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Review Article

Applications of Particle Accelerators in Various Industries and Biophysics-A Review

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Abstract

Ion implantation is still one of the most sustainable and reliable methods for incorporating a useful amount of one material in another. Particle accelerators have a wide range of applications in various industries and fields of science, including biophysics. In this review, we will explore some of the main uses of particle accelerators in different industries and how they are applied in biophysics research. Medical institutions and hospitals particle accelerators are commonly used for radiation therapy, which is a common treatment for cancer. In this process, high-energy particles are directed at cancer cells to destroy them while minimizing damage to healthy tissue. The most commonly used particle accelerators for medical radiation therapy are linear accelerators (LINACs). There is a clear movement to plasma implantation for modern device structures. Aerospace Industry Particle accelerators are also used in the aerospace industry for testing and research. For example, particle accelerators can be used to simulate the effects of cosmic radiation on spacecraft and electronic equipment. This helps engineers design spacecraft that can withstand the harsh radiation environment of space.

Keywords: Particle Accelerators, Biophysics, Radiation therapy

1. Introduction

Particle accelerators are often study under high energy or nuclear physics. As well studied in various review literature [1]. In biophysics research, particle accelerators are used to study the properties of biological molecules and their interactions. For example, synchrotron radiation facilities use particle accelerators to produce intense beams of X-rays that are used to study the structures of proteins and other biomolecules. This research can lead to the development of new drugs and therapies for diseases Electrons or X-rays also utilized to decontaminate microbial pathogens or prevent undesirable production of microbial toxins. Particle accelerators are used in the nuclear industry to produce radioactive isotopes for medical and industrial applications. These isotopes are used in medical imaging, cancer treatment, and playing an important indirect role in the improvement of different techniques of food, medical, agricultural, microbiological and biophysical features.

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In the semiconductor industry, particle accelerators are used for ion implantation, which is a process used to introduce impurities into semiconductor materials to modify their electrical properties. This process is crucial in the manufacture of computer chips and other electronic devices [2]. Particle accelerators have a wide range of applications in various industries, including medicine, aerospace, semiconductors, and nuclear industries. In biophysics research, particle accelerators are used to study the properties of biological molecules and their interactions, which can lead to the development of new drugs and therapies. With the continued development of particle accelerator technology, we can expect to see even more innovative applications in the future.

2 Sterilization and Pathogenic Microbial free Packaging

Particle accelerators can also be used for sterilization and pathogenic microbial free packaging in the food and medical industries. In these industries, it is critical to ensure that products are free from harmful bacteria and other pathogens that can cause illness or contamination packaging. Particle accelerators have the capability to destroy DNA chains in living microorganisms such as bacteria and entomogens.

Nuclear energy X-rays are need for solid materials. In the food industry, particle accelerators can be used to sterilize food products, such as spices, herbs, and dried fruits. This process involves exposing the food to ionizing radiation, which destroys harmful bacteria, viruses, and parasites that can cause food borne illness. The advantage of using particle accelerators for food sterilization is that it is a cold process, which means that the food is not heated and its nutritional content is preserved. Live entomogens elimination in cereals and masticators decontaminating harmful spices and herbs without using fumigation prohibiting flies in fruit and vegetables microbial decontamination in food industry *Salmonella, Listeria, Eschericha coli* removal from food stuffs. One of the main advantages of using particle accelerators for sterilization and pathogenic microbial free packaging is that it is a non-contact process. This means that the products do not come into direct contact with the source of radiation, which eliminates the risk of contamination. Additionally, the process can be easily controlled to ensure that the products are exposed to the correct amount of radiation to achieve the desired level of sterilization or pathogenic microbial free packaging.

Particle accelerators offer a fast, efficient, and safe way to achieve sterilization and pathogenic microbial free packaging in the food and medical industries. Their non-contact nature and precise control make them a valuable tool for ensuring that products are free from harmful bacteria and other pathogens. As technology continues to advance, we can expect to see even more innovative applications of particle accelerators in the sterilization and pathogenic microbial free packaging of various products.

In the medical industry, particle accelerators can be used for pathogenic microbial free packaging of medical devices and supplies. This process involves exposing the products to ionizing radiation, which kills bacteria, viruses, and other pathogens that can cause infection. The advantage of using particle accelerators for pathogenic microbial free packaging is that it is a fast and efficient process that can be used to sterilize large quantities of medical supplies at once. Additionally, the process does not use any harmful chemicals or gases, which makes it safe for the environment [3].

3. Gemstone Pigmentation

Gemstone pigments are a type of pigment that can be produced using particle acceleration technology. This process involves accelerating particles, such as electrons or ions, to high energies and directing them at a target material, which can be a gemstone or a mineral. The high-energy particles collide with the target material; they cause ionization and excitation of the atoms or molecules within the material. This leads to the emission of light in various colours, depending on the specific atomic or molecular properties of the material. Gemstone pigments can be produced by irradiating various gemstones, such as diamonds, sapphires, and rubies, with high-energy particles. The process can be controlled to produce pigments in a range of colours, from blue and green to pink and purple. One of the main advantages of gemstone pigments is their high refractive index, which means that they reflect light at a high angle, producing a vibrant and lustrous effect. This makes them ideal for use in cosmetic and artistic applications, such as in makeup products, paints, and coatings. Gemstone pigments can also be used in the jewellery industry to enhance the colour and appearance of gemstones. For example, a gemstone pigment can be applied to a diamond to enhance its colour and brilliance, making it more valuable and desirable.

In addition to their aesthetic applications, gemstone pigments also have potential uses in scientific research. For example, they can be used to study the properties of materials under high-energy irradiation, which can provide insights into the behaviour of materials under extreme conditions. In conclusion, gemstone pigments produced using particle acceleration technology offer a unique and versatile way to enhance the colour and appearance of various materials, including gemstones, cosmetics, and artworks. Their high refractive index and vibrant colours make them ideal for use in various applications, while their potential applications in scientific research highlight their value beyond their aesthetic appeal. Accelerator application is the better way to generate both highly oxidizing and highly reducing same concentrations in aqueous liquid [4 & 5].

4 Particle Accelerators for Medical Uses:

Particle accelerators have a wide range of medical applications, from cancer treatment to imaging and research. Here are some examples of medical uses of particle accelerator. The development of particle accelerators initiated in the past century and was well studied by P.J Bryant. It is mainly based on three acceleration mechanism direct current acceleration, resonant acceleration and betatron mechanism [6].

In the beginning first mechanism a wide set of electrostatic machines (Cockroft Walton generator, Van Der Graaf generator single or double stage) have been used. Their utilization for medical applications has been very limited. Resonant acceleration given by Ising in 1924 is based on the use of alternating electric current. He reported to accelerate particles with a linear series of conducting drift tubes and in 1928 Wideroe represent his validity building a 1 MhZ, 25 kV oscillator capable to accelerate 50 keV potassium ions. He realized the first linear accelerator (LINAC) prototype. At that time the realization of a LINAC was very difficult. In fact at that time Lawrence realized the first fixed frequency cyclotron accelerating 1.25 MeV proton beam. Cyclotron was limited in energy by relativistic effects. At that time Veksler discovered the principle of phase stability and invented the synchrotron. Betatron mechanism originally discovered by Wideroe in 1923 and found his proof in 1940 when Kerst reinvents the betatron and built the first working machine for 2.2 MeV electrons. Betatrons were applied in radiotherapy for several years. Currently they have been completely replaced by electron LINAC.

In routine radiotherapy, electron LINAC are generally used. A 3 GHz accelerating structure is used. The electrons are thermo cathode at 1000 °C and accelerated I ionically emitted from a concave metal in the gun to about ¼ the velocity of light by a pulsed direct electric current. Then they are formed into a pencil beam by a convergent electric filed between the gun electrodes. The RF electric field in the accelerating tube then forms the electron into bunches and accelerates them to more than 99% of light velocity, increasing rays their amount. The electrons are then applied to bombard a target typically done in tungsten. Electrons hitting the target will produce brems radiation in the forward direction. X rays emitted are applied for the therapy. Two sets of tungsten blocks allow the sizes of the radiation beam (square or rectangular sections) to be adjusted. All modern medical electron linacs employ an isocentric gantry. The accelerator wave guide is mounted in the gantry, either parallel to the gantry axis if a beam bending magnet is employed or perpendicular to the gantry axis if a beam bending magnet is not required [7 & 8].

5. Particle Accelerators Application for Cancer Cancer treatment

One of the most well-known medical uses of particle accelerators is in the treatment of cancer. High-energy beams of particles, such as protons and ions, can be used to target cancerous cells with great precision, while minimizing damage to healthy tissue. This form of treatment, called proton therapy, is becoming increasingly common in the treatment of various types of Cancer.

Imaging: Particle accelerators can also be used to produce high-resolution images of the human body. For example, in positron emission tomography (PET) scans, a small amount of a radioactive material is injected into the body, which emits positrons. These positrons interact with nearby electrons, producing gamma rays that can be detected by a scanner. The data collected from the scanner can then be used to create detailed images of the body.

Radiation Therapy: In addition to proton therapy, particle accelerators can also be used to deliver radiation therapy to cancerous cells. This form of treatment involves using high-energy X-rays or gamma rays to kill cancer cells. Particle accelerators can produce these high-energy beams of radiation, which can be directed at the cancerous cells with great precision.

Isotope Production: Particle accelerators can be used to produce isotopes, which are radioactive materials used in medical imaging and therapy. For example, technetium-99m is a commonly used isotope in medical imaging, and can be produced using particle accelerators.

Particle accelerators are also used in medical research to study the properties of materials and particles at the atomic and subatomic level. This research can help to develop new treatments and therapies for various medical conditions. Particle accelerators have numerous medical applications, ranging from cancer treatment and imaging to isotope production and research. As technology continues to advance, we can expect to see even more innovative medical applications of particle accelerators in the near future. Cancer treatment using particle accelerators are increasingly being used in the treatment of cancer. This form of treatment, called proton therapy, uses high-energy beams of protons to target cancerous cells with precision, while minimizing damage to healthy tissue. Here's a brief overview of how proton therapy works and the mathematical expressions involved:

Proton therapy works by delivering a high dose of radiation directly to the cancerous cells, while sparing nearby healthy tissue. This is achieved by using a particle accelerator to accelerate protons to very high energies, which are then directed at the tumour. One of the key advantages of proton therapy over traditional radiation therapy is that protons can be targeted very precisely, allowing for higher doses of radiation to be delivered to the tumour while minimizing damage to surrounding healthy tissue. This is because protons have a relatively short range in tissue, meaning that they can be directed to stop at the tumour site without penetrating deeply into healthy tissue. The effectiveness of proton therapy in treating cancer is described by various mathematical expressions, including the Bragg peak and the relative biological effectiveness (RBE). The Bragg peak is a phenomenon that occurs when high-energy protons are directed at a tumor. As the protons travel through the tissue, they lose energy and slow down, depositing most of their energy at a specific depth, known as the Bragg peak. This means that the tumor can be targeted with a high dose of radiation at a very precise depth, while minimizing radiation exposure to surrounding healthy tissue. The RBE is a measure of the effectiveness of proton therapy compared to traditional radiation therapy. This is because protons have a higher RBE than X-rays or gamma rays, meaning that they are more effective at killing cancer cells. The RBE is calculated by comparing the dose required to produce a certain biological effect with protons, to the dose required to produce the same effect with X-rays or gamma rays. In conclusion, proton therapy is an increasingly popular form of cancer treatment that uses high-energy beams of protons to target cancerous cells with precision. The effectiveness of proton therapy is described by various mathematical expressions, including the Bragg peak and the relative biological effectiveness [6].

6. Accelerator Based Facility for Radioisotopes Production

Accelerator-based facilities use particle accelerators to produce high-energy particles, which are then used to bombard target materials. When the particles collide with the target material, nuclear facilities produced Radioisotopes. One of the most common types of accelerator-based facilities for radioisotope production is a cyclotron. Cyclotrons are used to produce short-lived isotopes, which decay rapidly and can be used for medical imaging. The cyclotron works by accelerating charged particles, such as protons, and directing them at a target material, usually a metal or gas. If the particles collide with the target, nuclear reactions occur, it produce the desirable isotopes. Another type of accelerator-based facility for radioisotope production is a linear accelerator, or LINAC. LINACs are used to produce longer-lived isotopes, which are used in cancer therapy and other medical applications. LINACs work by accelerating electrons to very high energies and directing them at a target material, usually a metal or gas. The high-energy electrons can produce nuclear reactions occur, it is also responsible for the production of desirable isotopes. Once the radioisotopes are produced, they are separated from the target material and purified for use in medical and industrial applications. This typically involves a series of chemical and physical processes such as chromatography and distillation. Accelerator-based facilities are used to produce radioisotopes for medical and industrial applications. Cyclotrons and linear accelerators are commonly used to produce short-lived and longer-lived isotopes, respectively. The radioisotopes are then purified and used in a variety of applications, including diagnostic imaging, cancer therapy, and nuclear medicine.

Different commercial solutions are available. IBA, General Electric, CTI, EBCO and SUMITOMO are the main cyclotron producers. They also offer dedicated radiochemistry modules for the production of the labeled molecule to be used [10-12].

Conclusions

India has developed significant number of resources for the construction of particle accelerators over the past many years. The application of particle accelerators is rising for medical utilizations. The synergy between medicine (radiotherapy, radiology, nuclear medicine, oncology) and physics (nuclear and accelerator physics) is growing even more and will need the future challenge to achieved a better quality of life. The motivation has mainly been to carry out frontline basic and applied research by our scientists. The purpose has been and is being served extremely well. In the process, however, highly advanced and precision technologies have been developed in several specialized areas. The available knowhow in the country has now crossed the threshold where it is conveniently possible to develop small accelerator-based systems that will be of immense use in social, industrial and environmental domains. Cyclotrons along with the associated radiochemistry systems for the production of radiopharmaceuticals for medical diagnostics are presently being imported. In view of the sharply rising demand, *e.g.* of fluorine-18 for powerful diagnosis of cancer, it would be worthwhile to develop and produce them in the country. We should also manufacture ion implanter systems for large-scale and efficient production of latest employing semiconductor devices [13]. This would be an important step forward for reducing our dependence on the import of computational and communication devices. They are crucial for the quick implementation of digital revolution to benefit the whole person in the country. Environmental application (water and air) using accelerated electron beams may need future plan. India is facing serious pollution problems; development of some useful systems may become more fulfill immediate need. Formation of an autonomous accelerator corporation would facilitate the much-needed involvement of industry and biological area.

Conflict of Interest: Author declares that there is no conflict of interest.

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