

Ozone generation with directly cooled plasma channels

The present invention relates to an ozone generator with a high voltage electrode and at least one counter electrode which limit a gap in which at least one dielectric and an electrically non-conductive structure are arranged, and the corresponding non-conductive structure.

The efficiency of ozone generators depends to a great extent on the temperature in the discharge gap. On the one hand, this is due to the fact that the ozone-formation reaction proceeds better at low temperatures, and on the other hand the kinetics of the ozone depletion mechanism increase exponentially with the temperature. An effective cooling of the gas space is thus essential for efficient ozone generation. Ozone generators cooled with water on one or two sides are known from the prior art. Their limiting factor in terms of heat transport is the thermal conductivity within the discharge gap. In comparison with the gas which flows through the discharge gap, the electrode material, for example stainless steel, conducts the heat more effectively by two to three orders of magnitude.

Several different measures for cooling the ozone generator are realised in US 5,855,856. The tube-type ozone generator possesses both an inner cooling and an outer cooling. Heat-absorbing objects in the form of swarf or fibres are arranged within these cooling spaces. These objects can be made of materials with high thermal conductivities and non-corrosive properties. The gas is fed to the ozone generator tangentially in order to create a spiral flow which is in addition intended to cool the inner electrode. In addition, a part of the product gas is drawn off, cooled and fed to the gas. The whole construction is very complex, but does not improve the limiting step of the transport of heat from the discharge gap.

The specification EP 0 369 366 A3 describes an arrangement in which a plurality of thermally conductive solids is arranged in the reaction space.

These solids serve to create an equalisation of heat between regions within the ozone reactor with higher temperature and lower temperature. In order to achieve this, these solids need to touch one another and need to be in contact with the dielectric and/or an electrode and/or both electrodes.

A material mix of electrically conductive and electrically non-conductive material is described in the patent specification US 648,764. Pearls or plates made of the two materials are lined up like a string of pearls. The dimensions of the pearls of the electrically non-conductive material are thereby larger, since an improved ozone yield is achieved through a greater distance between the electrical conductor and the dielectric separator.

The introduction of dielectric materials serves generally to adjust the gap width (spacer), as flow-disrupting material (gas mixing) or to direct the flow.

It is the object of the present invention to provide an ozone generator which exhibits a good transport of heat in the discharge gap. It is also the object of the invention to provide an electrically non-conductive structure for use in a chamber of an ozone generator through which gas flows which transports the heat away efficiently.

The term "fabric" (woven or non-woven fabric) is known from textiles technology. A textile fabric can refer to any planar structure made from textile raw materials using a textile technology. Accordingly, in the context of the present patent application a fabric is understood to mean any flat, curved or convex planar structure manufactured using a textile technology. These include, inter alia, non-woven fabrics, such as tissue, knitted fabrics, meshes and nets, and fibre composite fabrics such as non-wovens and cotton wool. On the other hand, a structure is understood to mean any type of fabric and more solid structures such as lattices.

The aforementioned object is achieved by means of an ozone generator as described in the following.

In an ozone generator of the generic type, as the electrically non-conductive structure contains pores, wherein the nominal pore size (x) is

$100\text{ }\mu\text{m} < x < 1\text{ mm}$, the heat released in an individual discharge can be transferred quickly and directly to the non-conductive structure, so reducing the temperature-induced ozone depletion. This leads to an improved efficiency of the ozone generator.

A simple-to-manufacture structure results if the electrically non-conductive structure is a fabric. In particular, the electrically non-conductive structure can be a woven fabric or mesh.

The further dissipation of the heat is improved if the electrically non-conductive structure is at least partially in planar contact with the at least one dielectric.

Advantageously, the fabric has a nominal pore size greater than $100\text{ }\mu\text{m}$ and less than $1000\text{ }\mu\text{m}$, in particular less than $750\text{ }\mu\text{m}$. In particular, the nominal pore size (x) is advantageously less than $500\text{ }\mu\text{m}$ and particularly preferably less than $250\text{ }\mu\text{m}$.

The electrically non-conductive structure is preferably made of ceramic and/or glass.

A particularly high efficiency is achieved if the high voltage electrode is also at least partially formed from a metallic fabric.

The object is also achieved by means of an electrically non-conductive structure of the generic type which has pores which have a nominal pore size (x) of $100\text{ }\mu\text{m} < x < 1\text{ mm}$. Preferably, the electrically non-conductive structure is a fabric made of glass fibre or ceramic fibre.

In order to achieve a particularly high efficiency it is preferable if the nominal pore size (x) is $100\text{ }\mu\text{m} < x < 250\text{ }\mu\text{m}$, because in this case a particularly effective heat dissipation can be achieved.

An embodiment of the invention is described in more detail with reference to the drawings.

In the drawings:

Fig. 1: shows an electrode arrangement of a single-gap ozone generator;

Fig. 2: shows a combined electrode and fabric arrangement; and

Fig. 3: shows a non-metallic fabric.

Figure 1 shows a schematic cross-section of an electrode arrangement of a single-gap ozone generator 1 in the construction form of a plate-type ozone generator without a fabric arranged in the gap. In this respect, Figure 1 corresponds to the prior art. Such ozone generators 1 can be designed as plate-type ozone generators or tube-type ozone generators, depending on the field of application.

Plate-type ozone generators have a high voltage electrode 2 and at least one counter electrode 4 which are plate-formed in design. The electrodes 2, 4 limit a gap 5 through which an oxygen-containing gas 6 flows and in which a dielectric 3 is arranged. Conventionally, plate-type ozone generators are cooled on one or two sides by a cooling medium passed along the outer sides of the electrodes 2, 4. Air and water are used as cooling media.

Tube-type ozone generators are conventionally used in an ozone generator in groups. The ozone generators are thereby arranged parallel to one another between two tube plates in the manner of a tube bundle heat exchanger. Analogously to the plate-type ozone generators, tube-type ozone generators have a tubular-formed high voltage electrode 2, a tubular-formed dielectric 3 and a tubular-formed counter electrode 4. The arrangement is rotationally symmetrical. The high voltage electrode 2 and the counter electrode 4 are oriented concentrically to one another. They limit a gap 5 through which an oxygen-containing gas flows and in which the dielectric 3 is arranged. The externally-arranged counter electrode 4 is designed in the form of a stainless steel tube. The waste heat generated during the ozone production is cooled by means of cooling water (identified in Figure 1 with H₂O) which is passed along the outer side of the counter electrode 4. It is also possible for the generator 1

to be cooled on two sides in that cooling water also flows through the high voltage electrode 2 on the inner side.

In order to generate ozone, molecular oxygen is first dissociated into atomic oxygen, which then forms ozone through reaction with an oxygen molecule. The theoretical value of 1.47 eV required in order to generate an ozone molecule cannot be achieved in practice. Due to losses occurring during the course of the multi-stage reaction, the efficiency of the ozone generation is significantly lower. The dissociation of the oxygen molecule first takes place via different excitation states of the oxygen molecule. During the decomposition of the excited oxygen molecules or during the ozone formation, energy is released which is not available for the further dissociation of oxygen molecules, but leads to heating of the gas. These processes take place directly in the microdischarges.

According to the invention, an electrically non-conductive structure 7, represented in Figure 2 in an exemplary embodiment, is introduced into the gas flow 6 of an ozone generator 1 (plate- or tube-type generator) or the discharge gap. The electrically non-conductive structure 7 consists of an efficiently thermally conductive and porous material. The porosity of the electrically non-conductive material is defined by the nominal pore size, which corresponds to the average pore size (arithmetic mean). The pore size is the diameter of the largest spherical ball which can pass through the pore. The nominal pore size of the electrically non-conductive material is matched to the size of the microdischarges in the discharge gap. The microdischarges have a diameter of around 100 μm . The pore size of the electrically non-conductive materials therefore preferably amounts to between 100 μm and 1 mm. The electrically non-conductive structure 7 thus represents a direct heat coupling to the discharge and the adjacent cool electrode and dielectric surfaces. The structure 7 is in contact with the dielectric 3 and the electrode 2 at numerous points, or at least partially in a planar manner. The contact surface is thereby as large as possible. The electrically non-conductive material is ozone and corrosion-resistant. It is thereby preferable if the structure 7 is a fabric made of glass fibre or ceramic fibre 9. As a result of the pores in the structure 7, heat is coupled directly to the microdischarges.

Such a preferred structure 7 is illustrated in Figure 3, which shows a microscopic photograph of a woven fabric made of ceramic filaments.

All the described embodiments are used both in tube-type ozone generators as well as in plate-type ozone generators. The arrangement of the structure according to the invention is particularly preferable in multiple-gap systems, which have longer heat transmission paths than single-gap ozone generators. The electrically non-conductive structure 7 can thereby be provided in the outer gap and/or in at least one of the inner gaps.

The structure can be introduced into the discharge gap with or without carrier materials. The carrier materials can be designed in any form, for example as a rod, tube, plate, etc.

The high voltage electrode can be formed, completely or partially, of a metallic fabric. It can be seen in Figure 2 that a number of electrical conductors 8 are woven together with the structure made from the ceramic fibres 9.

The ozone generator according to the invention and with it the electrically non-conductive porous structure improve the efficiency of ozone generators in that the transport of heat in the discharge gap is increased. In addition to the pores, which couple directly to the microdischarges and transport the heat away, the electrically non-conductive structure has the largest possible contact surface with the adjacent electrode and/or dielectric surfaces. In this way, a very high cooling efficiency can be achieved even with larger gap widths. Moreover, the efficient heat coupling allows ozone generation at high temperatures above 40°C.

C l a i m s

1. Ozone generator (1) with a high voltage electrode (2) and at least one counter electrode (4) which limit a gap (5) in which at least one dielectric (3) and an electrically non-conductive structure (7) are arranged and through which a stream of gas (6) flows in a direction of flow, wherein the high voltage electrode (2) and the at least one counter electrode (4) are provided with a connection for an electrical voltage supply in order to generate silent discharges, and wherein the electrically non-conductive structure (7) contains pores with a nominal pore size (x) within a range of $100\text{ }\mu\text{m} < x < 1\text{ mm}$, **characterised in that** the electrically non-conductive structure is a fabric.
2. Ozone generator (1) according to claim 1, **characterised in that** the electrically non-conductive structure (7) is a woven fabric or mesh.
3. Ozone generator (1) according to any one of the preceding claims, **characterised in that** the electrically non-conductive structure (7) is at least partially in planar contact with the at least one dielectric (3).
4. Ozone generator (1) according to any one of the preceding claims, **characterised in that** the nominal pore size (x) is $100\text{ }\mu\text{m} < x < 750\text{ }\mu\text{m}$.
5. Ozone generator (1) according to any one of the preceding claims, **characterised in that** the nominal pore size (x) is $100\text{ }\mu\text{m} < x < 500\text{ }\mu\text{m}$.
6. Ozone generator (1) according to any one of the preceding claims, **characterised in that** the nominal pore size (x) is $100\text{ }\mu\text{m} < x < 250\text{ }\mu\text{m}$.
7. Ozone generator (1) according to any one of the preceding claims, **characterised in that** the electrically non-conductive structure (7) is made of ceramic and/or glass.

8. Ozone generator (1) according to any one of the preceding claims,
characterised in that the high voltage electrode (2) is formed at least partially from a metallic fabric.
9. Electrically non-conductive structure (7) for use in a gas flow of an ozone generator (1), wherein the electrically non-conductive structure (7) contains pores with a nominal pore size (x) of $100\text{ }\mu\text{m} < x < 1\text{ mm}$,
characterised in that the electrically non-conductive structure (7) is a fabric made of glass fibre or ceramic fibre.
10. Electrically non-conductive structure (7) according to claim 9,
characterised in that the nominal pore size (x) is $100\text{ }\mu\text{m} < x < 250\text{ }\mu\text{m}$.