ThreeBond
TECHNICAL NEWS

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69

Development of High-Precision Microdrop Coating Equipment for High-viscosity Materials

Introduction

ThreeBond sealants and adhesives are used in numerous products that play an essential role in our daily lives, including automobiles and electric appliances. To enable the most effective use of these sealants and adhesives, we have continued to develop various coating equipments to meet specific needs and applications. The development of our linear coating technologies for sealants/adhesives is based on our own proprietary technologies over many years of cooperative efforts involving and support provided by automobile manufacturers. In recent years, we have applied our extensive expertise in coating technologies to an in-house CIPG process (see Section 1) for computer-related parts. We are also seeking to establish various processing technologies, including sealant applications.

In this issue, we will introduce our linear sealant coating technologies and discuss major factors involving peripheral devices and ambient control for precision sealant applications. We will also describe a technology for precisely applying extremely small amounts of high-viscosity liquid sealant (CIPG process) – a key step in producing fuel cell separators, LCD panels, and organic EL panels.

Contents

1 FIPG and CIPG

Some of our liquid gasket products are used with FIPGs, while others are used with CIPGs. The characteristics of these gaskets differ from those of molded gaskets (Table 1). With FIPGs (Formed-in-Place Gaskets), parts are assembled before the sealant (liquid gasket) applied to the seal surfaces hardens. Since FIPG seals provide the requisite sealing performance as long as the specified amount of sealant is applied to the specified locations, there is no need for advanced control of the cross-sectional shape of the coated sealant (height and width of the applied sealant). In contrast, with CIPGs (Cured-in-Place Gaskets), the sealant (liquid gaskets) applied to seal surfaces is hardened before parts assembly. This makes control of the sealant cross-section (height and width of the applied sealant) critical. Since sealant height and smoothness directly affect sealing performance, high process control capability (Cpk) is the key requirement. With CIPG processes using a linear sealant coating method, even sections where a sealant line crosses another sealant line (overlapping sections) must preserve uniform height. This is the most difficult part of the linear CIPG process.

The CIPG process requires to establish a precision linear sealant coating technology. In the process of making CIPG seals for computer parts, we have established a processing technology that improves on precision coating technologies and coating processes (Photo 1).

Photo 1. Our CIPG process

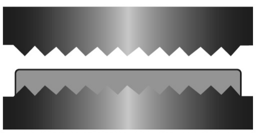
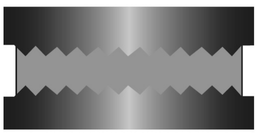
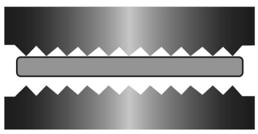
2 Introduction to Linear Sealant Coating Technology

2-1 Pneumatic syringe dispenser

Using compressed air (hereafter "*air*") to discharge sealant from a syringe, a pneumatic syringe dispenser is the simplest linear sealant coating method. (Some devices use a motor instead of *air* to mechanically operate a plunger that pushes out the sealant). Since this system has no sliding parts that contact the liquid sealant, use of a filler-containing material will not result in parts wear. This coating equipment offers excellent maintainability and high cost performance. But it is also associated with certain disadvantages: the discharge start position may deviate due to changes in the amount of sealant remaining in the syringe and sealant discharge rates can fluctuate due to changes in ambient temperature (since viscosity varies with ambient temperature). So, when high-quality linear sealant application is required, it is important to take measures to maintain a constant amount of sealant in the syringe at all times (see Figure 1) and to control the ambient temperature (or use a syringe temperature control system). These control measures enable precise sealant application suitable for CIPG.

The *air* can generally provide pressures of only 0.5 MPa or so – insufficient to discharge high-viscosity sealant. If the discharge amount is large and no automatic sealant refilling system is equipped, syringes will need to be replaced frequently, reducing productivity.

Table 1. Comparison of FIPG and CIPG

	CIPG	FIPG	Molded gasket
Sealing method	 One-side contact-pressure/one-side adhesive seal	 Adhesive seal	 Contact-pressure seal
Curing rate	O	×	O
Compression set	Small	-	Large
Seal pattern change	O	O	×
Flange surface precision	×/O	O	×
Line automation	O	O	△
Removability	O	×	O
Gasket dimensional precision	△	-	O

O Excellent; △ Somewhat unsuitable; × Unsuitable; - Not required

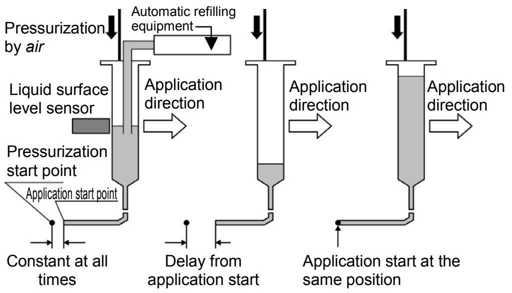


Figure 1. Advantages provided by constant liquid levels in a syringe

2-2 Gear Pump Dispenser

A gear pump dispenser continuously extrudes a sealant at a constant rate using a combination of gears. While it operates normally without ambient temperatures and offers highly stable discharge rates, this method is unsuitable when the sealant material contains a filler, due to rapid associated wear of internal sliding parts. With certain sealant types, this system may also generate pulses in proportion to the number of teeth and the module used, dealing with the problem to suppress pulsation when used with CIPG. However, since a gear pump dispenser is relatively compact and can continuously discharge a sealant, it is suitable for FIPG and two-part liquid gasket mixing and coating (Photo 2).

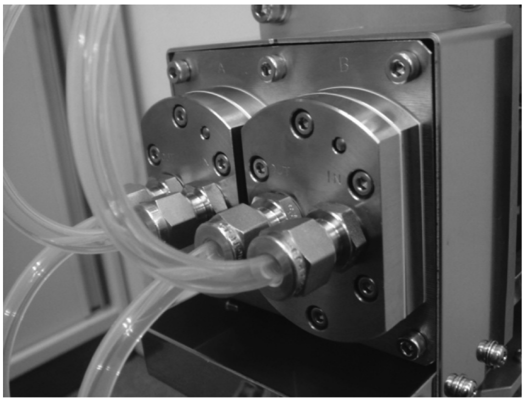


Photo 2. Gear pump dispenser

2-3 Power Booster

This system is relatively low cost and suitable for FIPGs using a one-part liquid gasket (RTV silicone). The system uses a dedicated power booster to pressure-feed sealant and to discharge it from the applicator head (Figure 2). Since the power booster uses an air cylinder (*air*) for drive source, the amount of sealant discharged from the power booster varies if sealant viscosity changes due to fluctuations in ambient temperature or if the sealant feed resistance varies due to changes in hose diameter or length. If a long, large-diameter hose is used, it may expand due to sealant pressure, making the amount of discharged sealant unstable immediately after the start of discharge operations. Therefore, when this system is required for precise linear sealant coating, select a pipe of the appropriate parameters (specifically, hose diameter and length), check the discharge rate at periodical intervals, and adjust pressure manually. If ambient temperatures fluctuate significantly, it is effective to control the sealant temperature and install a dedicated booster correcting device (Figure 3). Note that small volumes of sealant will remain in the applicator head when discharge stops due to the structure of the head. Take special care when using this system for CIPG.

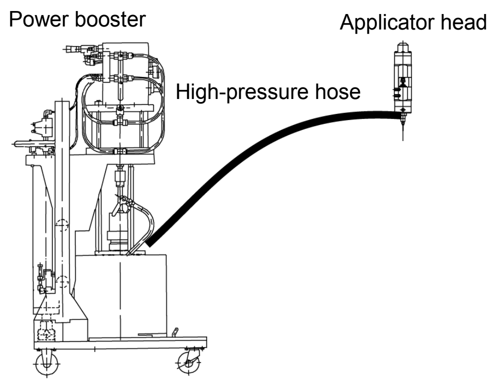


Figure 2. Power booster coating system

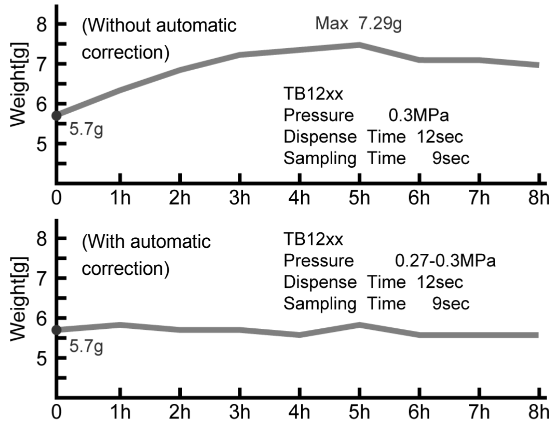


Figure 3. Effect of booster correcting device

2-4 Mohno Dispenser

Like a gear pump dispensing system, a mohno dispenser extrudes a constant sealant amount and operates normally without ambient temperatures, and offers highly stable discharge rates. This system generates minimal pulsation, making it suitable for CIPGs and high-precision FIPGs. We use this system with a power booster (described in Section

2-3) and a balance tank built into accurate application of a one-part liquid gasket (Figure 4). Since no sealant remains in the applicator head due to its structure, this system is suitable for CIPG. Note that the sliding section (stator) that contacts the sealant will wear relatively quickly when this system is used with a filler-containing material. The system requires parts replacement periodically.

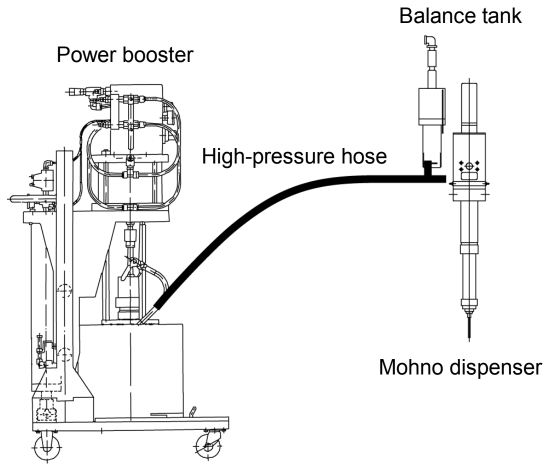


Figure 4. Coating system using mohno dispenser

2-5 Portable Booster

This plunger pump-type device is a constant-rate discharge device (Photo 3). This system operates normally without ambient temperatures and offers highly stable discharge rates. The system also generates minimal pulsation, making it suitable for CIPGs and high-precision FIPGs. The system structure can withstand high pressures, enabling high-speed discharge of high-viscosity sealant exceeding 1000 Pa•s. We use this system with a power booster (described in Section 2-3) built into one-part liquid gaskets and high-viscosity two-part liquid gasket mixing and coating equipments (Figure 5).

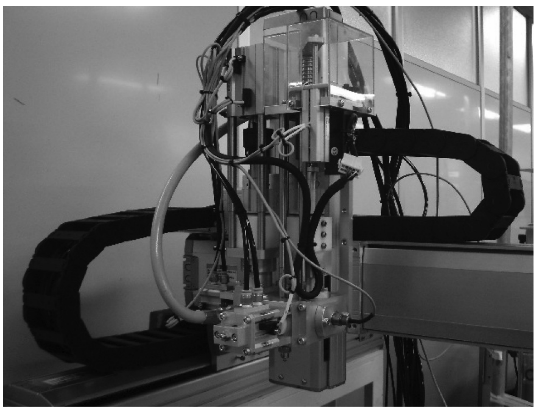


Photo 3. Portable booster

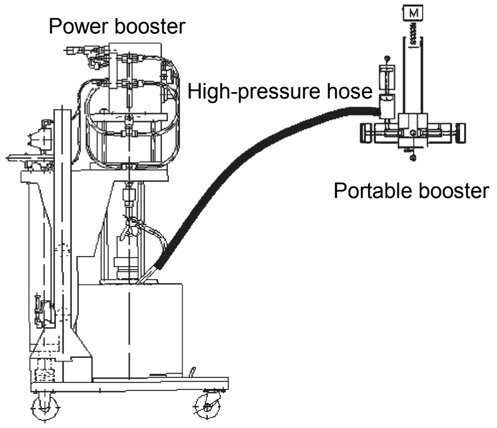


Figure 5. Portable booster system

3 High-Precision Microdrop Coating Equipment for High-Viscosity Materials

The sealant materials used in the production of LCD, organic EL, fuel cells, etc. require high-precision application of extremely small sealant amounts along a line measuring 10 to 300 µm in diameter. For low to medium viscosity sealant, a syringe dispenser or jet dispenser is used for a small amount of linear sealant applications. But for high-viscosity sealants exceeding 1500 Pa•s, many technical challenges remain to be solved, and no immediately applicable technologies are currently established. We have started work on developing coating equipment capable of CIPG processing or high-quality linear coating for high-viscosity sealant. Figure 6 shows the high-precision microdrop coating equipment that we developed. Figure 7 shows the application scope of various dispensers under different conditions.

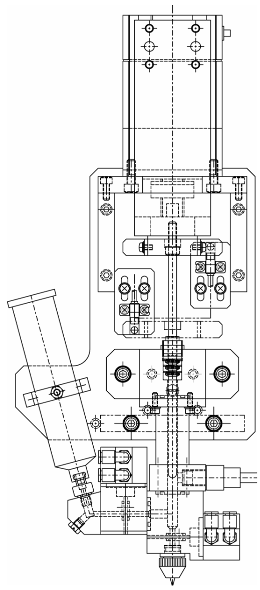


Figure 6. High-precision microdop coating equipment

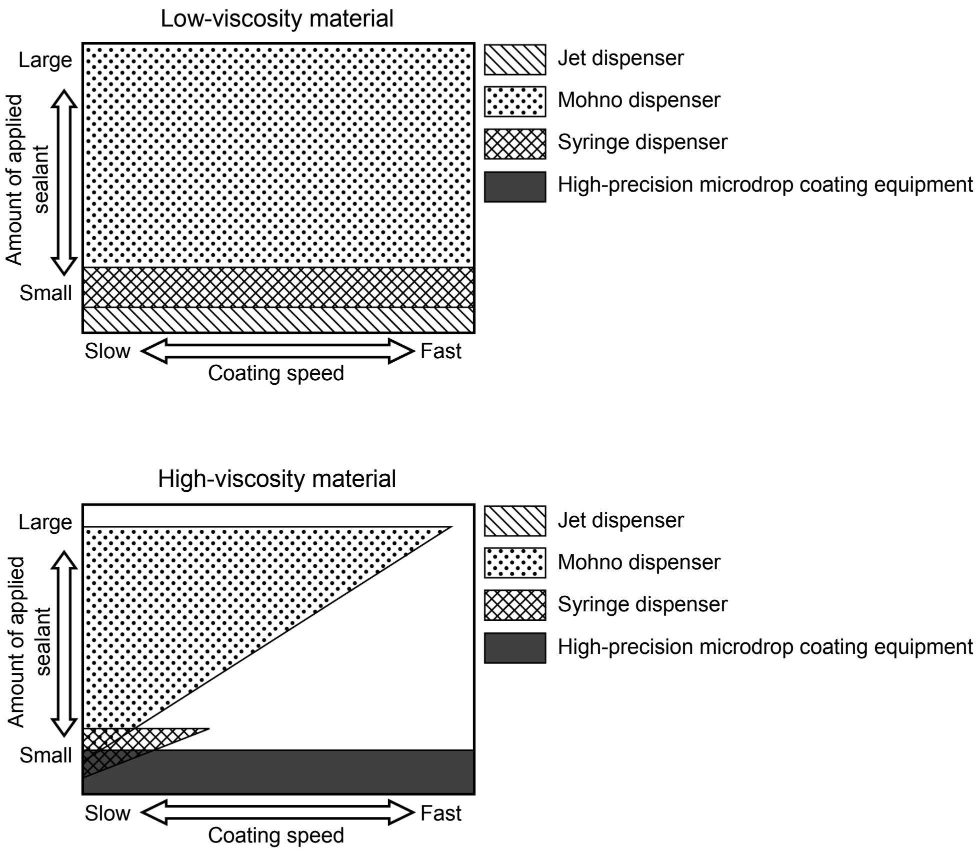


Figure 7. Coating system distribution chart

3-1 Key Development Points

Since the small-amount/constant-rate discharge of high-viscosity sealant requires high liquid pressures to feed small volumes of sealant, this system is incomparably more difficult than plunger pump-type dispensers. For example, pressure of about 3 MPa is required to discharge sealants with a viscosity of 1500 Pa•s in a diameter of 300μm at a rate of 30 mm/sec. This is nearly ten times the pressure applied by a typical syringe dispenser and may lead to large variations in compression rates in certain sealants. While Newtonian liquids are in theory non-compressible, with high-viscosity sealants that exceed 1500 Pa•s, the resin may contain extremely fine air bubbles invisible to the human eye, which allow the sealant to compress about 1 to 2%. Additionally, deformation of the packing material at the sliding section and expansion of the casing (which are negligible small in most cases) can apply high pressures on the sealant, and then change the volume of the section contacting the liquid. These volumetric changes prevent the discharge of sealant from the nozzle tip at constant rates, even if the sealant-extruding plunger moves steadily (Figure 8).

Also, when the plunger stops moving after the sealant discharge operation, the compressed sealant gradually expands and begins to drip. So, to create appropriate internal pressure before the application to prevent dripping after sealant coating, the nozzle tip must be equipped with a valve that causes no volumetric changes. Since current technologies cannot place a valve that can resist pressures of 3 MPa at the nozzle tip, the valve is placed at a position located at a certain distance from the nozzle tip. The resulting idle volume (material remaining in the space between the valve downstream point and the nozzle) allows the sealant to compress or expand at the time of sealant discharge start and stop, preventing constant-volume coating (Figure 9). As a countermeasure, we control both plunger moving speed and sealant pressure to maintain constant discharge rate. Table 2 lists the comparison of the performance between a high-precision microdrop coating equipment and the syringe dispenser.

Table 2. Comparison of high-precision microdrop coating equipment and syringe dispenser

	High-precision microdrop coating equipment	Syringe dispenser
Coating response	○	△
Adaptability to ambient temperature fluctuations	○	×
Constant-rate coating	○	×
Adaptability to short-beat/spot coating	×	△

* Comparison based on our products

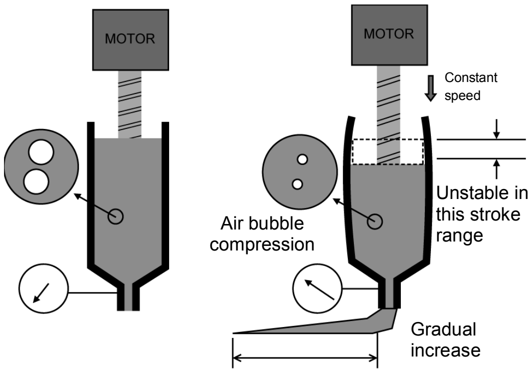


Figure 8. Expansion of casing and effect of air bubbles

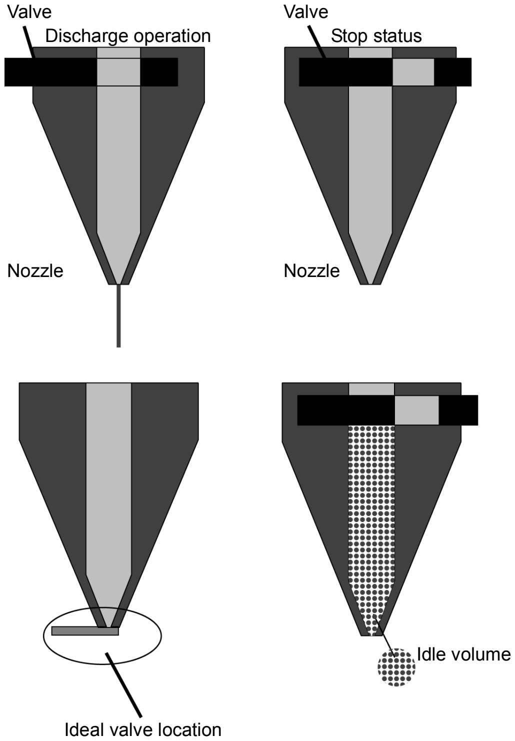


Figure 9. Ideal valve shape

3-2 Controlling Pressure When Discharge Begins

To ensure the stability of sealant discharge rate immediately after discharge begins, we need to identify an appropriate initial pressurizing value by considering the sealant contraction corresponding to the idle volume (Figure 10). The appropriate initial pressurizing value depends on the sealant type, target discharge rate, and defoaming levels. We have developed a program that automatically identifies the appropriate initial conditions, and we have verified the effectiveness of this program by comparing it with manual settings. While appropriate control of both plunger moving speed and liquid pressure enables high-quality constant-rate sealant discharge, it is also important to control the nozzle moving device (industrial robot) and other peripheral equipment if high-precision linear applications are required.

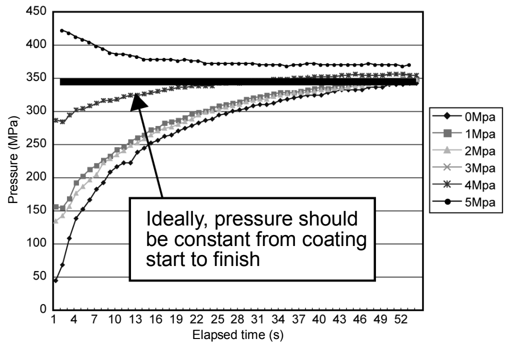


Figure 10. Relationship between constant discharge pressure and pressure immediately before discharge begins

3-3 Defoaming Control for Material

Materials containing large fractions of dispersed air bubbles will have high sealant contraction rates, making it difficult to maintain constant discharge rates, even when sealant pressure is controlled. The drip prevention function also has its own performance limits. This makes defoaming levels a critical factor. Figure 11 shows the principles of a planetary-type agitation and defoaming system suitable for removing air bubbles from high-viscosity materials. This equipment uses a vacuum to achieve advanced defoaming.

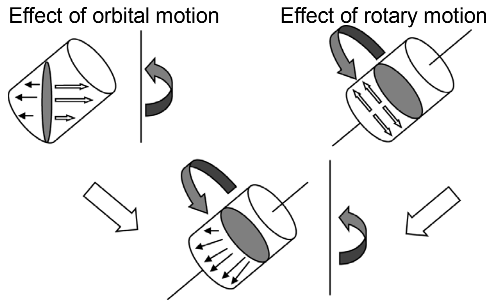


Figure 11. Planetary-type agitation and defoaming system

3-4 Coating Robot

To achieve a uniform linear coating with the sealant, it requires maintaining a constant-rate sealant discharge and constant nozzle travel speed. An industrial robot is generally used for nozzle movements. The robots used for linear sealant coating must be able to move at a constant speed and should not cause the nozzle tip to collapse. Since robots are driven by motors, acceleration or deceleration will always occur when a motor starts, stops, or changes speed (Figure 12). If there are any sharp corners in the seal line, the nozzle speed will change before and after the corner (effect of acceleration/deceleration), changing the amount of sealant applied. While seal lines should ideally curve smoothly so that the nozzle moves at constant speed, some seal lines are nearly orthogonal. For this reason, robots used for sealant coating must provide high acceleration performance and rigidity.

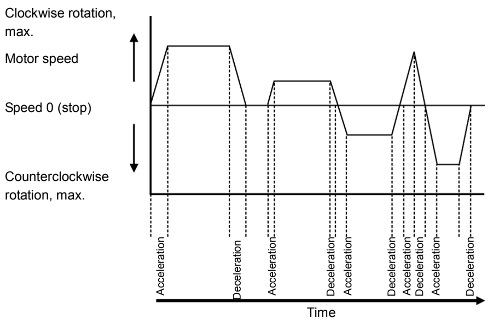


Figure 12. Operating modes of coating robot

3-5 Processed Products

The quality of small-amount linear coating depends on the dimensional accuracy of the part (workpiece) to be processed with CIPG. For example, if the seal surface of the workpiece is distorted or tolerances for the standard positioning dimension are large, the applicator nozzle may deviate from the coating path. But for high-quality linear coatings, the distance (clearance) between the nozzle and the workpiece seal surface must remain constant at all times. Deviations in clearance will significantly degrade the linear coating quality (seal position and line diameter). Thereofore, the linear nozzle path should be corrected as needed when high-quality linear coatings are needed. (Figure 13, Figure 14)

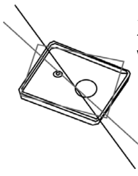


Figure 13. XY coordinate correction image

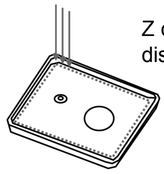


Figure 14. Z coordinate correction image

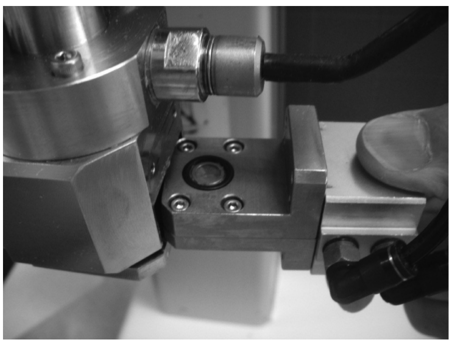
3-6 Ambience Control (for CIPG)

Another important factor is the control technique deployed to ensure high-quality curing of the properly applied sealant. The shape retention characteristic of sealant is affected by static electricity, ambient temperatures, and curing method (intensity, timing, etc. in the case of UV irradiation). Both the application process and pre-process and post-process technologies are critical for high-quality linear CIPGs. We have focused on establishing processing technologies based on this understanding.

3-7 Durability and Maintainability

Reliable quality and constant productivity must be achieved to ensure dependable use of coating equipment on production lines. The discharge of high-viscosity, filler-containing over 1500 Pa•s sealant under high pressures will cause wear to sliding parts relatively rapidly. Although we selects and uses packings whose material and shape are designed to be as resistant as possible to abrasion, periodic replacement remains unavoidable.

In response, we devised the fastest and least costly way to replace consumables. This uses replaceable units for consumable parts (Photo 4). An individual familiar with the replacement procedure can replace the parts within less than three minutes. We believe minimizing the potential damage caused by equipment problems is also an important parameter for high-precision sealant coating.



Structure designed for easy replacement of consumable parts

Photo 4. Easily changed shutter valve

Conclusion

Customers continue to pursue miniaturization and new technologies for their products and we expect that their needs for high-precision coating of high-viscosity sealant will be increasingly raised. In particular, demand for the development of high-precision coating technology is predicted to grow for the production of fuel cell separators, LCD panels, and organic EL panels.

Based on a vision of the high-precision/small amount application of liquid agents required in various industrial fields, we strive to provide advanced coating technologies through the sales of complete sealant and application equipment systems that help our clients create new products not possible with conventional technologies and help improve the quality of their existing products and production efficiency.

We are committed to create advanced coating technologies and provide reliable products. Your support and interest in our future products would be greatly appreciated.

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