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(54) Title: APPLICATOR OF MICROWAVE PLASMA GENERATOR AND MICROWAVE PLASMA GENERATOR INCLUDING THIS APPLICATOR

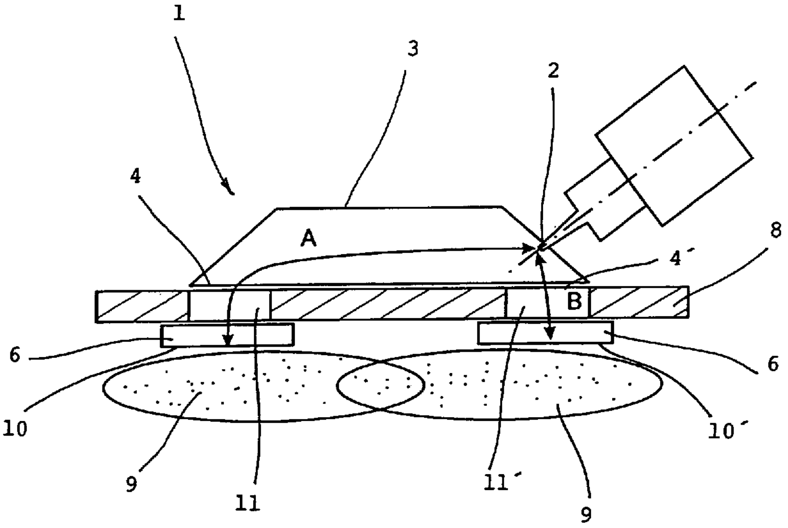

FIG.1

(57) Abstract: The microwave plasma generator is applied to transmission of electromagnetic field into plasma. The invention consists of the fact that the guiding part (3) has two outputs (4, 4') between which an input (2) of microwave is placed generated from the microwave power source (5). The input (2) is in the distance (A) from the separation (10) of the first output (4) and in the distance (B) from the separation (10') of the second output (4') while the absolute value of the difference of the distances A-B or B-A equals λ/2 where λ is the wave length of the microwave and distances A and B correspond to the trajectory of microwave propagation. A microwave plasma generator including microwave power source (magnetron) (5) is connected to the input (2) of the guiding part (3) of the applicator (1)

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Applicator of Microwave Plasma Generator and Microwave Plasma Generator Including this Applicator

Background and summary of the invention

The invention relates to an applicator of microwave plasma generator applied to transmission of electromagnetic field into plasma and it further relates to a microwave plasma generator including the dealt with applicator.

A large scale of types of microwave plasma generators that can be, in general, characterized as closed generators where the plasma chamber is surrounded by metal walls forming a microwave resonator, or as open generators including among others microwave emitters, slow-wave structures and surfatrons, eventually generators with magnetic field based on electron resonance ECR (electron cyclotron resonance).

The known microwave plasma generator consists from a microwave power source (magnetron), wave-guide, circulator and from an applicator ensuring transfer of microwave energy into plasma filler (plasma bulk).

The Horn antenna is most frequently used in current microwave plasma generators as applicator, which in fact is a casing with an input in one side and with a rectangle profile cross section enlarging towards the output provided with a dielectric window on the other side. The applicator transmits linearly polarized waves. It is connected to a wave-guide in which also a circulator is connected necessary for conduction of reflected waves.

One of the general problems in transmission of electro-magnetic field to plasma is the fact that a certain part of the supplied power is reflected back. The generated plasma has some electrical conductivity and it therefore does not absorb all waves a part of which is then reflected back. This problem is significant especially in microwave generators since the reflected waves are transmitted via the wave-guide back to the source (magnetron). A long time charging of the magnetron by the reflected wave can result in the destruction thereof. To avoid this effect the reflected wave must be conducted outside of the magnetron. Therefore between the magnetron and the applicator into the track of the wave-guide a circulator is included to ensure the exhaust of the reflected wave and its transformation into heat. Even though the circulator is an efficient device, it is relatively complicated and expensive. It increases considerably the size, complexity and price of the known microwave plasma generators. Besides in order to tune the applicator, the microwave guide must be terminated by a movable short connection (movable wall), serving to tune the guide in order to achieve the maximum efficiency of the applicator.

The invention aims at creating such microwave plasma generator that could remove the above described deficiencies and that would allow an efficient elimination of a part of the reflected wave without the necessity of application of the above-described complicated, expensive and bulky elements.

This task is solved by formation of an applicator and a microwave plasma generator including the said applicator according to this invention.

The invention consists of the fact that it is possible to interfere the reflected waves by other reflected waves of the same wave length but with an appropriate phase shift. This is achieved by an applicator with a guiding part of the closed profile and with two outputs in the opposite ends. In the separations of both outputs and the plasma field reflected waves are generated and they reflect back against each other into the guiding part where they meet and interfere. An efficient elimination of the impact of the reflected waves on the microwave power source (magnetron) is surprisingly achieved by placing the magnetron directly in the input of the applicator placed in the wall of its guiding part in the distance A from the separation of the first output and in the distance B from the separation of the second output while the absolute value of the difference of the distances A-B or B-A equals λ/2 where λ is the wave length of the microwave from the microwave power source (magnetron). Distances A and B correspond to the trajectory of microwave propagation.

Then the waves from the opposite outputs meet in the guiding part in the place of the input of the microwave power source (magnetron) with exactly the opposite polarity, which disturbs their impact resulting in liberating the magnetron from the impact of reflected waves.

In one preferred embodiment of the applicator the guiding part is fixed from one side to the metal vacuum flange provided with apertures placed on the near side against ouputs of the guiding part. On the reverse side, these apertures are covered by the dielectric cover.

It is also advantageous when the guiding part has the shape of a hollow body abutting the flange and covering the apertures by its outputs.

This embodiment has a very small size and great variability; it can be put in any device having an aperture corresponding to the circular flange.

In another preferred embodiment of the applicator according to the invention the guiding part has in the top view approximately a "U" shape the branches of which are provided by outputs in the ends and the input is placed in one of the branches. A longer track and greater stability characterize this embodiment.

A microwave plasma generator is also subject of the invention. It includes a microwave power source (magnetron) and an applicator where the microwave power source is connected to the guiding part of the applicator, provided on one of its ends by the first output, on the second end by the second output and the input is placed in the wall of the guiding part in the distance A from the separation of the first output and in the distance B from the separation of the second output while the absolute value of the difference of the distances A-B or B-A equals $\lambda/2$ where λ is the wave length of the microwave from the microwave power source (magnetron). Distances A and B correspond to the trajectory of microwave propagation.

The advantage of the above described applicator and microwave plasma generator including this present applicator consists in the fact that it is possible to exclude from construction of the device the expensive and bulky circulator including wave-guide and the tunable short connection of the microwave guide and that it is possible to create a simple, compact, easily transportable microwave plasma generator with a small size and low production costs.

Brief description of the drawings

The invention will be presented in more detail in the drawings where figure 1 is a schematic cross section of the open microwave plasma generator including the applicator with the guiding part of the shape of a hollow body and figure 2 is a schematic cross section of the open microwave plasma generator including the applicator having a "U" shape in cross section.

Examples of preferred embodiments

It should be understood that the hereinafter described and shown specific examples of embodiments of the invention are represented as examples only, not as a limitation of the invention. Those skilled in the art will find or will be able to find by routine experimenting a greater or smaller number of equivalents of the present invention, described here in a specific embodiment. Also these equivalents shall be included in the claims for protection.

In one specific embodiment of the invention shown schematically in fig. 1 there is shown an open microwave plasma generator supplied from a source of pulse voltage 3 kV not presented here adapted for plasma modification of powder materials on the polyethylene basis.

The microwave power source (magnetron) 5 is a Panasonic magnetron having 1 kW power with a pulse control of power, set in the wall of the guiding part 3 of the applicator 1 made of brass sheet. The guiding part 3 is of a hollow body shape with the first output 4 and the second output 4'. By the means of these two ouputs 4, 4' the guiding part 3 connects with apertures 11, 11' in the circular vacuum aluminium flange 8 and it is screwed down to it. On the reverse side of the flange 8 the apertures 11, 11' are covered by dielectric covers 6, e.g. made of corundum or silica glass. The sides of the covers 6 reversed from the outputs 4, 4' create separations 11, 11' reflecting microwaves and behind which by each output 4, 4' a plasma bulk 9 is made. The whole applicator 1 can be by means of the flange 8 made in the dimension scale ISO, attached to any vessel, not represented here, which usually is a chamber of rustless sheet. It is essential that the input 2 of microwave from the microwave power source 5 be set in the guiding part 3, e.g. in its wall in the distance A from the separation 10 of the first ouput 4 and in the distance B from the separation 10' of the second output 4' while the following applies: the absolute value of the difference of distance A-B or B-A equals $\lambda/2$, i.e. the half of the wave length of the microwave power source 5 and distances A and B correspond to the trajectory of microwave propagation.

In fig. 2 the same open microwave plasma generator is shown with a small modification consisting in the guiding part 3 having a "U" shape in cross section the branches 7, 7' of which have in their ends outputs 4, 4', and the input 2 is set in one of the branches 7, 7'.

The applicator of microwave plasma generator and the microwave plasma generator including this present applicator according to this invention can be used in many fields of human activity exploiting plasma and it is necessary to have a compact generator of small dimensions eliminating negative effects of the reflected component of microwave.

Overview of references

1	applicator
2	input of microwave
3	guiding part
4	first output
4’	second ouput
5	microwave power source (magnetron)
6	cover
7	first branch
7’	second branch
8	metal vacuum flange
9	plasma bulk
10	separation of the first output
10’	separation of the second output
11	first aperture of the flange
11’	second aperture of the flange
A	distance of the input 2 from the first separation 10 of the first ouput 4
B	distance of the input 2 from the second separation 10’ of the second ouput 4’

CLAIMS

1. An applicator (1) of microwave plasma generator including the input (2) of microwave from the microwave power source (5), guiding part (3) of a closed profile and at least one output (4, 4') of microwave covered by a dielectric cover (6) whose side reversed from the output (4, 4') creates a separation (10, 10') between the applicator (1) and the plasma bulk (9) **characterized in that** the guiding part (3) is provided on one of its ends by the first output (4), on the second end by the second output (4') and the input is placed in the wall of the guiding part (3) in the distance (A) from the separation (10) of the first output (4) and in the distance (B) from the separation (4') of the second output (10') while the absolute value of the difference of the distances A-B or B-A equals $\lambda/2$ where λ is the wave length of the microwave from the microwave power source (magnetron). Distances A and B correspond to the trajectory of microwave propagation.

2. An applicator according to claim 1 **characterized in that** the guiding part (3) is fixed to the metal vacuum flange (8) provided with apertures (11, 11') placed on the near side against outputs (4, 4') of the guiding part (3). On the reverse side, these apertures (11, 11') are covered by at least one dielectric cover (6).

3. An applicator according to claim 2 **characterized in that** the guiding part (3) has the shape of a hollow body abutting the flange and covering the apertures (11, 11') by its outputs (4, 4').

4. An applicator according to claims 1, 2 or 3 **characterized in that** the guiding part (3) has in cross section approximately a "U" shape the branches (7, 7') of which are provided by outputs (4, 4') in the ends and the input (2) is placed in one of the branches (7, 7').

5. A microwave plasma generator including microwave power source (magnetron) (5) and an applicator (1) **characterized in that** the microwave power source (5) is connected to the input (2) of the guiding part (3) of the applicator (1), provided on one of its ends by the first output (4), on the second end by the second output (4') while both outputs (4, 4') are covered by dielectric covers (6), the sides of the covers (6) reversed from the outputs (4, 4') create separations (10, 10') between the applicator (1) and the plasma bulks (9) and the input (2) is placed in the wall of the guiding part (3) in the distance (A) from the separation (10) of the first output (4) and in the distance (B) from the separation (10') of the second output (4') while the absolute value of the difference of the distances A-B or B-A equals λ/2 where λ is the wave length of the microwave from the microwave power source (magnetron) (5). Distances A and B correspond to the trajectory of microwave propagation.

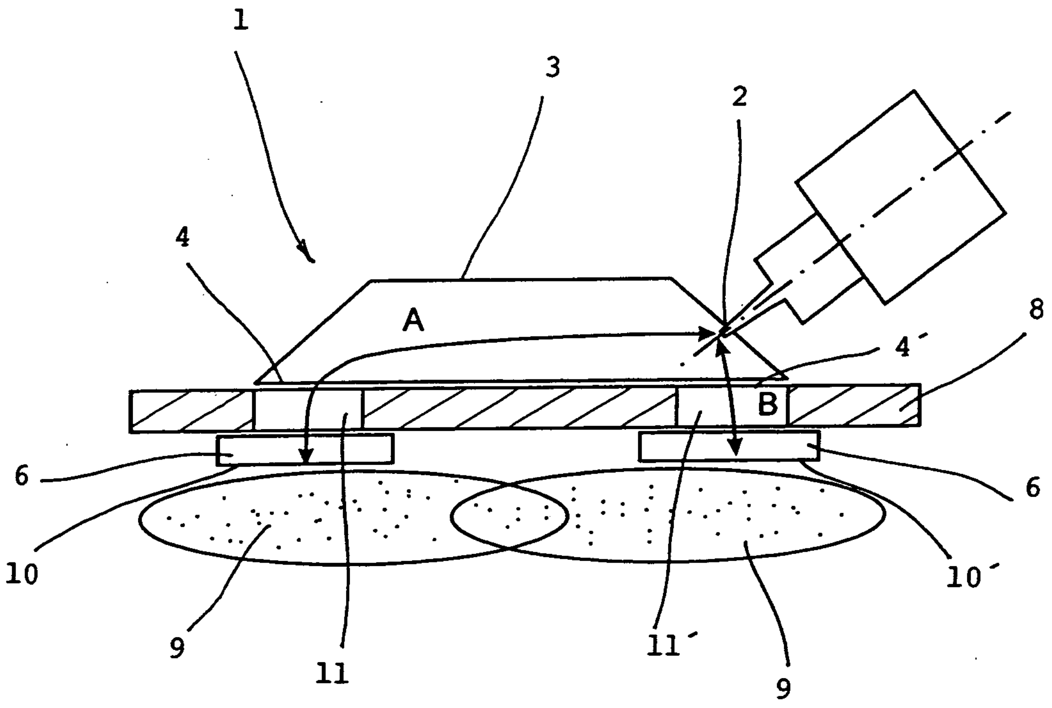

FIG.1

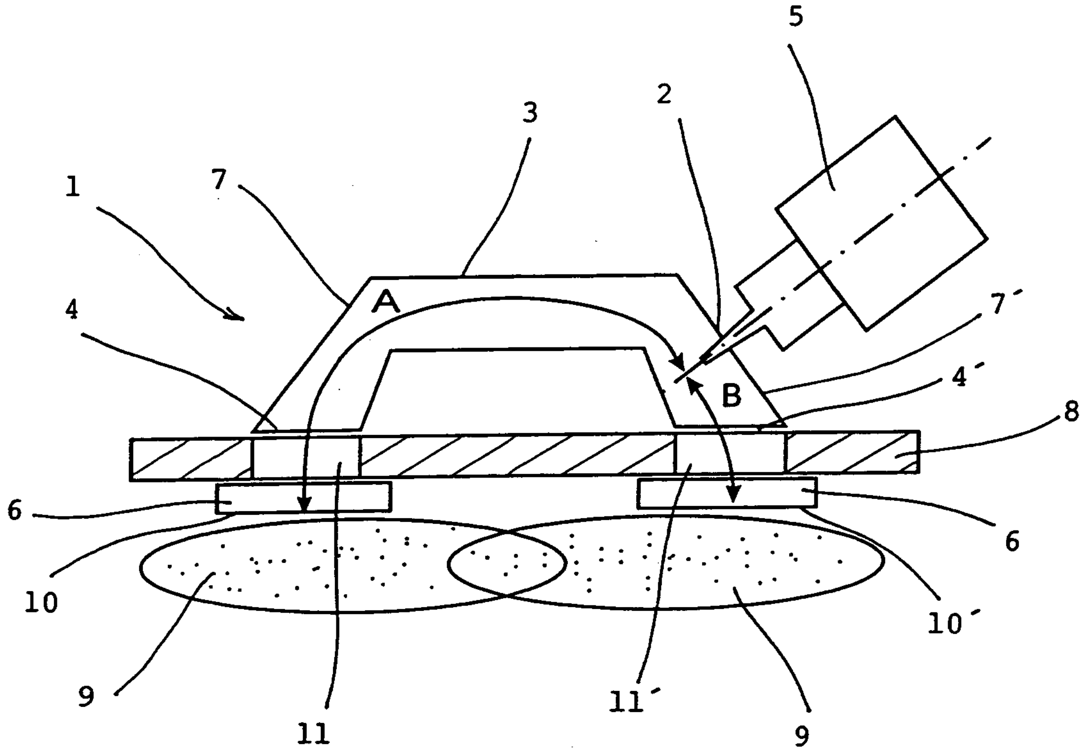

FIG.2

INTERNATIONAL SEARCH REPORT

International application No
PCT/CZ2008/000106

A. CLASSIFICATION OF SUBJECT MATTER
INV. H05H1/46

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H05H H01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	abstract; figure 1	4
P,X	-& EP 1 889 947 A1 (TOYO SEIKAN KAISHA LTD [JP]) 20 February 2008 (2008-02-20) paragraph [0022] - paragraph [0024] figure 1 -----	1-3,5
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A	US 5 538 699 A (SUZUKI NOBUMASA [JP]) 23 July 1996 (1996-07-23) column 23, line 40 - line 55 figures 4a-4c -----	1-3,5

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☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search 10 February 2009	Date of mailing of the international search report 19/02/2009
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Capostagno, Eros

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2004/026039 A1 (GOTO NAOHISA [JP] ET AL) 12 February 2004 (2004-02-12) paragraph [0060] figures 1,3,4 -----	1-3,5

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/CZ2008/000106

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