Technical Paper

EB Laboratory Systems Can Facilitate Research and Development

By Elizabeth deFriese and Stephen Lapin

Electron beam (EB) technology has been commercially available and established for more than 30 years. Many of the traditional applications are based on the use of low-energy EB equipment, which the industry defines as operating with an accelerating voltage of less than 300 kV.

The most common low-energy EB systems in use today utilize multiple filaments, where the number of filaments can be scaled to produce system widths corresponding to the products being processed. Standard commercial processing widths range from about 36 inches to more than 100 inches wide, and EB systems can be tailored to match those requirements. The low-energy EB units are completely self-shielded and require no external shielding.

The range of traditional commercial applications using low-energy EB applications is very diverse and includes:

- Curing of inks and coatings for packaging applications
- Curing of coatings used for the protection of decorative surfaces
- Curing of laminating adhesives for bonding multiple layers of paper, film or foils
- Crosslinking of pressure-sensitive adhesives for high-performance tapes
- Surface modification of membranes and non-woven materials
- Crosslinking of films for enhanced performance properties
- Surface sterilization of medical and food packaging

As the use of EB technology continues to expand, new products and processes must be developed for new and existing applications. These research and development (R&D) efforts are often conducted using commercial EB-production systems, as there have been limited options for small-scale systems to support these efforts.

Challenges of using existing production-scale systems for R&D include:

- Interruption of production schedules and related lost opportunity costs
- High operator and utility cost
- High cost of substrates and other materials consumed during testing
- Distance to production facility and travel, and material shipping costs/time for use of off-site location
- Risk of disclosing confidential developments and products within highly competitive industries

A few pilot-scale EB facilities are in operation. However, they may not be the best choice for some early phase R&D programs due to potentially inconvenient travel and scheduling requirements, as well as challenges to development at will and “on-the-fly” as adjustments need to be made.

Laboratory-scale EB systems might be the perfect solution for some R&D activities. They allow immediate “at will” access to equipment; can be conveniently located within an R&D facility; and the lab systems can be utilized by R&D personnel without extensive specialized training, unlike their larger production counterparts. Many different materials can be used and process conditions can be rapidly and systematically studied and adjusted. In addition, lab-scale systems may also be used for quality-control testing of materials such as EB-curable inks, coatings and adhesives to assure they have desired curing properties before being shipped for use with production-system applications.

Historically, a small group of lab-style systems has been available. Some are scaled-down versions of commercial production equipment and require the same critical components as the larger units, including external vacuum pumps, shielding and Sulphur hexafluoride-filled, high-voltage feed-through assemblies. These units also have filaments and window foils that must be periodically replaced. This process requires access to the vacuum chamber, and the system must be brought back up to a state-of-vacuum prior to operation.

In about 2001, Advanced Electron Beams (AEB) introduced a compact lab system (Applications Development Unit/ADU) incorporating a 10-inch wide, hermetically sealed tube emitter, which required no external vacuum pumps or on-site foil or filament replacement. More than 70 of these ADUs were installed globally, many of which are still in operation today. This compact system was the first of its kind and provided a great benefit to R&D activities involving EB technology. These systems had a maximum operating voltage of 150 kV, which allowed for surface treatment with limited penetration capabilities, but provided laboratories and formulators with an excellent tool to support their continued evaluation of EB products, processes and applications. Unfortunately, AEB is no longer in business, so company support of existing systems is no longer available.

Figure 1

EB laboratory system

Discussion

A new EB laboratory system has recently been introduced (Figure 1) with compact dimensions (about the size of business desk) that can easily fit into most laboratories. This system uses patented, sealed emitter technology that eliminates the need for external vacuum pumps, on-site foil changes and other periodic maintenance which are part of the overall operation and maintenance scheme of larger scale production systems. The sealed emitter along with the associated high-voltage cable and power supply (which are incorporated into these systems) are shown in Figure 2. This emitter technology allows processing voltages ranging from 70 to 210 k —which is significantly wider than previously available in other lab-scale systems.

The lower end of the range (<125 kV) is ideal for the development of applications requiring minimal beam penetration. This includes inks and coatings for printing and packaging applications as well as surface sterilization. The lowest end of the range (70 to 90 kV) may be important for applications requiring treatment of a thin surface layer while minimizing energy deposition in the substrate. The highest end of the range (210 kV) allows penetration into materials as deep as 250 micron (at unit density) with minimal energy loss. This high penetration may be important for lamination through multiple layers; curing of thick pigmented coatings; crosslinking of thick films or pressure-sensitive adhesives; or modification thick membrane or fabrics.

Samples in this lab system are carried in a removable tray (Figure 3).

Figure 2

Sealed EB emitter, cable and power supply

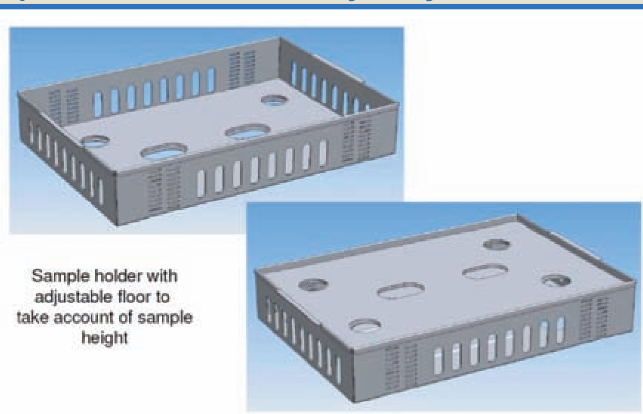
The sample holder can accommodate sheet samples up to A4 size. The tray is adjustable up to 50 mm (2 inches) deep. The tray is normally used at the highest setting for thin samples such as flat, printed materials, or coated paper or film. The lower settings allow the development of applications involving thicker materials that could include wood panels and three-dimensional, plastic, metal or composites.

The laboratory system is capable of operating in nitrogen or air atmospheres. Nitrogen inerting is normally needed for curing of inks, coatings and adhesives. The system includes a sensor to continuously monitor the oxygen level. Testing has shown that with appropriate nitrogen flow rates, a level of less than 200 ppm oxygen can be achieved less than 15 seconds after placing a sample in the system. EB treatment in air is often used for crosslinking and sterilization. The system is set up for exhaust connections to remove ozone from the air if formed during the system's operation.

In order to be useful as a development tool, lab systems should be capable of providing EB dose levels similar to commercial-scale equipment.

Figure 3

Sample holder for laboratory EB system



Typical dose levels for curing applications are in the range of about 20 to 50 kGy. Crosslinking applications may require dose levels up to 200 kGy. The lab system is capable of accurately delivering dose levels from less than 10 kGy up to 450 kGy in a single pass under the emitter. The speed of a shuttle system for transporting a sample under the emitter is adjustable from three to 30 m/min. A powerful aspect of EB technology is the ability to deliver a constant cure dose at all process speeds. Therefore, the dose for even a commercial system running at 300 m/min can be matched with a lab system running at 30 m/min. The dose levels may be confirmed by dosimetry systems that are traceable to National Institute of Standards and Technology standards.

The EB laboratory system is controlled by a windows-based operator interface. Depth/dose curves are displayed for any given voltage/dose combination which gives a clear indication of expected energy deposition in the material. The system logs data in standard file formats allowing export for additional reporting capabilities.

Conclusions

Although EB technology has been commercially available for several decades, it is clear that the technology continues to evolve based on industry demand. Laboratory-scale systems are critical to support this evolution. New systems, such as the one described in this paper, are capable of matching conditions for a wide range of commercial EB production conditions making it an ideal tool for R&D and quality control use.

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