

Device for generating homogeneous microwave plasmas

Various types of plasmas are generated using a wide variety of methods and the most varied devices. Plasma treatment is used, for example, for coating, cleaning, modifying and etching substrates, for treating medical implants, for inverting gases and in technology for purifying waste gases. The geometry of the workpieces to be treated ranges from flat substrates, fibres and webs, to any configuration of shaped articles. The size of the plasma chamber, and thus of the workpieces is limited. Materials in web form and fibre bundles can be processed only with difficulty.

Known devices have, for example, outer rings which can be constructed as a resonator. To feed the microwaves, use is made, inter alia, of waveguides and coaxial cables and, inter alia, of antennas, for example slots, as coupling points in the wall of the plasma chamber.

A disadvantage of the known devices are the formations of inhomogeneities in the plasma, particularly at high pressures and in relatively large plasma chambers and/or substrates.

The task therefore existed of generating a homogeneous plasma and rendering possible homogeneous plasma treatment.

It is proposed according to the invention to introduce the microwaves homogeneously into the plasma chamber serving the purpose of processing via a cylindrical chamber and via coupling points in the cylindrical wall of this chamber (2). The plasma chamber is then to be constructed on the outside completely or partially covering the cylindrical wall of the chamber (2).

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The subject-matter of the invention is a device for generating microwave plasmas, having a microwave generator (1), a feeding chamber (2) with coupling points (6) in the wall between the feeding chamber (2) and plasma chamber (3), as well as, if appropriate, receptacles, characterized in that the microwave-feeding chamber (2) is of cylindrical design.

The end faces of the chamber (2) are preferably not covered by the plasma chamber (3), the plasma chamber (3) completely or partially covering the cylindrical wall of the chamber (2).

The common wall between the chamber (2) and chamber (3) is preferably to be constructed completely, partially or substantially in a cylindrical fashion. The configuration of the outer wall of the plasma chamber (3) is of cylindrical or arbitrary configuration, for example, adapted to the type of processing. As resonator, the plasma chamber (3) can be constructed, for example, as a resonator of coaxial, rectangular or annular shape. As an annular resonator, the plasma chamber (3) can, given a rectangular cross section, form the common wall with the chamber (2) with the short or long side. The plasma chamber can also be constructed as a segment of the said shapes.

The plasma chamber (3) and the cylindrical chamber (2) preferably have a common preferred direction and, in the simplest, much preferred case, a common z-axis. It is also preferred for the chamber (2) to be of rotational symmetrical construction, at least in parts, particularly the parts near the end faces. Two tubes arranged inside one another and having a common z-axis are structurally the simplest, surprising and much preferred arrangement of the chamber (2) and (3).

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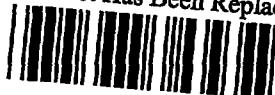
The chambers (2) and (3) can be constructed with the same or different lengths along the preferred direction or axis.

The cylindrical shape of the chamber (2) permits, also owing to a simple geometrical configuration, improved uniformity of the microwave launching and simple construction of the chambers (2) and (3) as resonators. The cylindrical shape of the chamber (2) also permits a previously impossible variation, variability and adjustabiling of the configuration and the effectiveness of the chamber (2) and also of the plasma chamber (3). For this purpose, at least one of the end faces of the chamber (2) can be arranged moveably and/or displaceably.

Furthermore, at least one of the end faces of the plasma chamber (3) can be arranged moveably and/or displaceably. Displacement in the preferred direction and/or rotation of the end faces (4) and (5) is possible in a particularly simple way. For this purpose, the end faces have exciting holders, tube stubs or the like at the cylinder wall. The tube stubs can have cutouts and be constructed over small or substantial parts of the cylinder wall in a fashion bearing against the cylinder wall. The coupling points can then be arranged variably, moveably and settably and be configured so that they can be covered or be switched in by opening. The cylinder wall is then thereby completely or partially of two-fold or three-fold structure.

Moveable coupling points can be arranged moveably with the aid of the end faces or by means of handles, for example, independently of the end faces. In many cases, the feeding and/or feeding chamber (2) preferably has an ideal or substantially cylindrical shape and azimuthal slots, for example, as coupling points. The end faces are then circular, or the contact surface with the cylinder wall is

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a circle and the slots, which can be switched in and out, can be moved through the end face and/or from the outside.

The feeding chamber (2) can also deviate from the ideal shape of a cylinder, for example have an elliptical or angular, for example, triangular to hexagonal cross section, completely or partially. A shape curving around the z-direction is also possible. The cylinder of the chamber (2) can be curved. The two end faces can touch one another or be eliminated and the chamber can have an annularly closed structure. The shape of the chamber (2) stretched linearly along the z-direction is much preferred.

The plasma chamber can have a feed for gases and a device for the evacuation. The device of the invention can be used in a versatile fashion, but the treatment of materials in web form and of virtually arbitrary width is possible, in particular.

In order to generate a vacuum, the plasma chamber can include a receptacle (5) which consists completely or partially of a dielectric material with preferably low dielectric losses, for example silica glass or aluminium oxide ceramic. In the case of the construction of the plasma chamber as a coaxial resonator, the receptacle can be designed with the aid of a dielectric tube, for example made from silica glass, which is pushed over the cylinder resonator. In this case, the dielectric tube forms the vacuum receptacle (5) together with the outer conductor of the coaxial resonator and the end faces thereof. In the case when the device is operated at higher pressures, for example atmosphere, the receptacle prevents the formation of a plasma at the coupling points and/or in the feeding cylindrical chamber, the supply lead thereof, or else on the microwave generator itself. However, by introducing

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dielectric material the plasma region of the device can likewise be specifically limited to the desired regions. Thus, for example, by cladding the region around the coupling point and the coupling points themselves with dielectric material, it is possible to prevent the production of a plasma in this region.

If the plasma chamber is designed as a coaxial resonator, it is preferably constructed as a TEM resonator. However, other modes such as, for example, TE modes or TM modes are also possible. In a case of treatment of materials in web form such as, for example, plastic or material webs, the material to be treated can be fed and/or removed through slots in the outer conductor of the TEM coaxial resonator, for example along the z-axis, without being coupled outwards owing to this microwave power. Designing the cylindrical chamber to be fed as an TM₀₁₀ resonator with azimuthal slot couplers is preferred in this case. The spacing of the slot couplers in the z-direction is in this case preferably a wavelength of the microwave used. Likewise possible are a plurality of slots which are distributed around the circumference of the cylinder resonator and tilted out of the azimuthal direction in the direction of the z-axis by, for example, 45 degrees. It is also possible in this case to design an arrangement of rows of slots at a spacing of half the wavelength, in which case the tilting direction of the slots should be opposite from one row of slots to the next.

It is also possible to construct the chamber (3) as feeding and the chamber (2) as a plasma chamber.

Moveable coupling points and/or end faces lead, if appropriate, to assigning the function of conduction to the

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outer chamber (3) and the function of the plasma chamber to the inner chamber (2).

Launching the microwaves into the plasma source can be performed using the known tuneable supply leads via a wall of the chambers; preferably via an end wall or chamber wall, the tuning of the plasma source being performed completely or partially by setting in and through a chamber wall. The tuning can also be performed via the known tuning elements.

All the parts of the devices can be present in multiple fashion.

In the drawing, Fig. 1 shows a device having a cylindrical feeding chamber (2) surrounded by the plasma chamber (3) with a microwave generator in an end face of the chamber (2). The end faces (4) of the chamber (2) and the end faces (5) of the plasma chamber (3) lie in one plane in this case.

Fig. 2 shows developments of the lateral surfaces of the cylindrical chamber (2) with coupling points in the wall with the plasma chamber (3). Fig. 2a shows azimuthally circulating slot couplers with a spacing D of preferably one or half a wavelength at resonance. Fig. 2b shows azimuthal slot couplers with a spacing D of equal phase, which cover the circumference of the cylindrical surface only partially. Fig. 2c shows two pairs of azimuthal slot couplers with a spacing D , which are displaced relative to one another by D' of, for example, a quarter wavelength. By mechanically displacing the end faces (4) and/or (5) by D' in the direction of the z -axis, coupling is produced by both or only one pair of slots. The slots need not also be displaced. In the case of only one slot row, end faces and

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slots must be displaced in order to achieve the homogenization. A slot pair is connected to the end face (5) with the aid of a holder and is displaced in the z-direction by the movement thereof. The end faces (4) of the chamber (2) are displaced until resonance is achieved. Fig. 2d shows two pairs of rows of slot couplers having opposing directions of tilt with a spacing of respectively D and half of the spacing D from one another, as a result of which use is made of co-phasal launching into the plasma chamber, that is to say the opposite flow direction of the wall flows through opposing coupling of the rows of slots at a spacing of, for example, half the resonator wavelength. Additional rows of slots at a spacing of, for example, a quarter wavelength are possible. Rows of slots can be displaced, as in Fig. 2c.

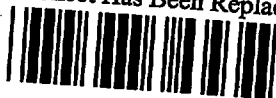
Fig. 2e and Fig. 2f show a plurality of coupling slots which run parallel to the z-axis and can be changed, for example, by rotating and/or displacing the end face (5). The slots are interrupted in Fig. 2f. Other coupling elements can be used instead of slots.

Fig. 3 shows a device having a plasma chamber (3) in the preferred construction as an annular resonator of rectangular cross section, the microwave launching from (2) being performed via a short rectangular side (3A) or a long rectangular side (3B).

Fig. 4 is the same as Fig. 3, but the chamber (2) is enclosed by a plasma chamber (3) which is constructed as a 180° cylinder segment.

Fig. 5 shows the feeding chamber (2), enclosed by the plasma chamber (3), which is constructed with the same

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length as the chamber (2) in the z-direction and as a 180° segment.

Fig. 6 shows a long chamber (2) enclosed by a chamber (3) which is constructed to be longer than a 180° segment and through which a web-shaped substrate (11) to be treated is moved continuously through the slot (10). The exit slot is not represented.

Fig. 7 shows two devices • and •• for treating a web-shaped substrate 11 using optionally identical or different methods, the web-shaped substrate being guided sequentially through the respective slots 10a and 10b.

Fig. 8 shows a device for continuous processing of tubes (11) which are guided continuously through the plasma chamber (3) at right angles to the plane of the drawing of Fig. 8a through annular slots (10). The tube to be processed always has the same spacing from the coupling elements (not shown) of the annular feeding chamber (2), whose centre line (4) is produced in the form of a circle by imaginary constant curvature of the cylindrical axis. In Fig. 8a, the chamber (2) has a circular cross section, but it can also have a curved oval cross section or else an angular one. Fig. 8b shows a section through the devices in accordance with the line of section AB in Fig. 8a. The plasma chamber (3) is arranged as a 180° segment of a circular ring outside around the ring of the chamber (2), such that the outer 180° segment of the chamber (2) can be provided with coupling elements. The semicircle of the cross section of the chamber (3) can also be constructed as a rectangle.

Fig. 9 shows a device having coaxial chambers (2) and (3), which follow a curved axis (not shown) in being

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geometrically adapted to substrates, for example. In the plane of the azimuthal slot couplers (6), the cross sections can be circular or, for example, elliptical and of constant or non-constant diameter along the curved axis.

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PATENT CLAIMS

1. Device for generating microwave plasmas, having a microwave generator (1), a feeding chamber (2) with coupling points (6) in the wall between the feeding chamber (2) and plasma chamber (3), as well as, if appropriate, receptacles, characterized in that the microwave-feeding chamber (2) is of cylindrical design.
2. Device according to Claim 1, characterized in that the plasma chamber (3) completely or partially encloses the feeding cylindrical chambers (2).
3. Device according to Claims 1 or 2, characterized in that the chamber (2) and chamber (3) have a common preferred direction.
4. Device according to Claims 1 to 3, characterized in that chambers (2) and chambers (3) are constructed with the same or different lengths along a common preferred direction or in a rotational symmetrical fashion relative to a common axis.
5. Device according to at least one of the preceding claims 1 to 4, characterized in that at least one of the end faces of the chamber (2) and/or chamber (3) is arranged displaceably or / and rotatably in a variable fashion.
6. Device according to at least one of the preceding claims, characterized in that the wall between the chamber (2) and plasma chamber (3) is constructed completely or partially in a multiple fashion, and the wall or at least one of the walls with the coupling

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points is arranged displaceably or / and rotatably in a variable fashion with the aid of an end face or independently of the end faces.

7. Device according to Claim 5 or 6, characterized in that the chamber (2) is designed as a plasma chamber, and the chamber (3) is designed as a chamber which feeds microwaves.
8. Device according to at least one of the preceding claims, characterized in that the microwave generator (1) is arranged in or near an end face or a wall, and the setting of the resonance is performed in and through a chamber.

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