UV technology

Sterilization Technology using an Ultraviolet-radiation Source

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1. About UV-radiation sterilization

Ultraviolet (UV) radiation is classified according to its wavelength as UV-A (wavelength: 315–400 nm), UV-B (280–315 nm), and UV-C (100–280 nm). UV-C, which is the UV radiation contained in sunlight, is absorbed by the ozone layer. UV-A and UV-B, which reach the surface of the earth, cause sunburn, but their sterilization effect is low. UV-C (with short wavelength) imparts high energy per photon, and it can be efficiently absorbed by the DNA and RNA possessed by bacteria and viruses and thereby destroy the genetic information held by the DNA, suppress cell division and proliferation, and sterilize things (i.e., inactivate microorganisms). The maximum absorption of UV by DNA is around the wavelength of 260 nm. Accordingly, as for the light source for UV sterilization, two kinds of lamps are widely used: (i) low-pressure mercury lamps (which efficiently emit the 254-nm bright line of mercury) and (ii) medium- and high-pressure mercury lamps, which have lower luminous efficiency but higher radiation density that low-pressure mercury lamps and generate broad light emission around 260 nm. In recent years, LEDs in the deep-ultraviolet radiation region have also been developed, and they are expected to be a “mercury-free” light source in the future. In this article, the usefulness of such UV-radiation sterilization, including the features and practical examples of various UV-radiation light sources, is explained.

2. Advantages and precautions concerning UV-radiation sterilization

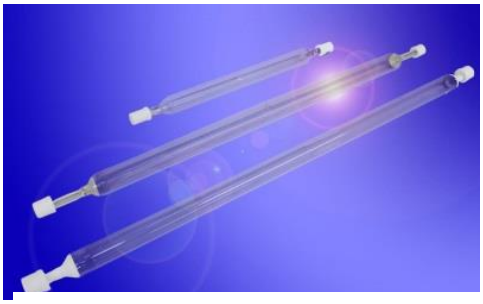
As for the touted merits of UV-radiation sterilization, compared to sterilization methods like those using heat, chlorine, and ozone, UV-radiation sterilization can be expected to be effective against various bacterial species, and it uses no residual chemicals and does not require control of temperature or management of chemicals. In particular, compared to means of sterilization using chemicals such as chlorine, UV-radiation sterilization poses no risk of generation of trihalomethane by residual chlorine, so it is used in fields such as food and medicine as a safe and secure means of sterilization. In addition to the merit of low operating cost, products equipped with various UV-radiation light sources are being considered as a

countermeasure against infection by the novel coronavirus that is currently spreading around the world. However, UV-C and other short-wavelength UV radiation increase the risk of developing skin cancer. Moreover, looking directly at UV irradiation may damage the cornea of the eye. Accordingly, it is necessary to follow the instructions and advice of a person with proper knowledge of UV irradiation and use the appropriate product correctly. In addition, since cryptosporidium, which is a chlorine-resistant pathogenic protozoan, can be inactivated by UV irradiation even in water-treatment applications, which is an important lifeline, UV-radiation sterilization is combined with chlorine disinfection and utilized as a sterilization means for water purification.

3. Ultraviolet-light source and applied products

Sterilization technology using an UV-radiation light source is explained in detail hereafter with specific examples. A feature of a low-pressure mercury lamp is high UV-emission efficiency. Luminous efficiency of the GL15-type mercury lamp, known as a general "germicidal lamp," is about 30% of the power consumption of the lamp, and it is about four- to five-times higher than the luminous efficiency near 254 nm of the medium-pressure and high-pressure mercury lamps described hereafter. Thanks to its advantages in terms of that high efficiency and low cost, germicidal lamps are widely used for sterilizing air, surfaces, water, and so on. Air-circulation UV purifiers equipped with low-pressure mercury lamps are also used in food factories and medical-care facilities.

In the meantime, medium- and high-pressure mercury lamps utilize mercury emission in a similar manner to low-pressure mercury lamps. They are characterized by having mercury vapor pressure of one to several atmospheres during emission and being able to input a large amount of electric power at high density. Although luminous efficiency around 254 nm is about 6% to 8%, high UV radiation can be utilized thanks to a lamp output that is 10 times or more that of a low-pressure mercury lamp. This high UV radiation at 254 nm is widely utilized for decomposition of organic matter in ultrapure-water purification and for sterilization of seawater used for ship ballast[1)].



Mercury lamp for water treatment

Deep-ultraviolet LEDs (which emit UV light at wavelengths of 265 nm or 280 nm) using AlGaN-based semiconductors have low luminous efficiency (a few percent) and high cost per unit of UV radiation; even so, thanks to their advantages such as mercury-free LEDs, compact design of appliances, and energy saving, they are increasingly

expected to be used in places where it was difficult to use conventional mercury lamps and in food and medical settings where their use was avoided due to concerns about mercury diffusion. For example, a running-water sterilization module equipped with 280-nm UV-radiation LEDs and compatible with a processing flow rate of 100 L/min is in practical use[2]. As mentioned above, various lamps and LEDs are used as UV-radiation light sources; however, in consideration of efficiency, sterilization effect, and implementation cost, the means using mercury discharge is mainstream at this stage.

Flowing-Water sterilization module

4. Summary

The so-called "with-corona society" is demanding a new lifestyle, and on top of infection-prevention measures for each person, sterilization measures in various situations in daily life are being considered. Sterilization technology using a UV-radiation light source introduced in this article is an important means that can play a part in those measures. We hope that by developing a photo-sterilization product that takes advantage of the merits of both a mature product (namely, a discharge lamp) and an expected new product (namely, an LED light source), we will help provide a safe living environment during this coronavirus crisis.

References

[1] Akihiko Tauchi, Atsushi Fujioka, and Tomoyuki Mineyama: TOSHIBA REVIEW Vol. 70 No. 11 (2015)

[2] Naoto Sakurai, Takeo Kato, and Akihiko Tauchi: TOSHIBA REVIEW Vol. 74 No. 4 (July, 2019)