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UV Emitter by Using a Molecular Gas Discharge/Plasma Confined in Multi-Pole Magnetic Fields and Its Applications

分子性ガス多極磁場中多相交流放電プラズマを用いた新規紫外線源の開発とその応用

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We have investigated and developed a ultra-violet (UV) emitter by using nitric oxide gas mixed with nitrogen molecular one, where gases are excited by a poly-phase ac discharge/plasma confined into multi-pole magnetic fields. An intense UV irradiation ranging from 200nm to 300nm was emitted, which is suitable for sterilization. We have applied this UV emitter to sterilizing powdered polysaccharides. Sterilization equipment has designed and manufactured, where powders are carried by an air flow and irradiated by the UV emitter. A conventional low-pressure mercury UV lamp was employed as a reference.

1. Introduction

As environmental issues have become serious, the need for mercury-free lamp has become an important subject. Molecular radiators are one of the candidates for mercury-free lamps [1,2]. An UV-emitter by using nitric oxide molecular gas NO mixed with nitrogen molecular one N_2 has been proposed by us, where plasma is produced by a poly-phase ac discharge and it is confined by an advanced multi-pole magnetic field [3].

The propose of present study is to develop a UV lamp by using NO/N_2 molecular gas and to apply the lamp for sterilizing foods, medicines and perfumes, especially powdered ones extracted from natural materials. It is not suitable to sterilize these by conventional high temperature wet steam or a toxic gas [4] such like an ethylene oxide gas. Because, powders become firm or include residues. Sterilization by irradiation from radioactive elements [4] is also one of promising candidates. But its use is prohibited legally in Japan.

2. A model of UV lamp and its features

Figure 1 shows a model of our UV emitter driven by a poly-phase ac discharge/plasma, where the cross section is drawn schematically. Discharges/plasmas are produced among divided electrodes whose surfaces are covered with a dielectric, which are confined by multi-pole magnetic fields generated by permanent magnets. Intense light emissions are irradiated from excited gases in confined regions. This UV lamp is expected to have the following characteristics: (a) high Intensity & efficient emission by magnetic confinement, (b) uniform emission from divided electrodes with flexible shape, (c) emission with no temperature dependence, (d) filament-less & rapid emission, (e) no electrical noise by canceling out symmetrical poly-phase ac discharges.

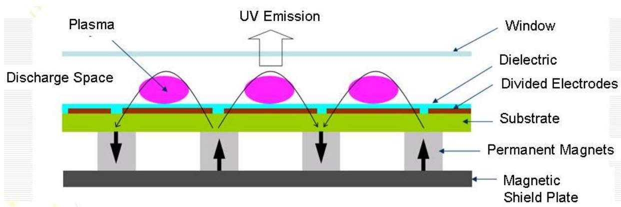

Fig. 1 Cross section of UV emission device, where a symmetric poly-phase ac power source is connected to divided electrodes.

Table Comparison with conventional UV lamps from the view point of industrial usefulness

LIGHT SOURCE / FEATUREs	Hg LAMP	Xe LAMP	LED (Light Emission Diode)	THIS LAMP
Emission Spectrum Profile	narrow	narrow	narrow	broad
Size Extendibility & Shape Flexibility	NVG	NVG	NVG	VG
Temperature Range	NVG	G	NG	VG
Irradiation Efficiency	G	NVG	NVG	NVG
Eco-Friendly & Earth Resource	NG	NG	G	VG

*VG: very good, G: good, NVG: not very good, NG: not good

A comparison between our UV lamp and conventional ones is summarized in a table, where shape flexibility, operating temperature and eco-friendly aspect are superior points of our lamp.

3. Results and discussions

Figure 2 shows a typical spectrum emitted from a NO/N_2 mixture gas-plasma, where a normalized curve of sterilizing efficiency versus wavelength is inserted. The ratio of NO to N_2 is 10% to 90%, the total gas pressure is 0.3 Torr and a twelve-phase ac power source is supplied. An intense UV spectrum from 180nm to 300nm is emitted from NO molecule, excited by discharge/plasma. Each line emitted from NO is identified γ spectrum [5,6].

We have applied this NO/N_2 UV emitter to sterilize several kinds of polysaccharide-powder, whose optical reflectivity and transmissivity are shown in Fig. 3(a) and 3(b), respectively. Here, a spectrophotometer with an integrating sphere is used and optical length is 1mm and powder density is ~$0.5 g/cm^3$. Experimental results indicate that UV components with wavelength less than 300nm have small reflectivity and transmissivity. It is found that UV components successfully penetrate into powers at the surface and dissipate their energy due to scattering among powers. Then, bacteria adhering to powders can be sterilized effectively by UV irradiation.

Figure 4 shows a photograph of sterilization equipment originally designed and manufactured, where powders are carried by an air flow through a quart tube installed along the central axis. And powders are irradiated from the circumference, where poly-phase NO/N_2 ac discharges are generated. The equipment is ~1500mm in length and ~100mm in inner diameter. The wall is cooled by water. The quartz tube is ~50mm in inner diameter.

Photograph of visible light emission from the above UV device is shown in Fig. 5, where electrode is divided into 12 pieces and twelve-phase ac power source is supplied. Pressure of NO/N_2 gas is 0.3Torr and ac discharge power is ~100W. The radiant flux density is ~ $1 mW/cm^2$.

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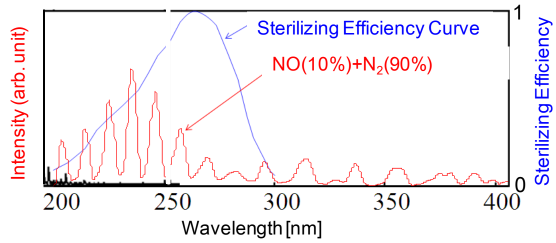

Fig. 2 Spectra observed in NO/N_2 mixture gas excited twelve-phase ac discharge/plasma; blue solid curve shows sterilizing efficiency versus wavelength.

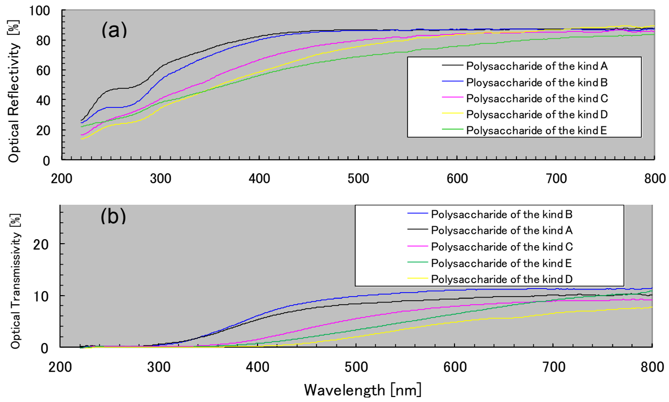

Fig. 3 Optical characteristics of five kinds of polysaccharide powder whose average sizes are ~80μm. Reflectivity is for (a) and transmissivity for (b), where optical length is 1mm, power density is ~$0.5 g/cm^3$.

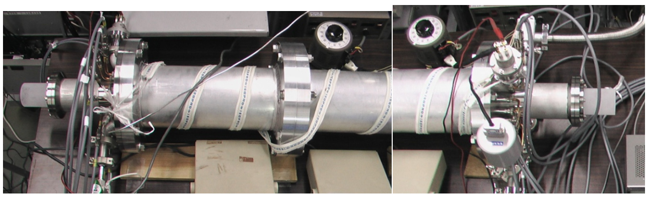

Fig. 4 Photograph of sterilization equipment originally designed and manufactured, where powders are carried by an air flow through a quart tube and irradiated from the circumference.

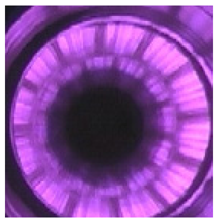

Fig. 5 Photograph of visible light emission from the above UV device, where electrode is divided into 12 pieces and twelve-phase ac power source is supplied. Pressure of NO/N2 gas is 0.3Torr and ac discharge power is ~100W.