional microwave heating apparatus.

Of late, a microwave heating apparatus adapted for heating a sheet-like material being heated using a rectangular waveguide has been proposed and is disclosed in Japanese Patent Publication No. 873/1980, for example. Fig. 1 is a perspective view showing a portion of one example of a conventional microwave heating apparatus which constitutes the background of the invention. The conventional microwave heating apparatus shown comprises a rectangular waveguide 1, having leakage openings 2 formed on the top surface thereof. When a microwave of 2450 MHz, for example, is supplied to the rectangular waveguide 1, the microwave is leaked through the openings 2. Therefore, a sheet-like material being heated, such as a paper sheet, being transferred close on the waveguide 1 is heated with the leaked microwave. According to this conventional approach, it is possible to uniformly heat a sheet-like material or the surface of a material being heated having a given thickness.

However, the Fig. 1 conventional approach still involves the shortcomings to be solved set forth in the following. More specifically, the size of a rectangular waveguide shown in Fig. 1 depends on the cut-off frequency and mode and, assuming that the frequency used is selected to be 2450 MHz, as described above, the internal geometry must be 109.2 mm × 54.6 mm. Accordingly, a microwave heating apparatus employing a rectangular waveguide as shown in Fig. 1 becomes of an increase volume. On the other hand, it has also being well-known that a microwave heating apparatus is utilized to fuse a toner in an electrophotographic machine. However, in the light of a recent demand of a small sized or compact electrophotographic machine, incorporation of such microwave heating apparatus employing a rectangular waveguide having a large volume as described above in such electrophotographic machine makes it impossible to meet such demand of small sized or compact implementation.

SUMMARY OF THE INVENTION

Briefly described, the present invention comprises a microwave heating apparatus comprising a microstripline having a center conductor and at least one ground conductor, wherein a ladder circuit is formed on the center conductor or the ground conductor, the microstripline being supplied with a microwave, whereby a material being heated, such as a sheet-like material or the surface of a material having a given thickness, placed on or traveled along the ladder circuit portion of the microstripline is uniformly heated.

According to the present invention, a rectangular waveguide having a large volume conventionally employed can be dispensed with. Therefore, a microwave heating apparatus of a very small size as compared with a conventional one is provided. Therefore, the inventive microwave heating apparatus can be advantageously utilized as a toner fixing apparatus of an electrophotographic machine, for example. However, it is a matter of course that the inventive microwave heating apparatus can be widely utilized in a case where a sheet-like material or the surface of a material being heated having a given thickness is uniformly heated. Furthermore, employment of a microstripline in lieu of a rectangular waveguide considerably reduces a material cost and a manufacturing cost as compared with those of the conventional one.

In a preferred embodiment of the present invention, a coaxial line is utilized to supply a microwave on a microstripline. The coaxial line comprises an inner conductor and an outer onductor and the center conductor or the ground conductor of the microstripline is connected to the center conductor of the coaxial line while the ground conductor or the center conductor of the microstripline is connected to the outer conductor of the coaxial line. Means for achieving impedance matching therebetween is also provided at at least one of the microstripline and the coaxial line.

In order to achieve impedance matching on the part of the microstripline, a preferred embodiment of the present invention is adapted such that the width of the center conductor or the ground conductor at a junction of the microstripline and the coaxial line is made narrower than the width of the ladder circuit portion and more preferably the width of the center conductor or the ground conductor of the microstripline is tapered to be gradually narrowed toward the coaxial line. According to the above described preferred embodiment of the present invention, impedance matching of the characteristic impedances of the microstripline and the coaxial line can be readily achieved, whereby a microwave can be effectively transferred through the junction of both the microstripline and the coaxial line.

In the case where impedance matching is achieved on the part of the coaxial line, a dielectric member having a predetermined dielectric constant is mounted at the portion for coupling to the microstripline and between the outer conductor and the inner conductor of the coaxial line. The length of the dielectric material is preferably selected to $\frac{1}{4}$ of the efective wavelength of the microwave being utilized. By thus inserting a dielectric material between the inner conductor and the outer conductor of the coaxial line, an inconvenience of necessity of an increased length of the microstripline is eliminated through impedance matching on the part of the microstripline and hence impedance matching of the characteristic impedances of both the microstripline and the coaxial line can be readily achieved. In addition, formation of the inner conductor of the coaxial line in a tapered form to be gradually wider toward the microstripline prevents a spark from undesirably occurring between the inner conductor and the outer conductor as a function of the dielectric material.

By selecting the end surface of the dielectric material inserted between the inner conductor and the outer conductor of the coaxial line opposite to the microstripline to intersect at an acute angle with respect to the axis of the coaxial line, the reflection of the microwave from the dielectric material is prevented and hence the microwave is more effectively transferred.

In another preferred embodiment of the present invention, a microstripline is housed in a heating chamber. The chamber comprises an inlet for entry of a material being heated into the inside thereof and an outlet for discharge of the same therefrom. A plurality of dielectric resonators of the TE mode are also provided in the heating chamber associated with the inlet and/or the outlet for the purpose of preventing leakage of a microwave. The resonance frequency of the dielectric resonators is selected in association with the frequency of the microwave leakage of which is to be prevented. Thus, by employing the dielectric resonators for the purpose of preventing leakage of a microwave, a leakage preventing means can be implemented in an extremely small size as compared with a case where a so-called choke cavity is employed for the same purpose.

Accordingly, a principal object of the present invention is to provide a microwave heating apparatus of a small size and an inexpensive cost.

One aspect of the present invention resides in provision of a microwave heating apparatus employing a microstripline having a ladder circuit portion formed at a portion of a center conductor or a ground conductor.

Another aspect of the present invention resides in an arrangement for achieving impedance matching between a coaxial line and a microstripline for supplying a microwave to a microstripline.

A further aspect of the present invention resides in a structure for preventing leakage of a microwave from a heating chamber.

These objects and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view showing one example of a conventional microwave heating apparatus which constitutes the background of the invention;

Figure 2 is a perspective view showing one embodiment of the present invention;

Figure 3 is a sectional view showing a modification of the Fig. 2 embodiment;

Figure 4 is a perspective view showing another embodiment of the present invention;

Figures 5 and 6 are sectional views showing a major portion of a further embodiment of the present invention;

Figures 7 to 9 are sectional views for explaining an approach for adjusting the characteristic impedance on the part of the coaxial line, wherein Figs. 8 and 9 are sectional views taken along the lines VIII–VIII and IX–IX in Fig. 7;

Figure 10 is a sectional view of still a further embodiment of the present invention;

Figures 11, 12A and 12B are sectional views showing still a further embodiment of the present invention;

Figure 13 is a sectional view shownning a modification of the Fig. 11 embodiment;

Figures 14 and 15 are perspective views showing still a further embodiment of the present invention, wherein Fig. 14 is a top view and Fig. 15 is a bottom view;

Figures 16 to 18 are views showing a preferred embodiment of the present invention, wherein Fig. 16 is a sectional view, Fig. 17 is a plan view and Fig. 18 is a perspective view; and

Figure 19 is a view showing a modification of the Fig. 16 embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 2 is a perspective view showing one embodiment of the present invention. The embodiment shown comprises a microstripline 10, a coaxial line 20 for supplying a microwave to the microstripline 10, and a dummy load 30. The microstripline 10 comprises a dielectric base plate 11 made of ceramic of alumina, for example, and a center conductor 12 is formed on the surface of the dielectric base plate 11. The center conductor 12 is formed of an electrically good conductive material, such as silver, and a ladder circuit portion 13 is formed in the part of the center conductor 12 in the length direction. The ladder circuit portion 13 comprises a plurality of leakage openings or slits 14 arranged distributed in the length direction, i.e. the propagating direction of a microwave. The microstripline 10 further comprises a ground plane or ground conductor 15 made of silver or copper, for example, formed on the rear surface of the dielectric base plate 11 so as to be adhered to. The coaxial line 20 comprises an inner conductor 21 and an outer conductor 22 and the inner conductor 21 is connected to the center conductor 20 of the microstripline 10 and the outer conductor 22 is connected to the ground conductor 15. Alternatively, the center conductor 12 of the microstripline 10 and the outer conductor 22 of the coaxial line 20 may be connected and the ground conductor 15 and the inner conductor 21 may be connected, because an electric field being applied by the microwave is an alternating electric field. More specifically, there is no restriction to the polarity between the inner conductor 21 and the outer conductor 22 of the coaxial line 20 and between the center conductor 12 and the ground conductor 15 of the microstripline 10, respectively. A microwave oscillator of such as a magnetron, not shown, is provided at the input side, i.e. at the left side as viewed in Fig. 2, of the coaxial line 20, so that the coaxial line 20 is supplied with a microwave from the microwave oscillator to supply the same to the microstripline 10. A dummy load 30 is connected to the side opposite to the input side of the microwave of the microstripline 10. The dummy load 30 is aimed to absorb and comsume a microwave not consumed by the ladder circuit portion 13, thereby to protect the microwave oscillator. Meanwhile, the length of the leakage openings or slits 14, i.e. the length in the direction intersecting the propageting direction of the microwave is selected to be slightly shorter than a half of the effective wavelength being utilized.

A microwave is supplied to the microstripline 10 through the coaxial line 20 upon energization of the microwave oscillator, not shown, in the above described structure. A portion of the supplied microwave is leaked through the respective slits 14 at the ladder circuit portion 13 formed in the center conductor 12. Accordingly, a sheetlike material being heated 40 such as a paper sheet placed on the ladder circuit portion 13 is heated by the leaked microwave. Meanwhile, by providing a transfer means such as a conveyor or a roller, not shown, such that the material being heated 40 is in succession transferred in the arrow direction, the material being heated 40 is in succession and continually heated.

Fig. 3 is a sectional view showing a modification of the Fig. 2 embodiment. In the Fig. 3 embodiment, the microstripline 10 and the coaxial line 20 are connected at the right angle. An opening 15a is formed at the ground conductor 15 of the microstripline 10. The inner conductor 21 of the coaxial line 20 is connected to the center conductor 12 of the microstripline 10 through the opening 15a. The outer conductor 22 of the coaxial line 20 is connected to the ground conductor 15 of the microstripline 10 by means of a flange portion, for example. Thus, the microstripline 10 and the coaxial line 20 need not be necessarily connected in a coplanar manner, as shown in Fig. 2, but both may be connected in an orthogonal manner. Meanwhile, the above described connection opening 15a is preferably formed in the same diameter as the inner diameter of the outer conductor 22 of the coaxial line 20.

Since the present invention employs the microstripline 10 having the ladder circuit portion 13, the same can be implemented with an inexpensive cost and in a small size as compared with a conventional one employing a waveguide. Meanwhile, since an electric field is concentratedly formed by means of the above described ladder circuit portion, even a material being heated 40 of a sheet-like form such as a paper sheet can be effectively heated.

Fig. 4 is a perspective view showing another embodiment of the present invention. In comparison with the Fig. 2 embodiment, the embodiment shown is characterized by a means for achieving impedance matching between the microstripline 10 and the coaxial 20. The characteristic impedance of the coaxial line 20 is apploximately expressed by the following equation (1).

$$Zo = \frac{138}{\sqrt{\varepsilon r}} \log \frac{b}{a} \qquad (1)$$

where ε_r is a relative dielectric constant of a medium between the inner conductor and the outer conductor, a is a diameter of the inner conductor, and b is an inner diameter of the outer conductor. The characteristic impepedance of the coaxial line 20 is a function of the diameter a of the inner conductor 21 and inner diameter b of the outer conductor 22 and usually about 50Ω. Too small a characteristic impedance increases only a conductor resistance in supplying a microwave power.

On the other hand, the characteristic impedance of the microstripline is approximately expressed by the following equation (2).

$$Zo = \frac{10^4}{3\sqrt{\varepsilon_r}\{7 + 8.83(\frac{c}{h})\}} \quad (2)$$

where ε_r is a relative dielectric constant of the dielectric base plate 11, h is a thickness of the dielectric base plate 11, and c is a width of the center conductor, i.e. the length in the direction orthogonal to the microwave propagating direction. Thus, the characteristic impedance of the microstripline 10 is increased when the thickness h of the base plate 11 is increased or the width c of the center conductor 12 is decreased, assuming that the dielectric constant of the dielectric base plate 11 is constant. Assuming that alumina is employed as a material of the dielectric base plate 11, the dielectric constant is "9". Assuming that the thickness h of the dielectric base palte 11 and the width of the center conductor are 2 mm, respectively, the characteristic impedance thereof is approximately 50Ω, which means that impedance matching with the above described coaxial line 20 is attained. However, the present invention employs the ladder circuit portion 13 having a wide width as the center conductor. The length of the slits in the ladder circuit portion 13 is selected to be slightly shorter than a half of the effective wavelength of the microwave being employed, as described previously. Accordingly, assuming that the frequency of the microwave being employed is 2450 MHz, for example, the width of the center conductor 12 in the ladder circuit portion 13 must be at least 20 mm. Accordingly, the characteristic impedance of the microstripline 10 at the ladder circuit portion 13 becomes extremely small as compared with other portion without the ladder circuit portion 13, with the result that the impedances of the coaxial line 20 and the microstripline 10 having ladder circuit portion 13 are mismatched.

Some examples shown in Fig. 4 seq are directed to a particular structure for achieving impedance matching between the microstripline 10 and the coaxial line 20.

Referring to Fig. 4, a narrow portion 12a is formed in the center conductor 12 of the microstripline 10. The narrow portion 12a is formed to be tapered to become gradually narrower from the ladder circuit portion 13 to the junction 12b, i.e. the coaxial line 20. The width is set to be approximately 2 mm in the junction 12b. Since the narrow portion 12a is formed in the center conductor 12 and the same is tapered to become gradually narrower toward the junction to the coaxial line 20, the characteristic impedance of the microstripline 10 is increased, as is clear from the above described equation (2) so that the same may be approximately commensurate with the characteristic impedance of the coaxial line 20. Accordingly, a microwave can be efficiently supplied from the coaxial line 20 to the microstripline 10.

Figs. 5 and 6 are sectional views showing a major portion of another embodiment of the present invention. The embodiments shown in Figs. 5 and 6 are aimed to achieve impedance matching with the characteristic impedance of the coaxial line 20 by changing the thickness h of the dielectric base plate 11 in the above described equation (2) and by increasing the characteristic impedance of the microstripline 10. More specifically, in the case of the embodiments shown in Figs. 5 and 6, the thickness of the dielectric base plate 11 is gradually increased in the microstripline 10 from the ladder circuit portion 13 towards the junction 12b. By gradually increasing the thickness of the dielectric base plate 11, the characteristic impedance at the input end of the microstripline 10 can be made to be approximately equal to that of the coaxial line 20. In the case of the Fig. 5 embodiment, the center conductor 12 of the microstripline 10 is maintained flat, while the thickness of the dielectric base plate 11 is changed such that the ground conductor 15 constitutes an inclined portion 15b. Conversely, in the case of the Fig. 6 embodiment, the thickness of the dielectric base plate 11 is changed such that the ground conductor 15 is maintained flat and the center conductor 12 may be inclined. By changing the thickness of the dielectric base plate 11 such that the ground conductor 15 may constitute the inclined portion 15b as in the case of the Fig. 5 embodiment, the inclined portion 15b performs a function of a ridge and accordingly an electric field strength of a microwave leaking from the ladder circuit portion 13 can be increased. The same applies to the Fig. 6 embodiment.

Fig. 7 is a sectional view showing another approach for eliminating inconveniences in the embodiments shown in Figs. 4 to 6 and constitutes the background of the invention. More specifically, in the case where the characteristic impedance of the coaxial line 20 is maintained approximately 50Ω and the characteristic impedance at the junction of the microstripline 10 is approximated thereto or is made to be matched thereto, the length in the microwave propagating direction of the microstripline, i.e. the distance between the ladder circuit portion 13 and the junction 12b becomes large. Therefore, another approach can be considered in which a large diameter portion 21a is formed in the inner conductor 21 of the coaxial line 20, as shown in Figs. 7 to 9. More specifically, the inner conductor 21 of the coaxial line 20 is adapted such that the diameter a thereof is different at the input and the output of the microwave, as shown in Figs. 8 and 9 and the diameter at the output is selected to be larger than that in the input. Since impedance matching between both can be attained by not changing the characteristic impedance of the microstripline 10, if the above described approach is employed, the distance between the ladder circuit portion 13 of the microstripline 10 and the junction 12b is prevented from being undesirably elongated, as shown in Fig. 7. However, too large a diameter of the inner conductor 21 and thus too small a difference between the diameter of the inner conductor 21 and the inner diameter of the outer conductor 22 threatens to cause a spark between the inner conductor 21 and the outer conductor 22 due to microwave power.

Therefore, Figs. 10 to 13 show embodiments having an impedance means provided on the part of the coaxial line without any fear of such spark.

The Fig. 10 embodiment comprises dielectric materials 23a, 23b and 23c inserted at the output end of the coaxial line 20. The respective dielectric members 23a, 23b and 23c have different dielectric constants ε_a, ε_b and ε_c, respectively, in which these dielectric constants are selected to be in a relation of $\varepsilon_a < \varepsilon_b < \varepsilon_c$. Generally, when different dielectric materials are laminated and a microwave is propagated in the laminating direction, a multiple reflection occurs in the lamination. However, if and when the thickness of the dielectric material, i.e. the length in the propagating direction of the microwave is selected to be a quarter of the effective wave length of the microwave being propagated, reflection from the respective lamination plates as described above is canceled, whereby undesired reflection is prevented from occurring. Therefore, in the Fig. 10 embodiment, the respective lengths of the dielectric members 23a, 23b and 23c are selected to be $\frac{1}{4}\lambda a$, $\frac{1}{4}\lambda b$ and $\frac{1}{4}\lambda c$, respectively. Meanwhile, λa, λb and λc each denote an effective wavelength of a microwave propagating through the dielectric material. Thus, by inserting a dielectric material between the inner conductor 21 and the outer conductor 22 of the coaxial line 20, the characteristic impedance Zo of the coaxial line 20 is decreased, as is appreciated from the above described equation (1). Accordingly, by properly selecting the dielectric constant of the dielectric material, the characteristic impedance of the coaxial line 20 can be further smaller than the above described 50Ω and can be approximated to the characteristic impedance of the microstripline 10. According to the embodiment shown, even if the distance between the ladder circuit portion 13 and the junction 12b in the microstripline 10 is elongated, impedance matching with the coaxial line 20 can be easily attained. In addition, it is not necessary to change the diameter of the inner conductor 21 and accordingly an undesired spark is prevented from occurring between the inner conductor 21 and the outer conductor 22. Meanwhile, although the ceramic material such as alumina, titanium oxide, etc is preferred, any other type of dielectric material may be utilized.

Fig. 11 is a sectional view showing a major portion of still a further embodiment of the present invention. Even in the case of the Fig. 11 embodiment, the dielectric member 23 is inserted between the inner conductor 21 and the outer conductor 22 at the output end of the coaxial line 20. The microwave input end surface 23d of the dielectric member 23 is formed in a conical shape such that the diameter is gradually increased in the propagating direction of the microwave with the inner conductor 21 as a center, as is clear from Figs. 12A and 12B. In other words, the end surface 23d of the dielectric member 23 is formed to have a surface intersecting the inner conductor 21 of the coaxial line 20 at an acute angle. According to the Fig. 11 embodiment, a microwave fed from the microwave oscillator, not shown, is supplied to the microstripline 10 as a function of the end surface 23d without being reflected from the dielectric member 23 and hence with high efficiency. Even in the case of the embodiment shown, the impedence matching can be readily achieved by means of the dielectric member 23.

Fig. 13 is a sectional view showing still a further embodiment of the present invention. The Fig. 13 embodiment comprises a combination of the Fig. 7 embodiment and the Fig. 11 embodiment. More specifically, a large scale portion 21a is formed in the inner conductor 21 of the coaxial line 20 and a dielectric member 23 is filled in the coaxial line 20. By doing so, the length L of the dielectric member 23 can be shortened as compared with that of the Fig. 11 embodiment. The reason is that the effect of decreasing the characteristic impedance as a function of the large diameter portion 21a formed in the inner conductor 21 and a function of decreasing the characteristic impedance through insertion of the dielectric member 23 coact with each other. According to the Fig. 13 embodiment, even if a large diameter portion 21a is formed in the inner conductor 21, an undesired spark is prevented from occurring between the inner conductor 21 and the outer conductor 22 as a function of the dielectric member 23. Meanwhile, the inclining direction of the microwave entering end surface 23d of the dielectric member 23 as shown in Figs. 11 and 13 may be reversed to that shown as a matter of course.

Figs. 14 and 15 are perspective views showing still a further embodiment of the present invention, wherein Fig. 14 is a plan view and Fig. 15 is a bottom view. As seen from the figures, the embodiment comprises a ladder circuit portion 13' formed at the ground conductor 15 of the microstripline 10, the center conductor 12 being formed in a constant width as in the case of the ordinary microstripline, as compared with the previously described embodiments. More specifically, as is different from the previously described embodiments the embodiment shown in Figs. 14 and 15 is performed with the slits 14' and thus the ladder circuit portion 13' at a portion or all of the ground conductor 15.

As is clear from the previously described equation (2), the characteristic impedance of the microstripline depends on the width c of the center conductor. The smaller the width c, the larger the characteristic impedance. Therefore, by making small the width of the center conductor 12 to be constant, as in the case of the embodiment, the characteristic impedance of the microstripline 10 is increased to be as large as approximately 50Ω as compared with a case where the width is increased by forming the ladder circuit portion 13 in the center conductor 12 as in the case of the previously described embodiments. On the other hand, the characteristic impedance of the coaxial line 20 is also approximately 50Ω, as described previously. Therefore, according to the embodiment shown, any particular structure or means for achieving impedance matching between the coaxial line 20 and the microstripline 10 could be dispensed with. For example, in the case of the previously described embodiments, the characteristic impedance of the microstripline 10 of the ladder circuit portion 13 is approximately 15Ω and that of the embodiment in discussion is approximately 50Ω.

On the other hand, it has been well-known that the characteristic impedance Zo of the microstripline 10 is

$$Zo = \frac{E}{H},$$

where E is an electric field component and H is a magnetic field component. The microstripline of the above described characteristic impedance of approximately 50Ω exhibits a large electric field component (E), as compared with that of the characteristic impedance of approximately 15Ω. Thus, the fact that the electric field component of the microwave being propagated is large means that the electric field component of the microwave being leaked through the slits of the ladder circuit portion 13' becomes accordingly large. Therefore, electric energy fed to the material being heated 40 such as a paper sheet is accordingly large. Thus, according to the embodiment shown in Figs. 14 and 15 wherein the ladder circuit portion 13' is formed not in the center conductor 12 but in the ground conductor 15, a heating efficiency is enhanced. According to the experimentation conducted by the inventors, it was observed that microwave power required for supplying the same energy in the embodiment in discussion may be approximately one tenth of microwave power required for supplying the same heating energy in any of the embodiments shown in Figs. 2 to 13. Accordingly, it is intended that the present invention broadly covers a case where the ladder circuit portion 13 is formed in the center conductor 12 and a case where the ladder circuit portion 13' is formed in the ground conductor 15.

Figs. 16 to 18 show a preferred embodiment of the present invention. The embodiment shown comprises an application of the heating apparatus employing the microstripline 10 as a toner fixing apparatus of an electrophotographic apparatus. The microstripline 10 is housed in a heating chamber and the heating chamber is formed with half shells 51 and 52. The half shells 52 are preferably made of an electrically good conductive material such as metal, electrically conductive plastic or the like in consideration of a shielding function. The half shell 51 houses and holds the microstripline 10 above a paper sheet 40 being transferred by means of a conveyor 55. The paper sheet 40 is carried into the inlet 53 of the heating chamber and is carried from the outlet 54. Transfer of the paper sheet 40 is carried out by the conveyor 55 housed in the half shell 52. In the case of the embodiment shown, toner layers 41 are adhered selectively on the surface of the paper sheet 40. Grooves 56 are formed at both ends of the half shell 51 in the transfer direction of the paper sheet 40. The grooves 56 extend in the direction orthogonal to the transfer direction of the paper sheet 40, i.e. in the propagaging direction of the microwave. A plurality of dielectric resonators 60 of the TE mode are housed and fixed in the grooves 56. These dielectric resonators 60 are provided to prevent leakage of the microwave outside the heating chamber and the resonance frequency and thus the geometry is selected to the optimum value in association with the frequency of the microwave leakage of which is to be prevented. A microwave is supplied from the coaxial line 20 to the microstripline 10 in such structure. The paper sheet 40 with not fixed toner layers 41 adhered is transferred in succession from the inlet 53 to the outlet 54 by means of the conveyor 55. When the microwave is thus supplied to the microstripline 10, the microwave leaking through the ladder circuit portion 13 heats the paper 40 and the toner layers 41. The heated toner layers 41 are melted and fixed to the paper sheet 40. The microwave leaked through the ladder circuit portion 13 is about to leak through the inlet 53 and/or the outlet 54 of the heating chamber; however, the same is trapped by means of the dielectric resonators 60 of the TE mode arranged in the vicinity thereof and accordingly there is no fear that the microwave is leaked through the normally opened inlet 53 and/or the outlet 54. Although provision of a so-called choke cavity is known as another approach for the purpose of preventing leakage of the microwave, employment of a plurality of dielectric resonators 60 of the TE mode as in the case of the embodiment shown enables leakage preventing implementation in a very small size as compared with a case where a choke cavity is employed, which, together with a small sized implementation due to employment of the microstripline 10, more enables an implementation of the apparatus as a whole in a small size. Meanwhile, it is needless to say that any of the embodiments shown in Figs. 2 to 15 can be applied to the Fig. 16 embodiment.

Fig. 19 is a modification of the Fig. 16 embodiment. More specifically, in the Fig. 19 embodiment, the microstripline 10 is provided below the paper sheet 40 being transferred and accordingly a plurality of dielectric resonators 60 are also provided below the paper sheet 40 in the vicinity of the inlet 53 and the outlet 54. The conveyor 55 is provided outside the heating chamber. The other portion of the structure and the effect of preventing leakage of the microwave are the same as those of the previously described Fig. 16 embodiment.

Meanwhile, in the foregoing the preferred embodiments were described as employing the inventive microwave heating apparatus as a heating apparatus of an electrophotographic apparatus. However, it is a matter of course that the present invention can be applied with any suitable modifications in order to uniformly heat the whole portion of a sheet-like material or to uniformly heat the surface of a material having a given thickness. By way of one example, the present invention could be advantageously utilized in a process for curing rubber, for example.

Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of the present invention being limited only by the terms of the appended claims.

CLAIMS

1. A microwave heating appartaus, comprising:

microstripline means having a center conductor and at least one ground conductor, at least one of said center conductor and said ground conductor including a ladder circuit portion,

microwave supply means for supplying a microwave to said microstripline means, and

means for subjecting a material being heated to said ladder circuit portion.

2. A microwave heating apparatus in accordance with claim 1, wherein

said microwave supply means comprises further microstripline means coupled to said microstripline means.

3. A microwave heating apparatus in accordance with claim 2, which further comprises

impedance matching means for achieving impedance matching between said two microstripline means.

4. A microwave heating apparatus in accordance with claim 1, wherein

said microwave supply means comprises coaxial line means having an inner conductor and an outer conductor coupled to said microstripline means.

5. A microwave heating apparatus in accordance with claim 4, wherein

the center conductor of said microstripline means is connected to the linner conductor of said coaxial line means and the ground conductor of said microstripline means is connected to the outer conductor of said coaxial line means.

6. A microwave heating apparatus in accordance with claim 4, wherein

the center conductor of said microstripline means is connected to the outer conductor of said coaxial line means and the ground conductor of said microstripline means is connected to the inner conductor of said coaxial line means.

7. A microwave heating apparatus in accordance with claim 4, which further comprises

impedance matching means for achieving impedance matching between said microstripline means and said coaxial line means.

8. A microwave heating apparatus in accordance with claim 7, wherein

said impedance matching means is provided on the part of said microstripline means.

9. A microwave heating apparatus in accordance with claim 8, wherein

said impedance matching means comprises a narrow portion formed in at least one of said center conductor and said one ground conductor of said microstripline means, and

said narrow portion is formed to be narrower than said ladder circuit portion at the side connected to said coaxial line means.

10. A microwave heating apparatus in accordance with claim 9, wherein

said narrow portion is formed to be gradually narrower from said ladder circuit portion toward said coaxial line means.

11. A microwave heating appratus in accordance with claim 9 or 10, wherein

said microstripline means comprises a dielectric layer inserted between said center conductor and said ground conductor, and said dielectric layer comprises an increased thickness portion where the thickness thereof is gradually increased from said ladder circuit portion toward said coaxial line means.

12. A microwave heating apparatus in accordance with claim 11, wherein said increased thickness portion of said dielectric layer is formed such that said center conductor of said microstripline means is maintained flat while said ground conductor is inclined as per the change of said thickness.

13. A microwave heating apparatus in accordance with claim 11, wherein said increased thickness portion of said dielectric layer is formed such that said ground conductor of said microstripline means is maintained flat while said center conductor is inclined as per the change of said thickness.

14. A microwave heating apparatus in accordance with claim 8, wherein said impedance matching means is formed on the part of said coaxial line means.

15. A microwave heating apparatus in accordance with claim 14, wherein said coaxial line means comprises a dielectric layer inserted between said inner conductor and said outer conductor at the junction between said coaxial line means and said microstripline means.

16. A microwave heating apparatus in accordance with claim 15, wherein the dielectric constant of said dielectric layer is selected such that the characteristic impedance of said coaxial line means is matched to the characteristic impedance of said microstripline means.

17. A microwave heating apparatus in accordance with claim 16, wherein the length of said dielectric layer is selected to be a quarter of the effective wavelength of the microwave being utilized.

18. A microwave heating apparatus in accordance with any one of the preceding claims 15 to 17, wherein said dielectric layer comprises two or more portions sectioned in the length direction, each portion having a different dielectric constant, the dielectric constant of each said different portion of said dielectric layer being selected such that the dielectric constant of the portion coupled to said microstripline means is larger than that of the other portion.

19. A microwave heating apparatus in accordance with claim 15, wherein said dielectric layer has an end surface intersecting the axis of said coaxial line means at an acute angle at the input side of the microwave.

20. A microwave heating apparatus in accordance with claim 19, wherein said inner conductor of said coaxial line means comprises an increased diameter portion formed at the junction between said coaxial line means and said microstripline means.

21. A microwave heating apparatus in accordance with claim 20, wherein said increased diameter portion is formed such that the diameter is gradually increased toward the junction between said coaxial line means and said microstripline means.

22. A microwave heating apparatus in accordance with claim 1, which further comprises a heating chamber having an inlet and an outlet and being provided in association with said ladder circuit portion, said material being heated being carried in said inlet and carried from said outlet, and microwave leakage preventing means provided in said heating chamber in association with at least one of said inlet and said outlet.

23. A microwave heating apparatus in accordance with claim 22, wherein said leakage preventing means comprises a plurality of dielectric resonators of the TE mode, the resonance frequency of the respective dielectric resonators being selected in association with the effective wavelength of the microwave leakage of which is to be prevented.

24. A microwave heating apparatus in accordance with claim 22 or 23, wherein said heating chamber is made of an electrically conductive material.

25. A microwave heating apparatus comprising a microstripline, a ladder-shaped conductor connected to one of the conductors of the microstripline, means for supplying microwaves to the microstripline, and means for moving a sheet past the ladder-shaped conductor so that the sheet is heated by microwave energy.

26. A microwave heating apparatus substantially as herein described wih reference to any of Figs. 2 to 19 of the accompanying drawings.

Printed for Her Majesty's Stationery Office
by Burgess & Son (Abingdon) Ltd.—1982.
Published at The Patent Office, 25 Southampton Buildings,
London, WC2A 1AY, from which copies may be obtained.