Compact Beam Sources for Low-Energy Electron Treatment of Seeds

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Introduction

With profound expertise in low-energy technology, Fraunhofer FEP develops specialized electron beam sources with optimized control and supply systems tailored to various customer requirements and tasks and qualifies new electron beam processes for innovative applications in research and production. Electron beams are highly versatile tools for material processing, environmental engineering, surface finishing, medical and technical imaging, process control, and analytics. They combine a multitude of physical, chemical, and biological effects with high energy efficiency, excellent precision, and technological flexibility.

The disinfection of seeds is one application example with high ecological relevance. The entirely chemical-free electron beam treatment of seeds is an environmentally friendly alternative to traditional treatments. The method utilizes accelerated low-energy electrons to effectively eliminate pathogens and stop crop diseases without compromising the seed's viability or introducing chemical residues. This poster presents an overview of the general principles and advantages of electron beam treatment of seed, with a focus on Fraunhofer FEP's mobile and compact sources for seed treatment. FEP has established a large toolbox of dosimetry and quality control equipment such as customized setups for radiochromic film dosimeters and optically stimulated luminescence dosimeters as well as beam intensity monitors to ensure stable operation and consistently good treatment successes in field operation [1].

Electron Beam Treatment of Seeds

For more than 25 years, the gentle treatment of seeds with accelerated electrons has been an important area of work at Fraunhofer FEP. The treatment process uses low-energy electrons to effectively kill pathogens on and within the seed coat while leaving the embryo unaffected. This is possible due to the limited penetration range of low-energy electrons which can be precisely tuned by the acceleration voltage of the beam generator. Depending on the size and thickness of the seed coat, tailored recipes make sure that the optimum dose of 12 kGy [2] is absorbed on the surface and, by purpose, to a decreasing degree, within the seed coat, following typical dose depth curves (see Fig. 1). While the free falling and rotating seed receives an all-around treatment, a short exposure time allows high throughputs.

Since the process operates purely physically, there is no toxic dust, no contamination of soil or water, or chemical residues, preventing the creation of resistant pathogens and ensuring a user safe and environmentally friendly operation. The phytosanitary effect of the process has been proven in long term studies together with German Federal Authorities [2] with 25 years field experience in practical farming. The treated seed is long-term storable and unplanted seeds can be safely fed to livestock. The process is recommended for ecological farming.

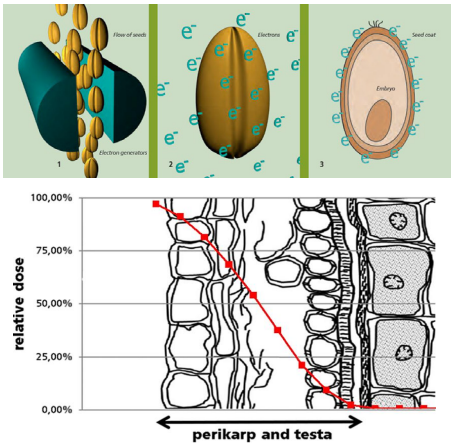

Fig. 1. Top: Electron treatment of falling and rotating seed for an all-round phytosanitary effect [3]. Bottom: Dose deposition of accelerated electrons on & within a seed coat.

Mobile Treatment Plants

To facilitate the integration of this treatment process into existing seed preparation workflows, Fraunhofer FEP has developed container-based treatment units (see Fig. 2). Such plants can be deployed stationarily at wholesalers or mobile to serve various locations of smaller seed companies.

The plants feature two 30 kW electron beam line emitters with 150 kV maximum energy (Fig. 3). Dose rates above 5,000 kGy m/min and a beam width of 1,500 mm allow maximum throughputs of up to about 25 metric tons per hour depending on the type of seed. There are now five mobile large-scale plants of this type operative in Germany, each producing over 10,000 tons annually.

Fig. 2. FEP's mobile plant for seed treatment.

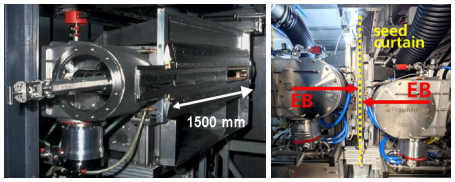

Fig. 3. Electron beam line emitters inside FEP's mobile plant for seed treatment: opened beam generator (left) and treatment setup with two opposing generators (right).

Fraunhofer FEP will continue to work actively with various partners to advance physical and biological seed treatment.

Through industrial contracts and publicly funded projects, we are committed to promoting sustainability in agriculture.

Inverse Electron Ring Source

Through close collaboration with different end users, Fraunhofer FEP has gained valuable insights into process and plant performance and is further improving its seed treatment technology, recently complementing its product line with new small-scale electron beam sources with a very compact footprint. In contrast to the wide line emitters, this source will emit electrons radially outwards in all directions from one heated filament. The falling seed curtain has the shape of a hollow cylinder. With all the accelerator structure being placed inside this cylinder, the overall size of the source is a lot smaller, offering an affordable treatment option for customers with smaller throughputs. The intention is to cut in half both the space requirements and the investment costs. A laboratory source of this type is undergoing commissioning (Fig. 4) and will be integrated into a mobile container setup in the next step.

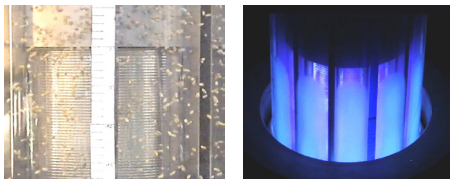

Fig. 4. FEP's inverse electron ring source. Left: close-up of high-speed analysis of falling seed. Right: visible plasma in the treatment volume during source operation.

Conclusions

The electron treatment of seeds serves as an excellent example of process-oriented research and development at Fraunhofer FEP. The optimization of electron sources requires a comprehensive understanding of mechanical, electrical, and physical properties and effects. Furthermore, technical skills and hands-on experience are essential for converting the technology into a production-ready system.

Acknowledgements

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