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Electron Beam and X-Rays Machines: overview of the current offer

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Joint FAO/IAEA Programme Nuclear Techniques in Food and Agriculture

Summary

Electron Beam and X-Ray characteristics & properties

Electron Beam Accelerators and X-Ray Generators

- Low Energy
- Medium Energy
- High Energy

Food applications & prospective





Electron Beam Processing

Energy = penetration

Low mass charged particles explaining penetration curves

Up to 10MeV

No radioactivity induced

Penetration; less than 6 cm in water





Standardized Depth (g / cm²)

→ 1.0 MeV → 1.5 MeV → 2.0 MeV → 2.5 MeV → 3.0 MeV → 3.5 MeV → 4.0 MeV → 4.5 MeV → 5.0 MeV

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Electron Beam Processing

Power = treatment speed

Energy determines Penetration

$P(kW) = E(MeV) \times I(mA)$

Power determines Throughput





Electron Beam Properties

Beam directed toward products **Finite product penetration Controlled treatment zones (scanning)** High dose delivery (kGy/s) giving short treatment time Many type of accelerators Wide range of energy and power ratings Parameters are electrically controlled Dose = k . beam current / scan . product speed (at given energy)

Equipment can be switched on and off



X-Ray Converters

From EB up to 7,5MeV maximum (FDA approval by Dec 2004 ref 21 CFR part 179) Large penetration in water 10 40 7.5 MeV X-Ravs Competes with gamma rather than electrons Need high power EB to compete with gamma Dose can be adjusted (rotation, speed and scan adjustment,...)

Nearly all manufacturers of EB have converters

EB @150kW ≈ 12kW X-rays ≈ 1MCu



X-Rays Properties

Rays mainly emitted toward products **Exponential product penetration** Dose delivery of kGy/min Low efficiency of X-Ray conversion (8% max @7,5MeV) **Requires high power with high energy accelerators** Better DUR (Dose Uniformity Ratio) than electron and gamma

Equipment can be switched on and off





EB machine range

Low energy: 70 to 300keV Medium energy: 300keV to 5MeV High energy: 5 to 10MeV





Electron Beam machines

DC machines:

- Single gap acceleration
- Electrostatic : Van de Graaff

 High Voltage DC source ; voltage multiplier type Cockroft-Walton, Dynamitron[®], Insulated Core Transformer,...

Linear Accelerator (Linac)

Recirculation based machines (Rhodotron®)

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Low Energy Electron Beam

Low Voltage machines (up to 300keV)

Direct acceleration, long or multiple filaments, so called "curtain beam"

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Low Energy Machines

High voltage DC power supply and single gap acceleration

2 types:

Low power (generally sealed vacuum tube) at max around 30mA (few 1 000 kGy by m/min)
Industrial machines up to 1A (12 000 kGy by m/min)

Low penetration (less than 1mm in electron)

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Low Power Low Energy

COMET



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Low Power Suppliers

Crosslinking AB ebeam (Comet) Getinge Hitachi Zosen **Nissin High Voltage** Istok (Russia)



ebeam GETINGE

Hitachi Zosen







Industrial machines





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Industrial machines Suppliers

Crosslinking AB Energy Science Inc. (EZCure®) Nissin High Voltage (Curetron®) PCT Engineered System (BroadBeam®)













Electron Beam Generation

High voltage machines (higher than 300keV)

High voltage source (DC or RF) associated with electrons acceleration section with a filament at the origin to generate electrons as well as optic coils (focus, steering, scanning)







Medium Energy machines

DC Electron beams

Charge transfer Van de Graaff
Voltage multipliers, the "Dynamitron" family
Transformer type ICT
Power up to 500kW





Van de Graaff

First accelerator ever built (1929) Now used in laboratories, universities Voltage can be 5 MeV and current of few 100µA







Voltage multiplier



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Voltage multiplier suppliers

Dasheng Electron Accelerator El Pont Hi-Wits Tech IBA Industrial (previously RDI) Nissin High Voltage Corp.









Insulated Core Transformer



ICT Suppliers

Budker Institute of Nuclear Physics (BINP) Novosibirsk ELV (EB-Tech in Korea), Efremov (Russia)

Dasheng Electron Accelerator (associated with Russian ELV) High Voltage Eng., Nederland Nissin High Voltage Vivirad Wasik

















Linac suppliers

Budker with ILU, Corad (St Petersburg), SINP (Moscow) associated with EB-Tech in Korea **El Pont** Getinge GETINGE **Hi-Wits Tech** L3 Applied Technologies Nuctech (China) Mevex **Mitsubishi Heavy Industries** RadiaBeam



APPLIED TECHNOLOGIES











Recirculation machine principles

Rhodotron = resonant cavity with recirculating electron beam associated with EB and X-Ray system





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Recirculation machine suppliers

- IBA Industrial with Rhodotron



Alternate equipment (not actually proven) : NHV with FFAG (fixed Field Alternating Gradient) Tsinghua University Beijing with Cylindertron Tokyo Institut of Technology with Ridgetron Seoul National University with Fantron





Food applications & products

Decontamination of food and packaging, surface treatment, sterilization using high energy electrons, low one (soft beam) or X-Ray. As well as aseptic filling markets (Hitachi, Krönes, Serac, Shibuya, Tetra Pak,...). Mechanically deboned poultry, seeds, ground beef, fresh fruits & vegetables, spices, liquids, sea food, ...





Food applications

Direct EB use X-ray generated by high power EB Low energy X-ray





Direct EB applications

Guyomarc'h, old but remarkable application with adjustment product thickness to energy and on line treatment at 7MeV 5kW Linac electron beam with 3,5T / hour (replaced latter by 10MeV 10kW).

See also "Soft Beam" and Texas A&M publications





Direct EB applications





Direct EB applications



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X-Ray applications

Classical large treatment centers using high power electrons and X-ray converters (see Hans Hartmann presentation) or Rhodotron Duo (see Philippe Dethier presentation) to get EB & X-ray

Innovative low energy compact X-ray units (see Terry Thompson presentation)



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X-Ray applications









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Best choice: EB or X-Rays ?

Did we have the right equipment for the product at affordable price?

Required penetration?

Depends on or adjust product density/thickness to be treated

Required throughput?

Depends on power of equipment

Required homogeneity of treatment?

X-ray better than Electron Beam (especially for high density products)





Best choice: EB or X-Rays ?

Food don't means only High Energy X-Ray but also Electron at the right energy And also Low Energy X-Ray





Thank you for attention

Questions ?

For more information : www.nacre.fr fm@nacre.fr



