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(54) PLASMA ACTIVATED WATER FOR DISINFECTING HOME APPLIANCES

(57) The present invention relates to a home appliance having a water cycle, in particular a dishwasher (1), a washing machine or a dryer, wherein a plasma generator (16) for generating a cold atmospheric pressure plasma is integrated into the water cycle so that it can activate water circulating in the home appliance. More specifically, the present invention relates to a home appliance having a water cycle, wherein a plasma generator (16) is integrated at a specific position of the water cycle so that the activated water is circulated in the water cycle of the home appliance. The present invention also relates to a process for operating a home appliance having a water cycle, wherein plasma activated water is generated and circulated in the home appliance.

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Description

[0001] The present invention relates to a home appliance having a water cycle, in particular a dishwasher, a washing machine or a dryer, wherein a plasma generator for generating a cold atmospheric pressure plasma is integrated into the water cycle so that it can activate water circulating in liquid or gaseous phase in the home appliance. More specifically, the present invention relates to a home appliance having a water cycle, wherein a plasma generator is integrated at a specific position of the water cycle so that the activated water is circulated in the water cycle of the home appliance. The present invention also relates to a process for operating a home appliance having a water cycle, wherein plasma activated water is generated and circulated in the home appliance.

[0002] In the water conducting and intermittently wet internal spaces of home appliances, in particular dishwashers, washing machines or dryers, microorganisms are continuously introduced by contaminated objects such as dirty dishes or clothes. Especially during times when the appliance is not used, biomass can grow in the moist environment. This hygienic problem has become more severe with the increasing use of energy saving programs in home appliances because the process water does not reach temperatures anymore, at which microorganisms are devitalized. In addition, e.g. rinsing water which is not very dirty yet, may be reused for ecologic and economic reasons at least within one wash cycle. As a consequence, contaminated water or moisture remains within the appliance or is repeatedly reintroduced into the water cycle.

[0003] In order to control the contamination of the appliance's internal space, special cleaning methods including hot steam treatment and disinfection with chemicals, in particular strong oxidants such as ozone, are used. While certain internal spaces of an appliance cannot easily be decontaminated without creating direct access, the health risk associated with chemicals that are introduced over the water cycle requires complex safety precautions as well as waste disposal management.

[0004] In particular ozone has been used for disinfecting appliances via the water cycle; but it has to be used in high concentrations in order to have the desired effect. Since the solubility of ozone in water is very low, a significant portion leaks into the surrounding environment as a gas and represents a security hazard.

[0005] The disinfecting activity of plasma activated water has been demonstrated. The active species are generated by ionization of molecules present in the gas phase (e.g. air) and then dissolve in water to result in plasma activated water (cf. Fig. 1). In particular, reactive oxygen species (ROS) and reactive nitrogen species (RNS) formed in the air dissolve upon contact with water to generate hydrogen peroxide, nitrate, nitrite and peroxynitrite species. The strong oxidant and acidic properties of the active species account for the bactericidal or fungicidal activity. The plasma activated water can for example be used for disinfecting surfaces by contacting them with the water.

[0006] Active species can be generated in the gas phase by applying an electric field and creating an electric discharge or electromagnetic radiation. An electric discharge between an electrode and a water surface, for example water flowing over the other electrode, in the presence of air or a discharge in a reaction chamber, in which a vapor of water droplets or water containing air bubbles is present, can create plasma activated water. The generated plasma can be either thermal (or "hot") or non-thermal (or "cold") depending on the relative temperatures of the electrons, ions and neutral species present.

[0007] A method and a system that includes employing both thermal and non-thermal plasma for generating plasma activated water is described in WO 2016/096751 A1. This document discloses a thermal and non-thermal plasma activated water reactor system, where the two plasma modes can be generated individually or simultaneously in order to control and optimize the composition of the active species in the water. The system is proposed for application to disinfect water or objects and surfaces such as e.g. human skin as well as for producing nitrogen compounds that can be used as fertilizer and to enhance seed germination and plant growth.

[0008] WO 2011/098918 A2 relates to a method and apparatus for applying plasma particles to a liquid. The plasma is generated by electric discharge in a biphasic stream of liquid droplets suspended in a gas phase. To create the biphasic stream, the liquid may be subjected to a drop in pressure, e.g. sprayed through a nozzle. By varying the ratio of gas and liquid as well as the power of the discharge, the reactions happening during activation can be controlled. The method and, respectively, the apparatus are intended to be used to sanitize water e.g. if a water supply has become contaminated by harmful biological agents.

[0009] The integration of a plasma discharge unit into a washing machine to enhance the washing and rinsing performance is disclosed in US 2004/0206133 A1. The washing machine comprises an outer tub disposed in a casing for receiving washing water, and inner tub rotatably disposed in the outer tub for receiving laundry and a plasma discharge unit for performing a plasma discharge in the washing water inside the outer tub. According to the description, the washing water is heated by the discharge unit and the detergent is activated to accelerate the reaction with the laundry.

[0010] In WO 2011/141263 A1, a home appliance, in particular a dishwasher, a washing machine or a dryer, is described, which comprises a container that is subjected to moisture during operation of the home appliance and tends to form a biofilm on one of its inner surfaces. A plasma generator, which can generate a cold atmospheric pressure plasma and is arranged at a distance of less than 5 cm from an inner surface of the container. This arrangement allows the generation of a cold atmos-

pheric pressure plasma in the air inside the container when the home appliance is not operating. The reactive species generated in the gas phase in contact with the inner surface of the container are able to exert their antimicrobial effect and disinfect the surface and prevent biofilm growth.

[0011] Since the active species in plasma activated water have a limited lifetime, the anti-microbial effect of plasma activated water is restricted to a more or less confined area around the place where it is generated. In order to achieve a sufficient active or preventive decontamination of all moist spaces within a home appliance, plasma activated water has to be generated in a way that allows it to circulate through most or, preferably, all of the water cycle within the lifetime of active species.

[0012] It is an object of the present invention to provide a home appliance having a water cycle, in particular a dishwasher, a washing machine or a dryer, in which plasma activated water can be generated and circulated so that it disinfects most or, preferably, all of the moist spaces with in the home appliance and prevents bacterial and fungal growth. In particular, it is an object of the present invention to integrate a plasma generator into the home appliance so that it can generate plasma activated water, which circulates through the entire water cycle during normal operation of the home appliance or during a separate decontamination program independent of the normal operation. It is a further object of the present invention to allow integration of a plasma generator into the existing water cycle of a home appliance as a retrofitting.

[0013] The above identified objects of the present invention are met by a home appliance having a water cycle, in particular a dishwasher, a washing machine or a dryer, characterized in that a plasma generator for generating a cold atmospheric pressure plasma is integrated into the water cycle so that it can plasma activate the water circulating in the home appliance.

[0014] By a targeted integration of a non-thermal atmospheric pressure plasma generator into existing components of the water cycle of a home appliance, it becomes possible to sufficiently decontaminate the entire water conducting internal space of the home appliance by generating plasma activated water, which circulates through the water cycle within the life time of the active species in the water. The water can be activated and circulated in liquid or gaseous phase.

[0015] The plasma generator is configured to activate water passing through a component of the water cycle and continuing to circulate in the water cycle of the house appliance. The plasma generator may be integrated into a water conducting conduit within the water cycle, wherein all of the water or part of the water running though the conduit during operation of the circulation pump of the home appliance is passing though the plasma generator. The flow rate of water and/or air through the plasma generator can preferably be adjusted according to the reaction rate of the plasma generator.

[0016] While the active species in water activated by a non-thermal atmospheric pressure plasma generator are not as highly concentrated as in a water activated and heated up by a thermal plasma discharge, they provide enough antimicrobial activity over a time of about 15 minutes after their generation, which has turned out to be sufficient to disinfect the entire water conducting internal space of a conventional home appliance such as a dishwasher, a washing machine or a dryer.

[0017] Since a non-thermal atmospheric pressure plasma can be generated in air at atmospheric pressure, a complex and expensive vacuum technique can be avoided. The temperature of non-thermal plasma can be adjusted to be as low as room temperature and therefore does not influence the temperature of the water during activation.

[0018] Taking into account the lifetime of the active species in the plasma activated water, the existing components of the water cycle can be used to circulate the plasma activated water to achieve the desired disinfection. The operating time of the plasma generator can be adapted to the respective operating state of the home appliance and adjusted to the volume stream passing through the cycle in order to control the disinfection. It can e.g. be operated during a normal program of the home appliance, e.g. during rinsing with fresh water, or it can be operated in a separate decontamination program independent of the normal program of the home appliance.

[0019] Preferably, the plasma generator is integrated into a water conduit of the water cycle so that the water or part of the water running through the conduit during operation of the circulation pump of the home appliance passes though the plasma generator. If required, air for plasma generation can be supplied to the plasma generator via a ventilation duct.

[0020] A plasma generator used in the context of the present invention comprises a reaction chamber having at least one joined or two separate water and air inlet(s) and at least one outlet as well as electrodes to create an electric field within the reaction chamber. The inlet(s) is/are configured to receive water from the water cycle of the home appliance and the outlet(s) is/are configured for feeding the plasma activated water back into the water cycle of the home appliance. In addition, the plasma generator may comprise means to control the water and/or air volumetric flow rate through the generator and, preferably, the proportion of water and air present in the reaction chamber at the same time. The or, respectively, one of the inlet(s) may further comprise a means to vaporize water within the reaction chamber.

[0021] The plasma generator used according to the present invention is configured to generate a cold plasma, which does not heat up the water during activation.

[0022] A plasma generator can be integrated in one specific location in a home appliance or there can be more than one plasma generator integrated in two or more of the locations described below. Thus, the present invention also relates to a home appliance, in which a

combination of two or more plasma generators is integrated in different locations of the water cycle.

[0023] According to a preferred embodiment of the home appliance, the plasma generator is integrated at the sucking nozzle or the pressure outlet off the circulation pump.

[0024] A home appliance having a water cycle comprises a circulation pump to circulate the water during operation of the appliance according to the operation program. Integrating the plasma generator at the sucking nozzle or the pressure outlet of the circulation pump, allows to generate active species in the water being pumped through the water cycle and thereby continuously distributing them over the water cycle. The rotation speed of the pump can be adjusted to optimal volume flow rate according to the reaction rate of the plasma generator.

[0025] In a further preferred embodiment of the home appliance, the plasma generator is integrated into the fresh water supply line.

[0026] Fresh water is normally delivered to a home appliance from the home water supply via a delivery pipe in the wall. This pipe is connected to the home appliance and allows water intake when the inlet valve is opened via the fresh water supply line. Integrating the plasma generator at the fresh water supply line downstream of the inlet valve allows to ensure that the water is decontaminated before it enters the water cycle of the home appliance. This arrangement can prevent any of potential biological contaminants, which may cause growth of biomass within the home appliance, from entering when the plasma generator is operated during water intake.

[0027] According to a further preferred embodiment of the home appliance, the plasma generator is integrated into the supply line of a reservoir for fresh and/or washing water.

[0028] Home appliances normally have reservoirs to store fresh water or washing water that has already been used during a washing cycle, but is not dirty enough to be immediately discarded, such as e.g. rinsing water, which may be reused. The reservoir temporarily holds water, which is gradually fed into the water cycle according to the operation program. If a plasma generator is integrated into the supply line of the reservoir, the introduction of biocontaminants into the reservoir can be prevented because the entering water is decontaminated. This arrangement is particularly efficient because microorganisms entering the reservoir may start forming biofilms, in particular during the time when the water is stored and therefore more or less stagnant.

[0029] In a preferred embodiment of the home appliance, the plasma generator is integrated at the inlet site of the steam generating line.

[0030] If the home appliance has a steam generator, it is advantageous to integrate the plasma generator at the inlet site of the steam generating line. In this arrangement, the plasma activated water is generated right before it is transformed into steam. The homogenous distribution of droplets of activated water in the form of steam allows a particularly efficient decontamination of internal spaces of the home appliance. The steam is capable of filling internal spaces completely and therefore reaching otherwise hardly accessible locations.

[0031] In a further preferred embodiment of the home appliance, the plasma generator is integrated downstream of the water leakage safety system of the water supply pocket.

[0032] Integration of the plasma generator into the primary installation site of the water cycle allows efficient distribution of the activated water according to the operation programs.

[0033] In a further preferred embodiment of the home appliance, the plasma generator is integrated downstream at the outlet of the water softening unit.

[0034] In most home appliances a water softening unit removes ions such as Ca^{2+} and Mg^{2+} from the water entering the appliance. These ions may cause calcification and long-term damage to the appliance and interact with the soap reducing its detergent effect. If a plasma generator is integrated downstream at the outlet of the water softening unit, the water to be activated has just been softened, i.e. hardening ions have been removed. The activation is therefore particularly efficient because no interference with the generation of the active species in the water is possible.

[0035] In a further preferred embodiment of the home appliance, the plasma generator is integrated in the metering unit.

[0036] If the plasma generator is integrated into the metering unit, the delivery of activated water into the water cycle can be controlled according to the operating program (cf. Fig. 5).

[0037] In a further preferred embodiment of the home appliance, the plasma generator is integrated in a separated line of a water switch.

[0038] In a home appliance, water switches allow to supply separate lines, e.g. the spray arms in a dishwasher, with water. Integrating the plasma generator into a spray arm, allows a particularly fast and efficient distribution of the plasma activated water as the water is sprayed over a large space within the home appliance. A separate line with a plasma generator integrated therein can also be used as a decontamination line, which can decontaminate the internal space of the home appliance independently of the normal operating program. Particularly preferred is the integration of a plasma generator into the line supplying the top spray arm of e.g. a dishwasher with water.

[0039] In the further preferred embodiment of the home appliance, the plasma generator can be operated so that it is visible for a user from the outside.

[0040] This arrangement allows a visual check on whether the plasma generator is operating and indicates that water is activated when the plasma discharges are observed as flashes (cf. Figs. 6 and 7).

[0041] The present invention also relates to a process

of operating a home appliance, in particular a home appliance as described above, wherein plasma activated to water is generated and circulated in the water cycle.

[0042] According to the process of operating a home appliance having a water cycle and a plasma generator, the circulating water is activated while it is running through the water cycle and passing through the plasma generator. This process allows the plasma activated water, which is generated in a specific position of the water cycle to be distributed over most of or even all of the water conducting and moist internal space of the home appliance within the lifetime of the active species of the plasma activated water. It therefore becomes possible to decontaminate the entire water cycle with the plasma activated water without needing to introduce and subsequently dispose of potentially hazardous chemical agents. Since a cold atmospheric plasma generator is used, it can be operated at temperatures below 60 °C, preferably below 40 °C, particularly preferably below 30 °C and does not interfere with the operating temperature of the home appliance. Therefore, the plasma generator can be operated during a normal operating program of the home appliance. Preferably, it is operated during intake of fresh water or rinsing phases when fresh or only slightly dirty water is circulated.

[0043] In a preferred embodiment of the process described above the generation and circulation of plasma activated water is conducted when fresh water is circulated through the home appliance and the home appliance is not loaded with washing or drying goods.

[0044] The process of operating the home appliance having a water cycle and a plasma generator can be implemented so that the normal operation program of the home appliance, i.e. washing or drying of objects, is conducted independently of the plasma generator. The plasma generator is then operated during a special decontamination program, i.e. when no objects to be washed or dried are inside the appliance. In such a decontamination program, preferably, fresh water is introduced into the water cycle, activated and circulated so that it reaches all parts of the water cycle within 15 minutes or less. The circulation can be repeated several times while the water is repeatedly activated in order to achieve optimal decontamination.

[0045] According to a further aspect of the present invention, the plasma generator can be designed such that it can be retrofitted in existing home appliances.

[0046] The foregoing and other features and advantages will become more evident from the following detailed description of illustrative and non-limiting embodiments with reference to the accompanying drawings, in which:

Fig. 1 shows a schematic representation of the plasma reactants formed in the gas phase and dissolved in water at an interface between the plasma and water.

Fig. 2 shows a schematic representation of the water cycle of a dishwasher, wherein a plasma generator is integrated at the sucking nozzle and/or the pressure outlet of the circulation pump.

Fig. 3 shows a schematic representation of the water cycle of a dishwasher, wherein a plasma generator is integrated at the fresh water supply line, which is also the supply line of a reservoir for fresh and/or washing water.

Fig. 4 shows a schematic representation of the water cycle of a dishwasher, wherein a plasma generator is integrated into the line supplying a spray arm group with water.

Fig. 5 shows a schematic representation of a metering unit, into which a plasma generator is integrated.

Fig. 6 shows a window in the front door of a dishwasher, which allows a user to observe the operation of the plasma generator.

Fig. 7 shows a schematic representation of the front door of a dishwasher seen from the side, having a plasma generator integrated so that a user can observe the operation of the plasma generator though the window.

Fig. 8 shows a window in the front door of a washing machine, which allows a user to observe the operation of the plasma generator.

[0047] Fig. 2 shows a schematic representation of the water cycle of a dishwasher 1. Fresh water is supplied to the dishwasher through an inlet valve 4, which is followed by a security air gap 5 and enters the reservoir for incoming water 3 via the supply line 6. Ventilation line 7 allows air to enter the reservoir 3. From the reservoir, the water passes through an entering water switch 13 and is either directed to the waste water pump 8 or to the circulation pump 14. A plasma generator 16 is integrated either at the sucking nozzle or the pressure outlet of the circulation pump 14. This arrangement allows to generate active species in the water being pumped through the water cycle and thereby continuously distributing them over the water cycle. The rotation speed of the pump can be adjusted to the volume flow rate according to the reaction rate of the plasma generator to optimize the performance. The plasma activated water is pumped into the heating unit 15 and enters the supply lines supplying the spray arm groups 10, 11 via the circulation water switch 9, which distribute it over the internal space of the dishwasher. The water is then collected in the sump 2, passed again through the water switch 13 to be either re-fed to the water cycle or disposed via the waste water pump 8 to the waste water line 12.

[0048] Referring to Fig. 3, the plasma generator is in-

tegrated into the fresh water supply line 6. This arrangement allows the water to be decontaminated before it enters the water cycle of the home appliance and prevent growth of biomass.

[0049] In the schematic representation of Fig. 4, the plasma generator is integrated into the line supplying spray arm group 10 with water. Spray arm group 10 may then function as a decontamination unit. When water is supplied to the spray arm group 10 and the plasma generator is operated, plasma activated water is sprayed and distributed efficiently into the internal space of the home appliance via the spray arm group. Since the water is activated just before spraying, it still comprises a high concentration of active species.

List of reference signs

[0050]

1	dishwasher
2	sump
3	reservoir for incoming water
4	inlet valve
5	security air gap
6	fresh water supply line
7	ventilation line
8	waste water pump
9	circulation water switch
10	spray arm group 1
11	spray arm group 2
12	waste water line
13	entering water switch
14	circulation pump
15	heating unit
16	plasma generator

Claims

1. Home appliance having a water cycle, in particular a dishwasher (1), a washing machine or a dryer, **characterized in that** a plasma generator (16) for generating a cold atmospheric pressure plasma is integrated into the water cycle so that it can plasma activate the water circulating in the home appliance.

2. Home appliance according to claim 1, wherein the plasma generator (16) is integrated at the sucking nozzle or the pressure outlet off the circulation pump (14).

3. Home appliance according to claim 1, wherein the plasma generator (16) is integrated into the fresh water supply line (6).

4. Home appliance according to claim 1, wherein the plasma generator (16) is integrated into the supply line of a reservoir for fresh and/or washing water (3).

5. Home appliance according to claim 1, wherein the plasma generator (16) is integrated at the inlet site of the steam generating line.

6. Home appliance according to claim 1, wherein the plasma generator (16) is integrated downstream of the water leakage safety system of the water supply pocket.

7. Home appliance according to claim 1, wherein the plasma generator (16) is integrated downstream at the outlet of the water softening unit.

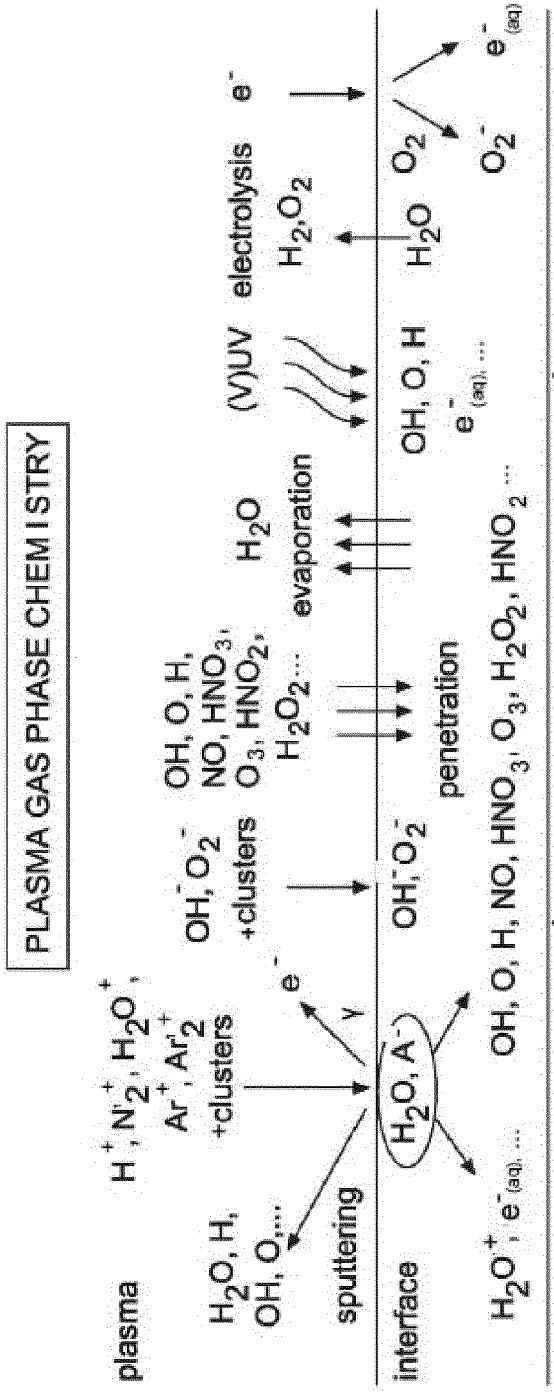
8. Home appliance according to claim 1, wherein the plasma generator (16) is integrated in the metering unit.

9. Home appliance according to claim 1, wherein the plasma generator (16) is integrated in a separated line of a water switch (10, 11).

10. Home appliance according to claim 1, wherein the plasma generator (16) can be operated visibly to a user from the outside.

11. Process of operating a home appliance having a water cycle, in particular a home appliance as described above, wherein plasma activated to water is generated and circulated in the water cycle.

12. Process according to claim 11, wherein the generation and circulation of plasma activated water is conducted when fresh water is circulated through the home appliance and the home appliance is not loaded with washing or drying goods.


PLASMA GAS PHASE CHEMISTRY
plasma
interface
bulk liquid
sputtering
penetration
evaporation
electrolysis
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+clusters
+clusters
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Fig. 1

Fig. 2

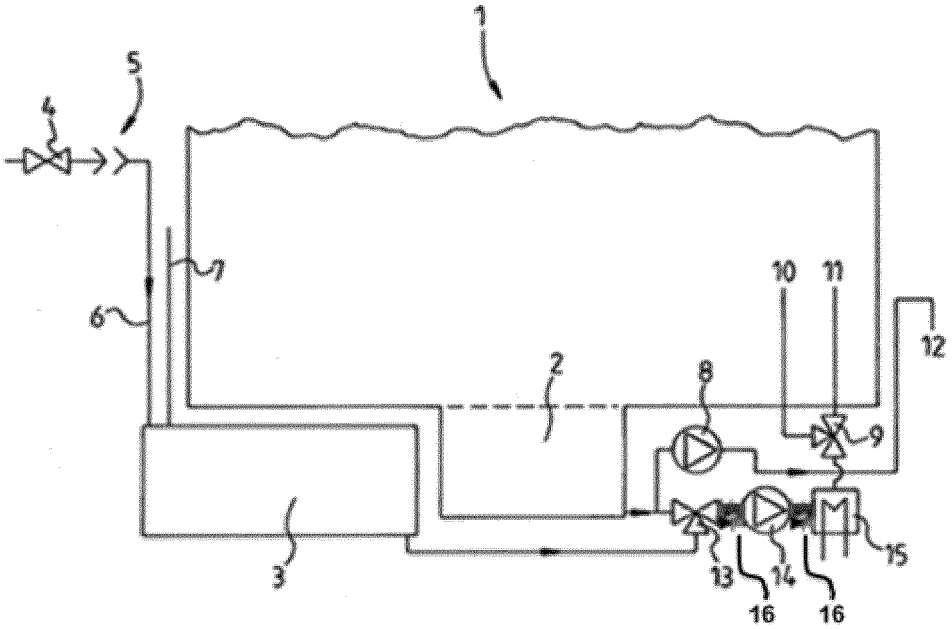

Fig. 3

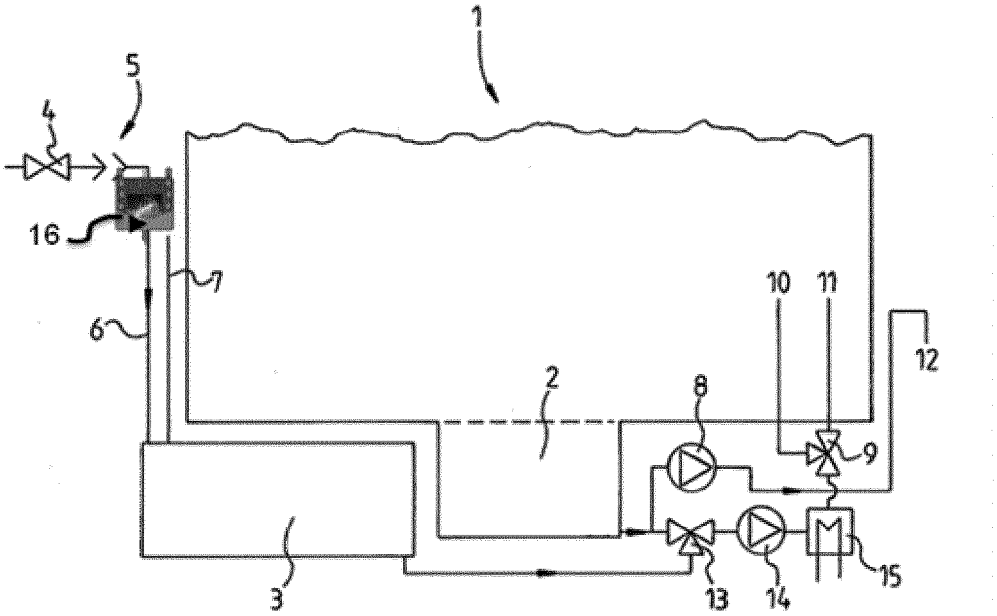

Fig. 4

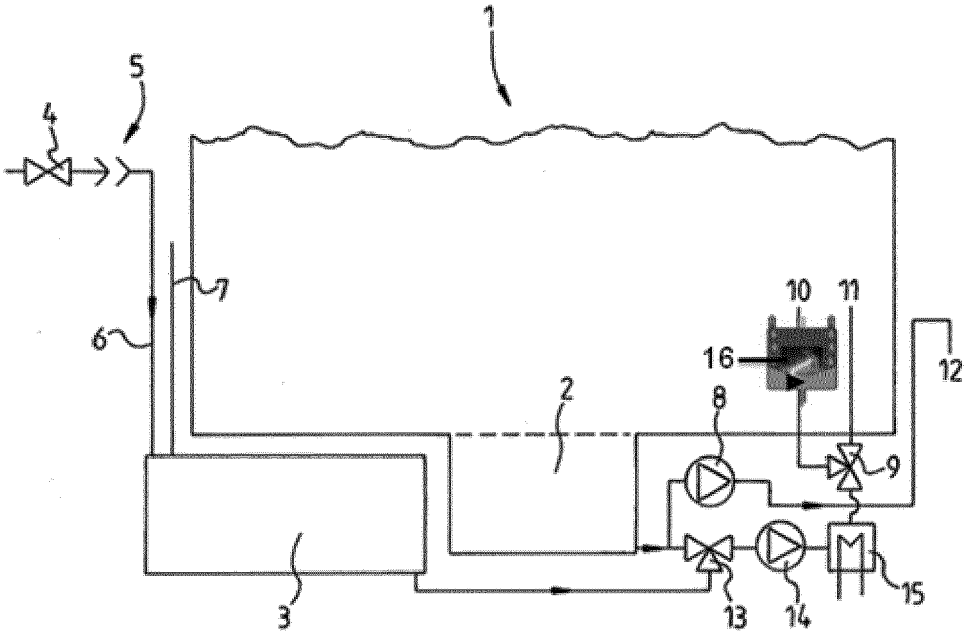

Fig. 5

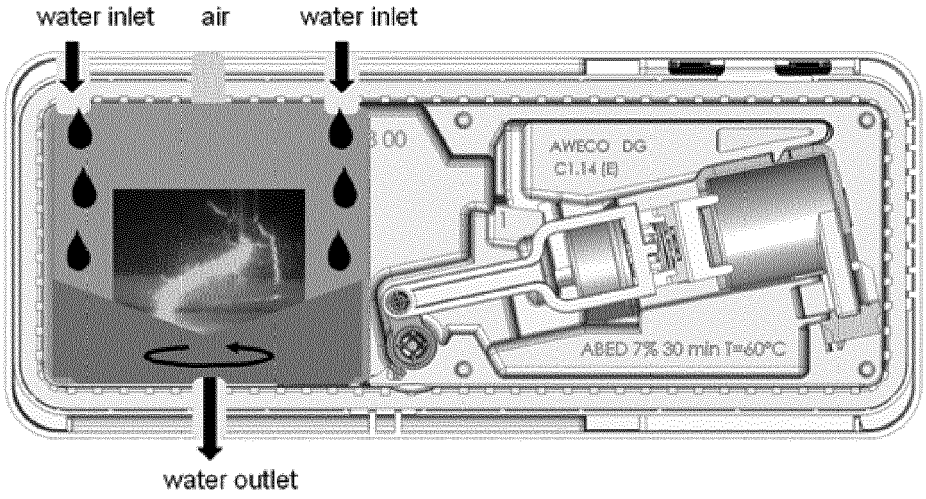
water inlet
air
water inlet
AWECO DG
C1.14 (E)
ABED 7% 30 min T=60°C
water outlet

Fig. 6

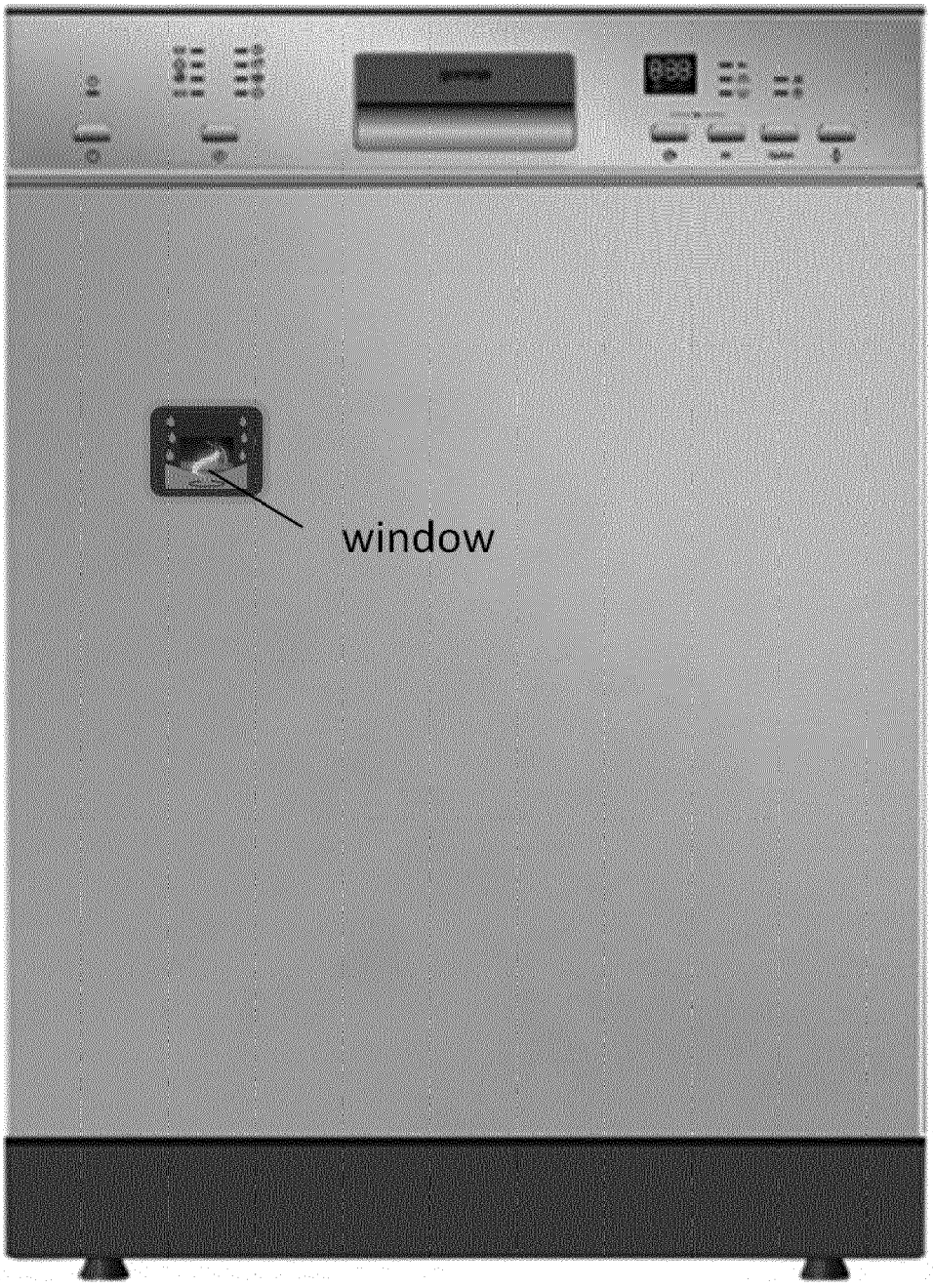

Fig. 7

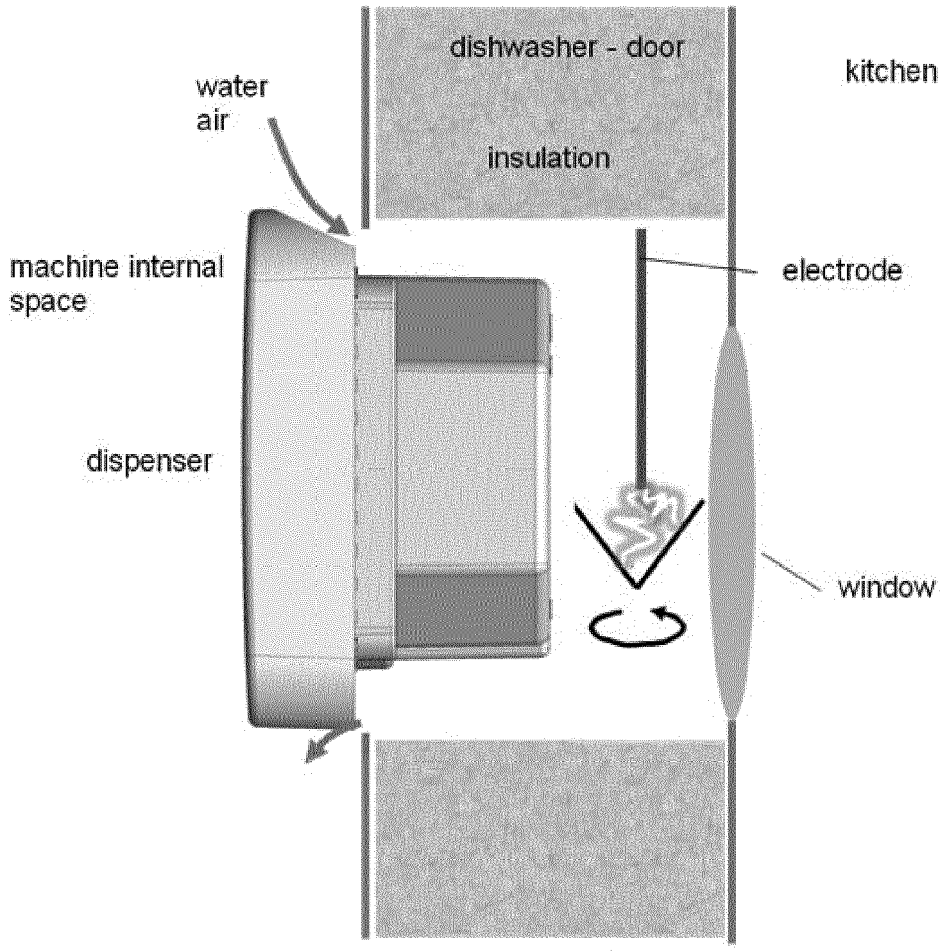
dishwasher - door
kitchen
water
air
insulation
machine internal
space
electrode
dispenser
window

Fig. 8

Europäisches Patentamt
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EUROPEAN SEARCH REPORT

Application Number
EP 17 17 6487

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	31 October 2017	Kirner, Katharina

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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P : intermediate document

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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 17 17 6487

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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31-10-2017

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