High-speed DLC Coating Equipment for Improved Gas Barrier Performance of PET Bottles

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Polyethylene terephthalate (PET) bottles are widely used as containers in the beverage industry owing to their advantages such as versatility, strength, formability and cost-effectiveness. As part of recent trends, especially for reducing the cost of containers, PET bottles are becoming more lightweight and thin-walled. Demand for PET bottles is expected to further increase with the development of relevant technologies.

However, the oxygen and carbon dioxide barrier performance of PET bottles is lower than metallic and glass containers. The quality of products therefore can be deteriorated by the inflow of oxygen and outflow of carbon dioxide through PET bottles, which is an obstruction to the use of PET bottles for some drinks such as alcohol.

Utilizing the characteristics of PET bottles, Mitsubishi Heavy Industries Food & Packaging Machinery Co., Ltd. worked to enable recent lightweight, thin PET containers to have better gas barrier performance and to be used for commercial purposes. Thus, we have developed our highly-productive DLC coating equipment (DLC: diamond-like carbon, denoting carbon that is similar to diamond in terms of physical properties), contributing to the expansion of PET bottle use and the realization of lower-cost production for our clients.

1. Features of DLC coating technology

DLC coating is a technology in which a thin DLC film is formed on the inner surface of PET bottles by plasma chemical vapor deposition (CVD) to improve the barrier capability for gases such as oxygen, carbon dioxide and water vapor. DLC coating technology, which uses high ion energy to form a dense film, provides PET bottles with better gas barrier capability than other technologies used for enhanced gas barrier performance in the beverage industry, such as multilayer bottles. A DLC film can also function as a water vapor barrier, something that cannot be obtained by other technologies. Thus, it prevents the evaporation of moisture in products and blocks the infiltration of moisture from the outside.

The DLC coating procedure is detailed below:

Step 1: Set a bottle in the coating chamber.
Step 2: Pump down the chamber to a vacuum.
Step 3: Supply acetylene (source gas of the DLC film) into the bottle.
Step 4: Apply electricity generated by high-frequency power source (6–13.56 MHz) to turn the source gas into plasma. Through deposition, form a thin film of 10–30 nm on the inner surface of the bottle.
Step 5: Release the bottle into the atmosphere and remove the bottle.

These steps for coating treatment are successively repeated in each of the aligned chambers or the chambers arranged on a rotary table.

2. Specifications and features of DLC coating equipment

In practical use, the DLC coating procedure in section 1 can be performed using high-speed, successive film formation equipment. The equipment was successfully developed by exploiting our technologies for bottle handling and production in the rotary beverage filling system, which is our main area of expertise.

The specifications and features of our DLC coating equipment are as follows:

(1) Higher gas barrier performance (in comparison with uncoated bottles)
- Oxygen barrier property: 15 times or more
- Carbon dioxide barrier property: 10 times or more
- Water vapor barrier property: 6 times or more

(2) High productivity
- Of our series of DLC coating equipment, the DLC33 (which processes small bottles of up to 0.5 L and has productivity of 300 bottles per minute, or bpm) and the DLC6 (which can handle both small and large bottles of up to 2.0 L and has a productivity of 30 bpm) have actually been used in factories.
- In addition to these two, the basic specifications of the following were determined, thereby making them available for commercial use.
  (a) DLC30: 0.5–2.0 L (applicable bottle size), 200 bpm
  (b) DLC60: up to 0.5 L (applicable bottle size), 600 bpm

(3) Safety and environmental considerations
- Certified safety of coated bottles as food containers (approved by U.S. Food and Drug Administration; FDA)
- Suitability for recycling use (satisfying the voluntary guidelines by the Japanese Council for PET Bottle Recycling)

3. Applications of DLC-coated bottles

In DLC coating, as mentioned in section 1, the chamber is pumped down to a vacuum. Other coating technologies also involve the creation of a vacuum, but in the process, they produce a difference in pressure between the inside and outside the bottle. DLC coating technology, on the other hand, can maintain the same pressures, thus making it more suitable for application to large bottles as well as lightweight and thin bottles, the use of which has been steadily increasing in recent years.

Since their use as a 350-mL container of hot green tea in 2004, DLC bottles have been used for a variety of containers with varying sizes, not only for beverages (e.g., 500-mL carbonated drink bottles, 1.5-L wine bottles, and 1.5-L sake bottles), but also for other purposes (cooking oil bottles).

Demand for PET bottles will continue to increase in the beverage industry. Moreover, the application of our DLC coating technology does not have to be limited to the beverage industry. It can be expanded to other industries as well, such as food, medicine and cosmetics.

For PET bottles, which are seeing ever-growing demand, we will continue to develop technologies and release new products in order to help our clients achieve their desired level of high productivity, high quality, safety, economic advantage and reduced environmental impact.