Basics and Applications of UV/EB Curing Technology

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1. Foreward
Recent years have seen the emergence of a focus on solvent-free coatings and curing technology, in particular UV (Ultraviolet) and EB (Electron Beam) curing technologies. Before proceeding with practical application, it is essential first to have a full understanding of the features of the various processing technologies. For this purpose, Table 1 sets out these characteristics including those of the previous thermal curing method.

2. UV Curing Technology
As shown in Table 1, UV curing devices are in common use due to their advantages in cost-related features.

These UV curing devices comprise a lamp, irradiator housing, power supply, cooling unit and, in some cases, a UV resin coating device or conveyor. Below is given an introduction to the lamp, which forms the very heart of the device.

2.1 Lamps
Although there are a great variety of UV-irradiating lamps, UV curing normally

<table>
<thead>
<tr>
<th>Curing Time (EB Method)</th>
<th>Several seconds</th>
<th>Several tons of minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment Footprint</td>
<td>Small</td>
<td>Medium</td>
</tr>
<tr>
<td>Curing Temp. (C)</td>
<td>Room temperature</td>
<td>40–80</td>
</tr>
<tr>
<td>Enamel Processing</td>
<td>Possible</td>
<td>Not possible</td>
</tr>
<tr>
<td>Coating Cost</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Pot Life</td>
<td>Long</td>
<td>Long</td>
</tr>
<tr>
<td>Volatile Constituency (%)</td>
<td>10–20 or less</td>
<td>10–20 or less</td>
</tr>
<tr>
<td>Work Environment</td>
<td>X-rays Ozone</td>
<td>Ultraviolet rays</td>
</tr>
<tr>
<td>Cost of Anti-pollution</td>
<td>Minor</td>
<td>Minor</td>
</tr>
<tr>
<td>Inert gases</td>
<td>Necessary</td>
<td>Unnecessary?</td>
</tr>
<tr>
<td>Equipment Cost</td>
<td>High effective for high line speeds</td>
<td>Low* effective for low line speeds</td>
</tr>
<tr>
<td>Running</td>
<td>ON-OFF</td>
<td>ON-OFF</td>
</tr>
<tr>
<td>Preparation Time</td>
<td>Several minutes</td>
<td>Several minutes</td>
</tr>
<tr>
<td>Energy Consumption</td>
<td>2</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 1. UV curing devices

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employs the lamps shown in Table 2. These lamps feature metal sealed into a quartz photogenic tube that illuminates by application of external energy as the vapor state. Different metal for illumination and vapor pressure together produce a lamp with various spectrum characteristics. It is necessary to select from these spectral characteristics the one that meets the requirements of UV resin curing. Lamp power is represented in units of input power per unit of light emission wavelength (W/cm) and lamps with a load of 80W/cm-240W/cm (metal halide: up to 320W/cm) are available with the emphasis in recent years on UV with higher output levels higher output levels.

![Fig. 1. Spectral energy distribution](image)

I would like here to introduce new lamps that are used for adhering and laminating. I

<table>
<thead>
<tr>
<th>Lamp Name</th>
<th>Features</th>
<th>Spectrum Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>High pressure Mercury Lamp</td>
<td>Comprises high purity mercury (Hg) and small amount of rare gas sealed into a quartz glass photogenic tube with a main wavelength of 365nm capable of effective emission of ultraviolet rays at 254nm, 303nm and 313nm. In comparison with other lamps, this lamp is notable for high output of low wavelength ultraviolet rays.</td>
<td><img src="image" alt="Graph 1" /></td>
</tr>
<tr>
<td>Ultra-high-pressure Mercury Lamp</td>
<td>Like the high-pressure mercury lamp, features sealed mercury and rare gas (gas pressure: approx. 1 pressure). However, because the gas operating at 10 pressures or more, the spectrum lines are not isolated, but continuous.</td>
<td><img src="image" alt="Graph 2" /></td>
</tr>
<tr>
<td>Metal Halide Lamp</td>
<td>The photogenic tube contains sealed mercury and halogenized metal and emits ultraviolet spectrum over a wide range of 200-450nm. This lamp features a high-end ultraviolet wavelength output of 300-450nm compared to mercury lamps.</td>
<td><img src="image" alt="Graph 3" /></td>
</tr>
<tr>
<td>High-power Metal Halide lamp</td>
<td>Unlike the metal halide lamp, contains sealed halogenized metal different from that for the metal halide lamp and features a particularly high-end output of 400-450nm.</td>
<td><img src="image" alt="Graph 4" /></td>
</tr>
</tbody>
</table>
refer to pulsed-xenon lamps that are capable of high irradiation from UV to visible light. These lamps produce a light emission equivalent in duration to a camera flash (half-bandwidth of single light emission: several hundred micro-seconds) producing emission from UV to visible light over a continuous spectrum as shown in Fig. 1, which represents spectrum energy distribution, resulting in a peak illumination of $W/cm^2$ one thousand times greater than that produced by a high-pressure mercury lamp. This lamp is therefore extremely effective for deeply-covered or thick coatings. Additionally, the lamp's ability to produce multiple pulses in a second means that temperature increases in the base material can be suppressed as long as the irradiation period is short.

As can be seen from the above, there are a great many types of lamp available and, from the point of view of efficient use of energy, selection of the lamp (light source) most suited to the required application is extremely important.

2.2 Example of UV Irradiation Device
2.2.1 Liquid Crystal Droplet Method/Shield Material Curing Device [1]

The now common liquid crystal droplet production method has undergone some major changes. In the past, one glass plate was shield-coated and laid over another glass plate; the two were then heated over a long period of time to produce empty cells and finally, liquid crystal was injected into the cells in vacuum.

This process requires fine attention due to a very narrow inter-cell space of only a few $\mu m$, a size difficult to achieve and took anywhere between several hours to several tens of hours to complete. The process was finally completed by sealing UV holes with UV-curing resin to produce a finished liquid crystal panel.

To provide improvements to solve these problems, a new liquid crystal droplet method was developed. Like the previous process, this method also requires the coating of one of the plates of glass with UV-curing shield material and, after injection of an appropriate amount of liquid crystal droplets into the resulting mold, the plate is laid over another glass plate in vacuum and the shield material cured by UV irradiation to complete the process. The finished panel is completed in several tens of minutes.

A comparison of the features of this new process and the previous process is presented below.

- Reduction in number of processes (major reduction in time required)
- Reduction in equipment costs
- Reduction of production line length, etc.

Photograph 1 shows an example of a processing device (size: 730mm×920mm) that uses three 14kW metal halide lamps.

2.2.2 Spot Type UV Irradiation Devices [1]

Because of its compactness, lightweight and high functionality, this device can be readily used during processing and is therefore commonly employed for adherence of small components such as light pickup lenses.

Most of these devices comprise a short arc type ultra-high pressure mercury lamp or a metal halide lamp as the light source with a quartz optical fiber as the light guide and typically feature the optics system illustrated in Fig. 2.
Fig. 2 The optical system

To ensure that as much of the light from the lamp is directed into the optical fiber, a supplementary mirror is used while a two-tier cold mirror structure is employed to suppress heat increases created from the condensed light.

3. EB Curing Devices
EB curing devices are actually electron acceleration devices and such devices are classified depending on the size of the voltage used to produce electron acceleration resulting in significant differences not only in size but also cost. EB acceleration devices employing an acceleration voltage of 1,000kV (=1MV) or higher require a concrete maze or building to shield against Bremsstrahlung X-rays and the electron beam generated is subject to regulation in accordance with categorization under radiation definitions established by the Atomic Energy Fundamental Act. However, the EB curing low-energy (acceleration voltage: 300kV or less) device introduced here not only falls outside the foregoing classification, but also is also compact and easy to use. Additionally, recent years have seen the development of even more compact and low cost EB curing devices featuring acceleration voltages of 100kV or less and these are introduced below.

3.1 Compact EB Accelerator for Experiments
The “Eye Light Beam™” (See Photograph 2), a compact experimental device approximately one-third of the weight of the EB accelerator for experiments featured above (BC250/15/180L) has been developed for experiments in the 80kV~110kV range and is effective for experiments in curing processing of thin coatings.

Model : EC110/15/70L
Acceleration Voltage : 80~110kV
Beam Current : 1~10mA
Irradiation Width : 150mm
Irradiation Capacity : 700kGy·m/min(at 110kV)
Tray Size : W 150 × L 200 × H 15 mm
Main Body Dimensions : W 900 × L 1450 × H 1500 mm

3.2 EZ-V™ Device
The EZ-V is a manufacturing device that offers compactness, lightweight and low cost

Photograph 2  "Low Energy EB Accelerator (For Experiments)
achieved by reducing the acceleration voltage to 70kV or less. The device comprises an EB generator (irradiation unit) and a high-voltage generator (power supply unit) and features the specification illustrated in Table 4, Fig. 3 and Photograph 3. For regular resin curing requiring a dosage of 30kGy, this device is capable of processing at a maximum of 100m/min. The price of the main body of the device is approximately Yen 35,000,000, an amount that will undoubtedly surprise those familiar with the past EB devices.

Additionally, if required, the irradiation width can be broadened and there are actual cases of EZ-V devices with an irradiation width of 1650mm built into the customer’s device.

3.3 Compact EB Irradiation Tube

This is a Min-EE device with a lamp-type vacuum tube structure that first appeared approximately five years ago.

With the acceleration voltage of the device at 25kV~75kV, one EB tube produces an irradiation area in the atmosphere of approximately 25mm and, for cases where greater irradiation width is required, an array of multiple tubes can be used.

The structure of this tube that is marketed by Ushio Inc., and Toyo Ink Mfg. Co. Ltd., is illustrated in Fig. 4.

![Fig. 3. Outline drawing of EZ-V](image)

![Figure 4. Structure of Min-EB](image)

![Photograph 3. EZ-V™ Device](image)

![Photograph 4. Ultra-Compact EB Accelerator "Beamsat"](image)

Additionally, in contrast to the sealed gun-type, “Beamsat” (Photograph 3), an
ultra-compact exhaust type EB accelerator has made its appearance making tabletop experiments possible.

Afterword

As described above, great strides have been taken in improvements in terms of the compactness, cost reduction and operability of EB curing devices while at the same time, use of UV curing devices has become the widespread norm. I would like to end by expressing my hopes that readers who interested in the devices described herein will take the opportunity to experience at first hand the effects by actually applying the EB/UV irradiation.

-Bibliography-