factsheet

# Electron Beam Technology

Electron beams (EB) are one of three types of ionizing radiation used in industry and research, the other two being gamma rays and X rays.

Initially designed for scientific research, the first electron accelerators used for industrial purpose were installed in the 1950s.  Electron beam accelerators are now used in diverse industries chiefly to enhance the physical and chemical properties of materials. Cross-linking of polymers used for wires, cables and heat-shrinkable products is a major application. Accelerated electrons are also used to inactivate microorganisms or to reduce the quantity of pathogens or toxic by-products in polluted waters.

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A majority of the several thousand industrial accelerators in operation in the world are installed within manufacturing sites but there are also machines used in contract radiation processing service centers. There are also thousands of accelerators used in hospitals and clinics for medical diagnostics or for cancer therapy.

## Accelerator technologies

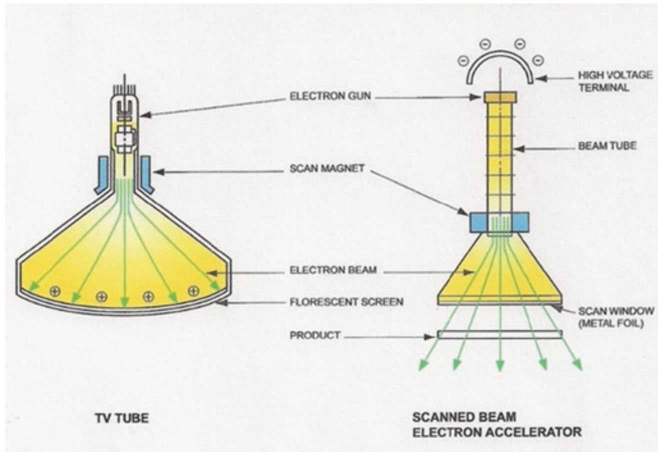
Electron accelerators are durable electrically sourced equipment that can be turned on or off as any other industrial electrical equipment. To give them enough energy to penetrate matter, electrons produced from a cathode are accelerated in vacuum and form a beam. This beam can be bent by a magnet in the required direction before scanning the product to be treated upon emerging from a scanning horn. The principle is the same as in the now defunct cathodic television sets.

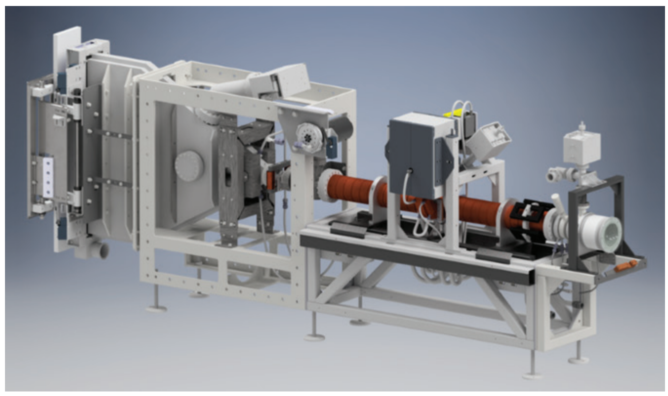
There are various modalities to produce accelerated electrons.

- In direct voltage (DC) machines, a high voltage gradient is applied to accelerate electrons. An example is the Dynamitron®, composed of voltage multiplier circuits at energies to up to 5 MeV and currents up to 160 mA (at low energy). Hundreds of Dynamitron® cross-link wires and cables around the world. Other types of DC machines include Cockcroft Walton generators, Van de Graaff machines (used in research) and Inductive Core Transformers (ICT).

- Linear accelerators, known as Linacs, are one of the most popular high energy industrial accelerators. RF Linacs use radio frequency cavities where the generated voltage gives successive "pushes" to groups of electrons. Standing wave cavities can range from 0.8 to 9 GHz and energies from 1 to 10MeV at beam power of up to 50 kW.

- In circular machines, magnetic fields are used to maintain a circular orbit with radio frequency acceleration. This is the principle in cyclotrons and synchrotron but for radiation processing, the reference is the Rhodotron® manufactured by IBA with energies from 1 to 10 MeV, at beam power up to 700 kW.



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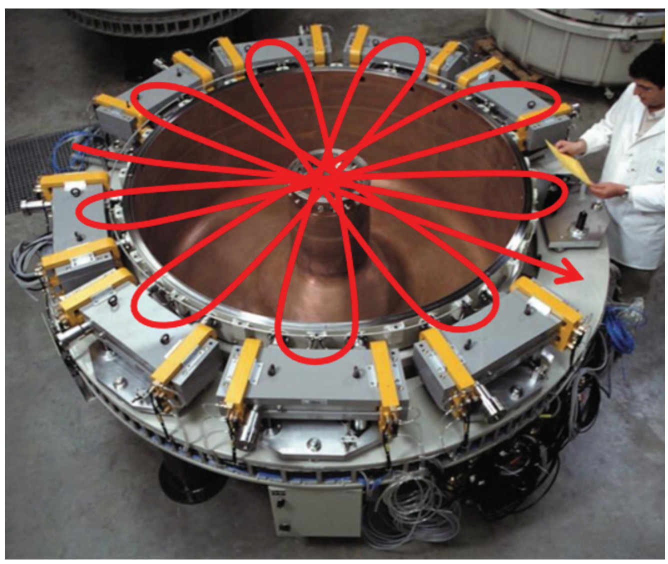

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## Key characteristics of electron accelerators

Accelerators are usually categorized into:

- High energy machines (5-10 MeV) typically used to sterilize medical devices or treat food;
- Medium energy machines (1-5 MeV) used for cables and wires;
- Low energies machines (< 1 MeV) used for surface treatments (curing or microbial decontamination).


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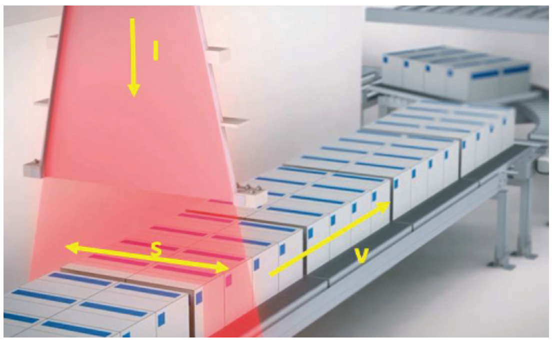
The **energy** of electrons expressed in thousands (keV) or millions (MeV) of electron-volts governs the depth of penetration in matter. For most industrial applications the energy is limited to 10 MeV to stay below the threshold where short-lived radioisotopes could be created into the treated product or package. The mass and electric charge of electrons reduce their ability to penetrate in matter and this is the main shortcoming of the technology though products of several tens of centimeters can be treated if their density is low enough.

Electron accelerators also require shielding as a protection from the penetrating X-rays that are produced when the electrons loose energy in the materials. The shielding may consist of a concrete bunker as for gamma and X-rays or at lower energies a less bulky shielding made of steel plates that is a component of the machine.



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Electron beam processing delivers large amounts of energy in a short amount of time. The **dose rate** is therefore high, typically kilograys per second compared to kilograys per hour for gamma irradiation. The very rapid processing thus possible is sometimes beneficial in terms of effects on polymers.

The **power** of the accelerators expressed in kilowatts (kW) governs the throughput *i.e.* the quantity of product that can be irradiated at a given dose over a given time period, *e.g.* tons per hour, with a great influence of the density of the material being processed. The power (P in kW), the acceleration voltage (U in MV) and the beam current (I in mA) are linked by the equation

$$P = U \times I.$$

Another important parameter is the scanning width, that determines the width of product that can be effectively irradiated while the product travels under the beam. The dose delivered to the product is adjusted by the speed of travel of the product under the beam.

The **dose distribution** pattern considerably differs from gamma and X-rays and generally leads to a higher maximum dose to minimum dose ratio.


## Outlook

There are more suppliers offering machines that are now more reliable, more flexible, and simpler than ever before. New applications and innovations such as the use of supra conductivity could make electron beam technology even more attractive in the future. With the advent of very high-current electron beam accelerators, conversion of electron beam power to X-rays may also become a commercially viable alternative to gamma rays in some cases.