High Speed and High Gas Barrier Rotary DLC Plasma Coating System for PET Bottles

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1. Introduction

Beverage and food containers have been rapidly replaced by polyethylene terephthalate (PET) bottles because of their advantages such as lightweight, designability, physical toughness and economy. As a result, 50% or more of the total number of such containers are now PET bottles.

However, a disadvantage of PET bottles compared with metallic containers and glass bottles is its lower gas barrier capability such that sensitive contents tends to deteriorated by permeation of gases such as the ingress of oxygen and the loss of carbon dioxide gas. Various gas barrier enhancing technologies have been developed to solve the problem.

Mitsubishi Heavy Industries, Ltd. (MHI) has developed a DLC plasma coating system(NOTE) which has the world's highest levels of productivity and gas barrier performance. This coating system is capable of forming a extremely thin but quite high gas barrier DLC (Diamond Like Carbon: carbon similar in physical properties to diamond) film on the inner surface of the bottle using plasma CVD (chemical vapor deposition). This report gives a brief introduction to the system.

2. DLC coating technology and function of DLC coating

The DLC film, which is deposited on the inner surface of the bottle via the plasma CVD provides remarkable high gas barrier performance against the inflow and the outflow of gases such as oxygen and carbon dioxide (**Fig.1**).

Compared with other film-forming methods, the plasma CVD process employed in the present system can form a dense DLC film utilizing its high energy ions, which strike the DLC surface during the deposition process, and therefore provides quite high gas-barrier performance compared with multi-layer PET bottles that have been appearing in ever-increasing quantities as a high gas barrier package for the sensitive contents.

The process for forming the DLC film on the inner surface of the PET bottle is as shown in **Fig. 2**.

(NOTE) The DLC coating technology for PET bottles was first developed by Kirin Brewery Co., Ltd. Based on this technology, MHI has commercialized the world's optimum rotary plasma coating system.

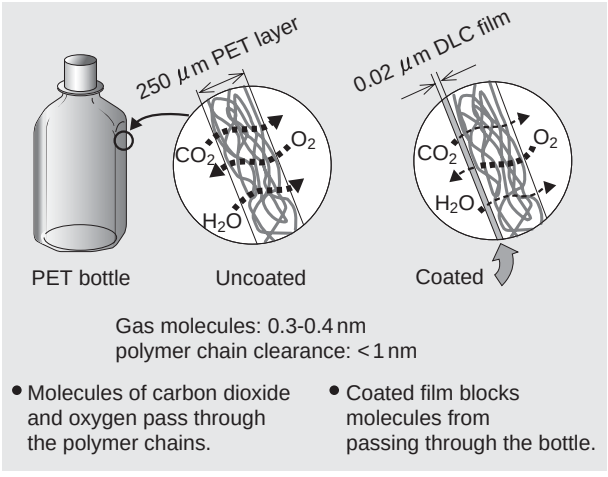

Fig. 1 Mechanism of gas barrier
Coated film blocks the passage of gas molecules through the film.

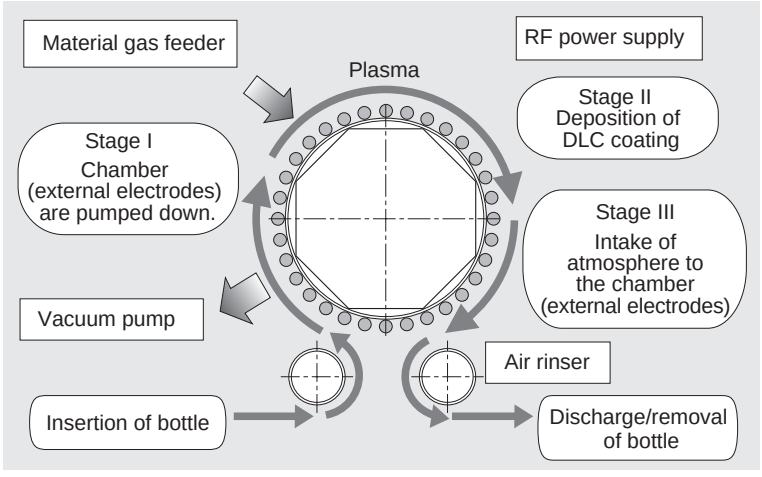

Fig. 2 DLC plasma coating process
Film-forming process of rotary DLC plasma coating system.

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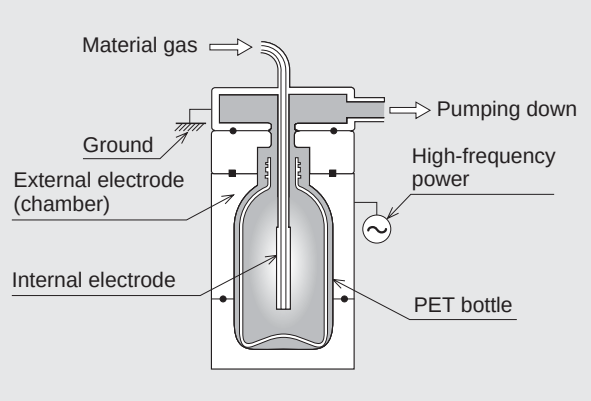

Fig. 3 Configuration of DLC coating electrodes

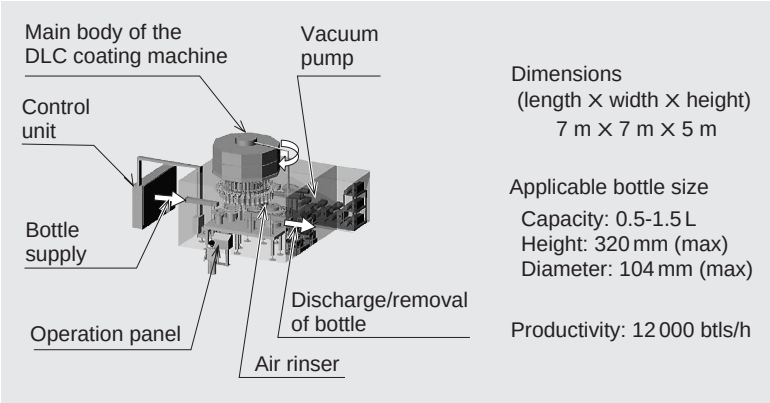

Fig. 4 Outline of DLC coating system
Outline, configuration, and specifications of system in the case of large-sized bottles.

This process essentially consists of five steps.

(1) A bottle is set into a vacuum chamber (external electrode).
(2) The chamber is pumped down to the vacuum.
(3) Acetylene (source gas of the film) is supplied into the bottle.
(4) Plasma is generated by RF (Radio Frequency: 13.56 MHz) discharge and the acetylene gas is decomposed and deposited on the inner surface of the bottle to form a thin film of 10 to 30 nm.
(5) The chamber is opened to the atmosphere, and then the bottle is picked up from the chamber.

The steps outlined above are repeated on a rotating rotary table to enable high-speed production of the coated bottles. The configuration of the electrodes is shown in **Fig.3**.

MHI's advanced expertise, such as thin film plasma deposition, high-frequency circuit, rotary vacuum seal and pumping system, which are cultivated in various MHI's products, as well as the bottle handling technologies in beverage filling machines, has been utilized to the development of this system.

3. Specifications and features of MHI's DLC coating system

MHI's DLC coating system has been commercialized based on four commodity concepts described in items (1) to (4) below. **Figure 4** shows an outline of the system for large bottles.

(1) High gas barrier performance

As can be seen from **Fig. 5**, DLC coated bottles provide the world's highest level of barrier performance with levels as much as 10 to 30 times higher than those of uncoated bottles. Also, as shown in **Fig. 6**, it is confirmed that the DLC bottles have barrier performance that are as high as 10 times those of uncoated bottles against carbon dioxide.

(2) High productivity

MHI's plasma coating system has a bottle production rate of 18 000 bottles per hour (for 0.5-litter bottle) and 12 000 btls/h (for 1.5-litter bottle), which is the highest rate in the world for this kind of bottle coating. MHI offers a series of systems: two standard models with throughput rates of 18 000 and 12 000 btls/h for small bottles and one model with 12 000 btls/h for large bottles.

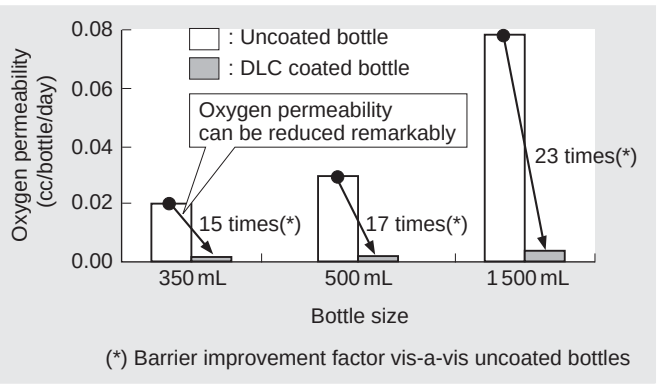

Fig.5 Oxygen barrier performance
DLC coated bottles have oxygen barrier performance for each bottle size that are 10 times greater or higher than those of uncoated bottles.

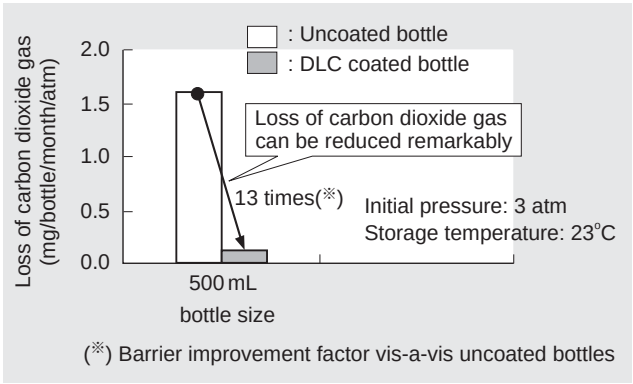

Fig.6 Carbon-dioxide gas barrier performance
DLC coated bottles have carbon dioxide gas barrier performance that are 10 times greater or higher than those of uncoated bottles.

(3) Measures for safety and the environment

Consideration is paid to safety and the environment. It has been confirmed that the DLC-coated PET bottles satisfy the voluntary guidelines of the Japanese Council for PET Bottle Recycling and there is no problem in the recycling process of the bottles. In addition, the U.S. Food and Drug Administration (FDA) has certified the safety of the DLC-coated PET bottles as food containers.

(4) Availability of wide range of bottle sizes

The coating system is readily applicable to a wide range of bottle sizes from 0.3 to 1.5-litters.

In addition, since the DLC-coated PET bottles are used mainly for beverages and foods, the reliability of the bottle quality is important from the viewpoint of safety. To ensure it, a process monitoring system checks all the histories of the film-forming process parameters (pressure in the chamber, RF power, and source gas flow rate etc.) for each bottle and can store those as traceable data for future reference.

4. Conclusion

MHI has developed a DLC plasma coating system depositing a extremely thin DLC film on the inner surface of the PET bottles. This system has the world's highest level of productivity and gas-barrier performance capable of preventing the quality of contents from deteriorating.

The commercialization of this system will expand the application of PET bottles for various beverages, such as sensitive soft drinks like green tea drinks and carbonated drinks, and alcoholic beverages, for which high barrier for oxygen and carbon dioxide permeation are essential to preserving good product quality. In addition, the use of the DLC coated PET bottles may be expand to a variety of non-beverage contents such as seasonings and cosmetics, as well.

It is anticipated that the PET container market will continue to grow rapidly all over the world in the future. MHI is dedicated to developing and delivering products to the customer that are high performance and reliable as well as environmentally friendly and safe.


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