New Ebeam Systems Incorporating Compact Sealed Ebeam Lamps

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Sealed Ebeam Lamps, Definition and Overview

Electron beam technology has been used for industrial applications for many years. The earliest systems relied upon linear accelerators with scan horns to distribute the energy across a surface. Subsequent developments resulted in “curtain” designs which utilized a single long filament capable of emitting electron energy over a wide area without the need for rastering of the electrons. More recent system designs implement a multi-filament array which enables a highly uniform distribution of the electron energy and are scalable up to widths of three meters. All of these traditional ebeam system designs reply upon active pumping systems to achieve and maintain the ultra-high vacuum levels necessary to produce a suitable environment for filament operation. Vacuum pumping systems are large, expensive and require regular maintenance. This led to the original interest in developing “sealed” ebeam systems, now known as “ebeam lamps”.

The basic concept of an ebeam lamp is to pump down the chamber housing the filament to the necessary vacuum level and then seal it off at the factory. In principle this is very similar to the construction of an incandescent light bulb. As a result the size and complexity of these ebeam units are significantly reduced. No vacuum system components are required to be part of the final installation. This eliminates the associated maintenance requirements and costs for continuous operation of the vacuum pump and compressor. An ebeam lamp is field replaceable. Simple connections for power and cooling water enable maintenance personnel to exchange a lamp within minutes. This is an attractive method for reducing production down time when compared to the time required for recovering the vacuum levels required for operation of an actively pumped ebeam system.

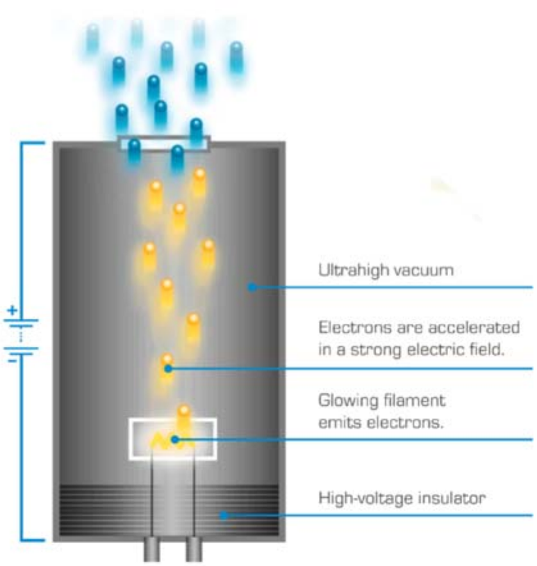

Figure 1. Sealed ebeam lamp

Applications for Sealed Ebeam Lamps

The availability of modern, highly reliable ebeam lamp models has fundamentally changed the types of applications and processes which can consider implementing electron beam technology. Their compact size and simplicity enable ebeam to be integrated into other process equipment instead of designing a process line around a traditional ebeam system. In the following sections examples of four significant application areas for ebeam lamps will be provided. Sterilization of medical devices and packaging material, grafting of materials, curing of coatings on three dimensional objects and curing of ink printed by ink jet are all examples of recent system advances. Further advancements in lamp designs promise to expand the range of viable applications even more. Additional power levels, sizes and even shapes are all under development.

Sterilization of Medical Devices

Sterilization of medical devices is most commonly achieved through the use of ethylene oxide (ETO) gas. The requirements for handling and disposing of chemicals associated with this method are a burden on the users. Gas permeable packaging is also required to enable use of ETO for sterilization. Gamma radiation is another sterilization method frequently used. The safety concerns and physical size of gamma facility make it impractical to install this approach in line at a production facility. Thus it is necessary for the packaged materials to be shipped out for sterilization adding to the associated time and expense. Electron beam energy can also be used to accomplish surface sterilization of medical devices. However, the size and arrangement of traditional ebeam system designs made this impractical for most installations. The introduction of ebeam lamps triggered the opportunity for practical integration into existing sterilization line layouts. Manufacturers of sterilization lines have begun to adopt ebeam lamps as the means of sterilization. For example, SKAN, Metall+Plastic, and Hitachi Zosen all offer equipment that utilizes lamp designs. SKAN has even posted a video on YouTube which provides a view of the inside of their ebeam sterilization tunnel in operation.[1]

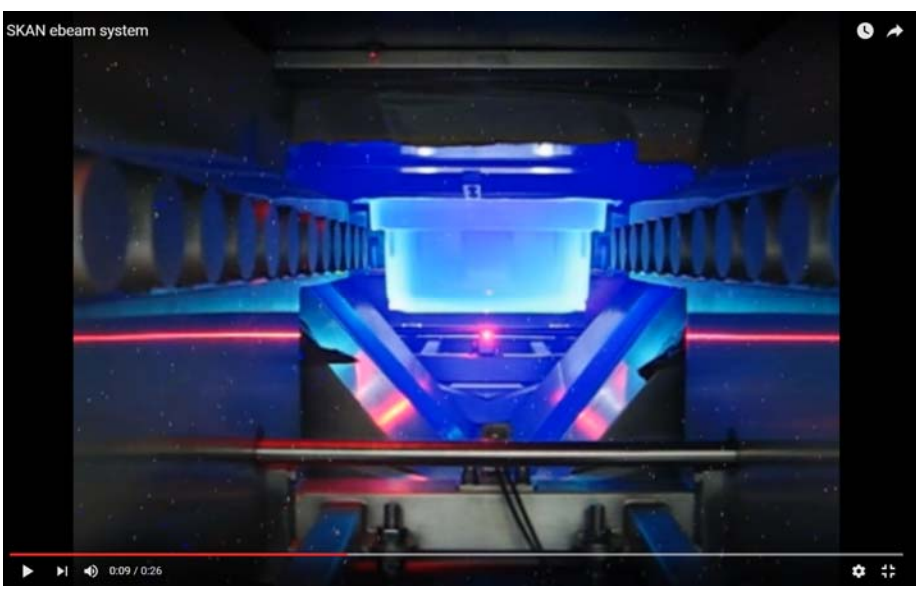

Figure 2. SKAN ebeam sterilization tunnel

Sterilization of Packaging Materials

A related application is the sterilization of packaging materials. These materials include paper, films and laminates used to form cartons and pouches as well as PET bottles. In this case the traditional sterilization method has been to use hydrogen peroxide. Again, the requirements for handling and disposing of chemicals associated with this method drive an interest to pursue other technologies. Hydrogen peroxide also imposes a limitation on the speed at which the filling line can operate. The use of ebeam lamps successfully addresses the requirements for sterilization and enables faster operating speeds. The market leader in implementing this approach is Tetra Pak. Their E3 filling machine, which uses ebeam lamps to sterilize the packaging material in-line with aseptic filling machines was introduced last year.[2] The benefits noted by Tetra Pak include improved sterility, 75% reduction in power for sterilization process, and a 30% reduction in the cost per package.

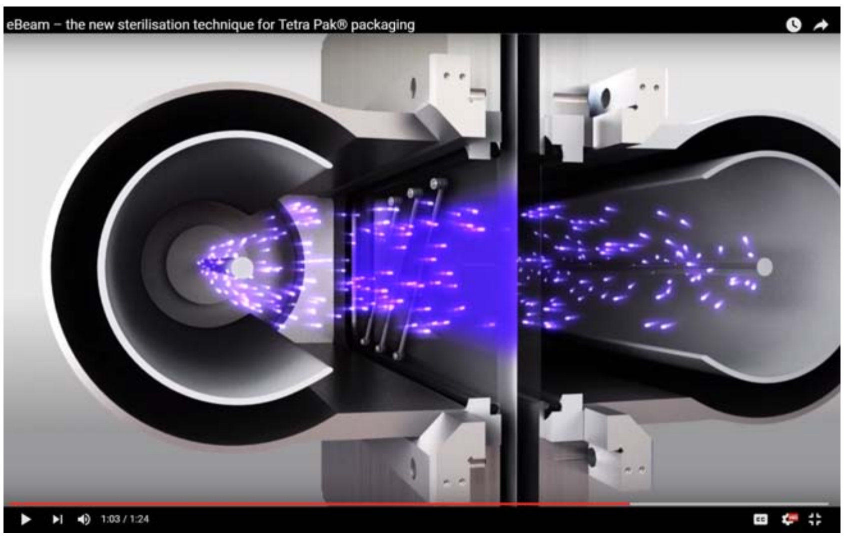

Figure 3. Tetra Pak ebeam sterilization

Ebeam lamps can also be used on filling lines for PET bottles. Conventional lamps can be used for the outer surfaces and specialized versions extend inside the mouth of the bottle to sterilize the inner surfaces. Hitachi Zosen is one supplier of systems for PET bottles.[3] They note the benefits of a chemical free process that removes the need for rinse water and waste fluid processing as well as a reduction in energy consumption of approximately 50%.

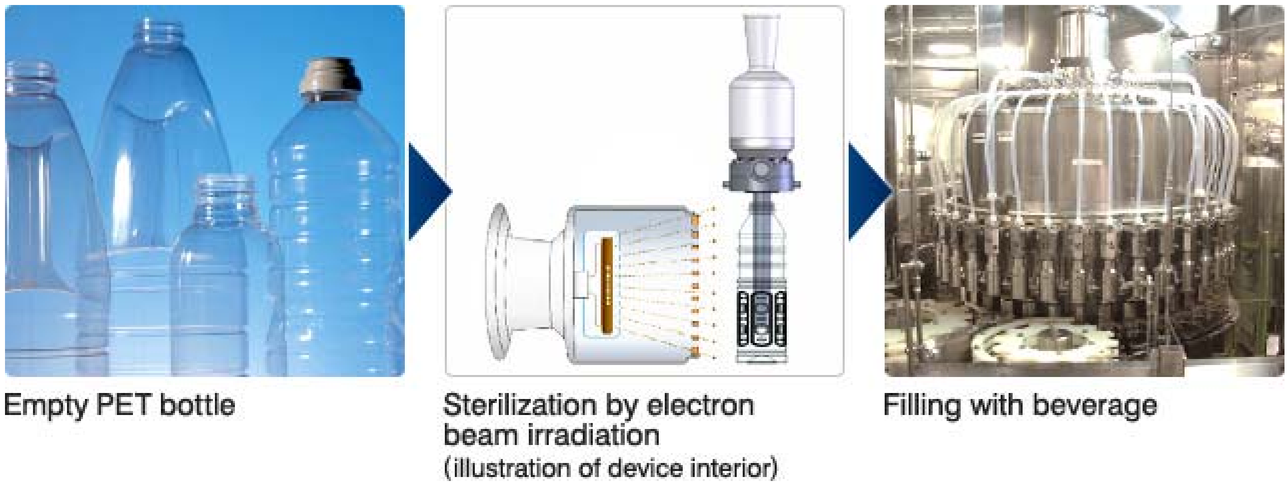

Figure 4. Hitachi Zosen PET bottle ebeam sterilization

Grafting of Films and Membranes

Ebeam induced graft copolymerization (EIGC) is a process whereby two dissimilar polymers are covalently joined to form a new copolymer material.[4] EIGC is less well known than curing or crosslinking but is an important process for creation of new functional materials. Use of this method allows for the transformation of low cost polymer substrates, such as polyethylene and polypropylene into significantly higher value materials. The results that can be achieved include:

1. Specialty fabrics (woven or non-woven) with modified properties such as water repellence or water absorption
2. Reinforcing fiber for composites where enhanced bonding properties between the fiber and matrix resin results in higher performance properties
3. Plastic films with enhanced adhesion properties such as print receptivity or enhanced bonding of multilayer structures
4. Production of media used for separation and purification purposes

A specific application area of much interest is the production of separation media. Much of this material, especially in the areas of biotechnology and fuel cells, is high value product produced on highly specialized, narrow web lines. This makes for a good fit between the process and ebeam systems based on the sealed lamp design. An example of one such system used in this field is shown in Figure 5.

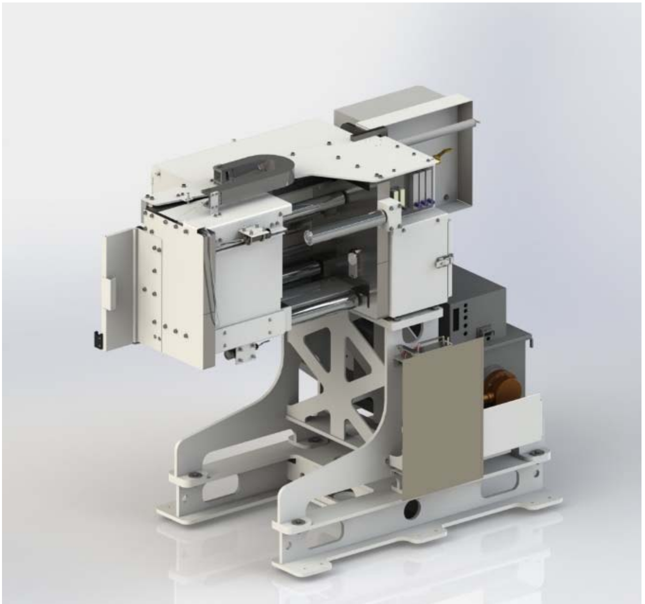

Figure 5. Ebeam system for grafting of separation media

Curing of Coatings on 3D Parts

Traditionally nearly all ebeam systems are applied on web-based process lines. The flexible substrates, high line speeds and wide widths of these processes match well to the capabilities and structural constraints of common ebeam designs. However, the world of coating and printing is certainly much broader than web lines. Many examples of coated, three dimensional objects could also benefit from the advantages provided by ebeam curing. Here is another application area where sealed lamps enable machine builders to produce innovative solutions.

The same machine design challenges exist for 3D curing systems as for web curing systems. Material handling, shielding and inerting must all be addressed. By leveraging the compact size and simplicity of sealed lamps a system integrator can produce curing units such as the one shown in Figure 6. This particular application involves dipping metal tubes into a bath of ebeam curable coating. The parts are then placed by a robot onto a spindle. The spindle turns as the part indexes through the ebeam exposure zone to ensure a uniform distribution of the ebeam energy over the surface of the part. The cured part is the unloaded by the same robotic arm.

Figure 6. Curing system for 3D parts

Ink Jet Printing

Digital printing is growing rapidly. Mass customization, ultra-fast delivery times and the drive for sustainable processes are all among the megatrends contributing to this interest. Producers of food packaging are actively evaluating options for utilizing this technology. The benefits of ebeam in this field include food-safe and photoinitiator-free inks, low temperature processing (especially good for thin films), and instant curing. System solutions based on ebeam lamp technology provide ebeam curing in an extremely compact module. These small, simple “modules” are suitable for installation on many narrow web ink jet printing lines. One example of an installation for this purpose is featured in a recent promotional video produced by Collins Inkjet.[5]

Figure 7. Collins Inkjet video

Summary

Even though the fundamental technology behind industrial electron beam systems has remained essentially unchanged for decades, the milestone innovation of reliable, sealed ebeam lamps promises to dramatically expand the number of applications and volume of systems in use. The small size, simplicity and dependability of currently available lamp designs enable creative solutions to a variety of challenging applications. Multiple examples are noted in this paper and several others are under development.

References

1. SKAN video on You Tube, https://www.youtube.com/watch?v=LfWEUGdfR6k, May 2016.
2. TetraPak video on You Tube, https://www.youtube.com/watch?v=uOS7f5DwoO8, May 2016.
3. Hitachi Zosen web site, http://www.hitachizosen.co.jp/english/csr/hitz/life06.html, May 2016.
4. Lapin SC, *Modification of Polymer Substrates using Electron Beam Induced Graft Copolymerization*, UV/EB 2014 Presentation, RadTech International, Rosemont, May 2014.
5. Collins Inkjet web site, http://www.collinsinkjet.com/ and You Tube https://www.youtube.com/watch?v=CEB9J95wqXY, May 2016.