Mini glide-arc plasma reactor for biological decontamination

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Abstract

Gliding-arc micro-reactors are used to generate non-thermal plasma. The aim of the work was to develop a compact plasma device for biological decontamination, which would not simultaneously contribute to thermal damage on the substrate material. Machining was performed on PET, stainless steel and silicone surfaces, after prior inoculation with cultures of E. coli. Air and nitrogen were used as plasma-generating gases. The maximum attainable reduction of the E. coli bacteria colonies within 5 min of machining was 3.82 log (cfu/mL).

Key words:

gliding-arc discharge, non-thermal plasma, biological decontamination

Introduction

Currently, low-temperature plasma is used in numerous industrial processes such as surface machining and the production of new materials for microelectronics and nanotechnology, waste disposal, disinfection, sterilization and the treatment of volatile materials, e.g. for the treatment of toxic gases arising from combustion processes and the chemical industry. Plasma is used for treating contaminated waters and soil [1-8]. Non-thermal plasma technologies allow the processing of organic materials such as rubber, fabrics, biomaterials, bacteria, fungi, spores, and are an ecologically justified alternative to conventional chemical methods [4,9].

The concept of plasma decontamination was proposed in the 1960s. Plasma methods are characterized by low toxicity for patients and operational staff. Despite the fact that the number of scientific papers and devices involved in plasma sterilization continues to grow, the development of industrial solutions based on non-thermal atmospheric pressure plasma is still a great challenge [10-13].

The aim of the work was to develop a compact, portable plasma device for biological decontamination, which would not simultaneously contribute to thermal damage in the treated substrate.

Plasma reactor

There are many designs of plasma reactors with different power supply parameters and discharge geometry [14-16]. A single-phase, two-electrode miniature reactor with gliding-arc discharge was designed and built along with a process gas distribution system.

Electrodes of 1.5 mm thickness, 10.4 cm length and 5 cm distance between the electrodes in the upper part and 3 mm in the bottom were made of copper. The major problem was the minimization of geometric dimensions of the reactor, while ensuring the homogeneity of the discharge on a relatively large area. The "flyback" power supply was utilized. The electrical parameters of the secondary power supply system were 15 kV, 40 mA and 16 kHz. The layout of the laboratory post is shown in Fig. 1.

Biological decontamination

Bacterial infections induced by the presence of layers of microorganisms on a variety of surfaces are a problem of numerous medical departments, biotech factories and food processing plants. Surfaces requiring additional disinfection techniques involve equipment (water dispensers, catheters, drains, masks, dental and ventilation components), underwear, materials, dressings, live tissues (bedsores in chronic diseases, slow-healing wounds), prostheses, implants, stents, containers for storing food and medicines and food itself [17]. Biological and medical applications of low-temperature plasma utilize the bactericidal properties of electrical discharge, especially those compounds such as ozone (O_3), nitric

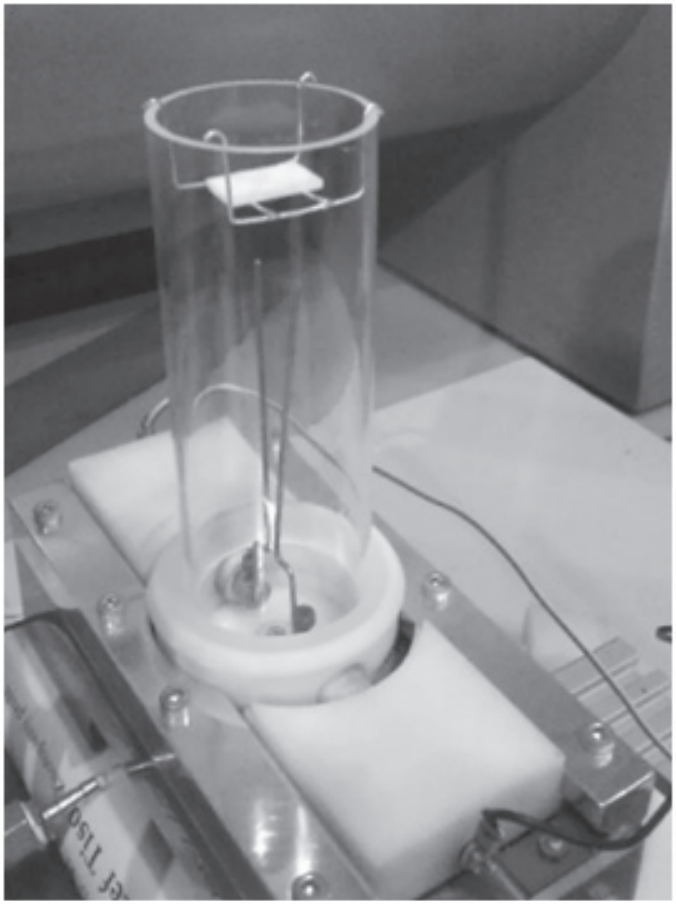

Fig. 1.
Photograph of the glide-arc reactor

oxide (NO) and hydrogen peroxide (H_2O_2) produced during these discharges.

To determine the decontamination effect using a gliding-arc reactor, selected surfaces of the materials were contaminated with the cultures of the pathogenic micro-organisms: Gram-negative colony (Escherichia coli); incubated at 37°C for 24 h. At the end of the incubation, the bacteria were counted in order to obtain the initial count of each bacterial culture. 100 µL of each bacterial culture of known count was inoculated with model surfaces (PET, stainless steel, silicone). The contaminated surfaces were left at 35°C for 1-2 hours. to obtain complete adhesion of the bacteria to the surface. Model surfaces were divided into control and low-temperature plasma. Plasma-surface-controlled surfaces were placed in the sample feeder in the field of activity of the reactants generated in the gliding-arc reactor. Air and nitrogen were used as substrate gases. The gas flow was 0.5 m^3/h. The processing time was set at 1 and 5 min.

To recover any tested bacteria, the contaminated surfaces were placed in sterile saline containing surfactant and shaken at different time intervals. Surfactants were used to reduce surface tension to increase the amount of bacteria recovered. Subsequently, the microorganisms from the plasma-treated surface and control samples were inoculated on agar substrates and incubated at 37°C for 24-48 hours. After this procedure, the number of colonies of recovered bacteria were counted. The results are presented in Tables 1 and 2. A five-minute plasma treatment with

Table 1.
Decontamination using a gliding-arc plasma reactor (process gas: air)

The initial E. coli count: 108cfu/mL / 8.00 log10 (cfu/mL) 5 min of shaking					
	Air flow: 0.5 m3/s				
The E.coli capable of living	1 min		5 min		Reduction level after 5 min, %
	(cfu/mL)	log10 (cfu/mL)	(cfu/mL)	log10 (cfu/mL)	
Stainless steel	1.18*107	7.07	7.46*105	5.87	26.6
Silicone	1.22*107	7.09	7.65*105	5.88	26.5
PET	7.62*106	6.88	3.83*106	6.45	19.4

Table 2.
Decontamination using gliding-arc plasma reactor (process gas: nitrogen)

Initial E. coli count: 108cfu/mL / 8.00 log10 (cfu/mL) 5 min of shaking					
The E. coli Capable of living	Nitrogen flow: 0.5 m3/s				
	1 min		5 min		Reduction level after 5 min, %
	(cfu/mL)	log10 (cfu/mL)	(cfu/mL)	log10 (cfu/mL)	
Stainless steel	9.00*107	7.95	1.22*107	7.09	11.4
Silicone	4.60*106	6.66	1.50*104	4.18	47.8
PET	6.70*107	7.83	1.00*106	6.00	25.0

a plasma reactor with a gliding-arc and a flow of 0.5 m^3/h resulted in reductions in *E. coli* populations on stainless steel, silicon and PET surfaces of 0.91, 3.82 and 2.00 log respectively (cfu/mL). In the case of air as process gas, we have obtained reductions of 3.13, 3.12 and 2.55 logs respectively (cfu/mL) for stainless steel, silicon and PET surfaces.

Conclusion

Non-thermal plasma produced in gliding-arc reactors can be used for biological decontamination of heat-sensitive materials. The ability to conduct biochemical processes at atmospheric pressure, at ambient temperatures and without environmental damage makes non-thermal plasma an alternative to chemical decontamination methods.

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