ELECTRON BEAM ACCELERATORS FOR MATERIALS PROCESSING: A BARC SCENATRIO

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Abstract

Over the last few decades, the electron beams have brought in revolutionary changes in the area of material processing. Beams varying from a few hundred keV to a ten of MeV and powers from a few hundred watts to a few hundred kW, have been employed for this purpose. Realising the enormous potential of these beams, Bhabha Atomic Research Centre (BARC) initiated steps to develop such machines. The first indigenously developed machine , 0.5 MeV / 10 kW, DC, is functional. Two more machines; a DC one with 3 MeV / 30 kW and the RF linac of 10 MeV / 10 kW, are in the advanced stage of completion.

INTRODUCTION

The charged particle accelerators have played a key role in the field of basic and applied sciences. Industry also did not remain isolated from the impact of these accelerators for which the major credit goes to electron beams[1,2]. Electrons up to energy of 0.5 MeV and 10 kW are being used for curing of coatings, adhesives and paints. Similarly heat shrink materials use electron in the range of 0.5 MeV to 2 MeV. To improve upon the lubrication property, Teflon is treated with beams of about 2 MeV and 10 kW. Diamonds with exotic colours are produced by using beams of 5-7 MeV & 10 kW. Green strength of the rubber gets enhanced by exposing it to electrons of 2 MeV & 30 kW. Beams up to 10 MeV and 10 kW are being routinely used for cross linking of cable, food preservation, medical sterilization etc. Even the pathogenic germs of the sewage & sledge are treated by the electron beams having energy as 1 MeV and power of 100 kW. The field is growing at a fast pace with more and more avenues opening up daily. With time, the demand for power is also going up. To cater to the present need, accelerators up to a beam power of 400 kW are being conceived & planned. The DC and the RF linear accelerators have been used for this purpose. Up to 3 MeV & 150 kW, DC accelerators are employed whereas for energies higher than this and power level of 50 kW, RF linacs are considered as best [3]. RHODOTRON, a newly developed accelerator by IBA Belgium [4] can go up to 10 MeV and 150 kW.

INDIGENOUS DEVELOPMENT

Bearing in mind the vast scope of such accelerators, a strong need was felt to build an indigenous base in these types of accelerators. That is why, way back in 1995, Accelerator & Pulse Power Division (APPD) of BARC was given the task of initiating a programme in this direction. To cover the diverse areas of radiation processing, three energy regimes were thought to suffice. The low energy, for catering to the surface modification processes, the medium, for taking care of the bulk load of cross linking, heat shrinkable materials etc, and the high energy, for meeting the large penetration depths for food processing etc.. For the low and medium energy, the choice went to DC accelerators but for the high energy, the obvious choice was the RF linacs. The basic configuration and the specifications chosen are, a Cockroft Walton based, 500 keV, 10 kW, DC accelerator, a Parallel (Capacitance) Coupled Voltage Multiplier based, 3 MeV, 30 kW, DC acceler and a coupled cavity type, 10 MeV, 10 kW, RF Linac.

Cockroft Walton based, 500 keV, 10 kW, DC Accelerator

An exploded view of this accelerator is shown in figure 1. The accelerator consists of a LaB_6 based electron gun which can deliver a beam of about 20 mA at a voltage of about 5 kV. The gun is of triode type. It floats at a voltage of 500 kV, generated through a chain of Cockroft Walton cascade rectifier. The beam after getting accelerated to 500 keV passes through the sweep scanner and the scan horn. It is extracted into air through a Titanium foil of 25 μ thick. The acceleration column is maintained at a pressure of 6 kg/cm^2 of Nitrogen.

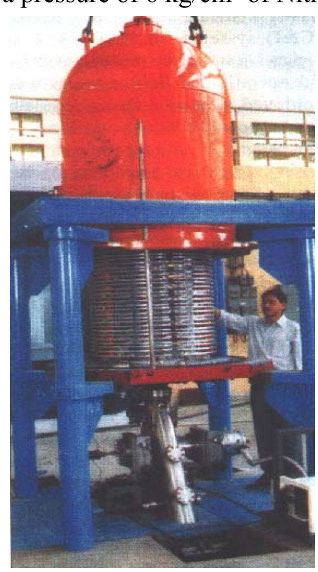

Figure 1: A view of 500 keV, 10 kW accelerator

The products are irradiated by putting them either on the movable or a static conveyor belt. Since this was the first accelerator, several problems were encountered in various sub systems like electron gun, scanning magnet, power supplies and the high power feed throughs. All of them have been addressed. The system has been made quite rugged. The stability in beam energy and current is measured to be within ± 1 % and ± 3.5 % respectively and is depicted in figure 2. This performance compare very well with the machines, available commercially. The accelerator is installed at BRIT Vashi and is in regular use for the surface modification & cross linking processes including plastic sheets and granules. Extensive programme has also been undertaken to study the physical & electrical properties of insulators and dielectrics.

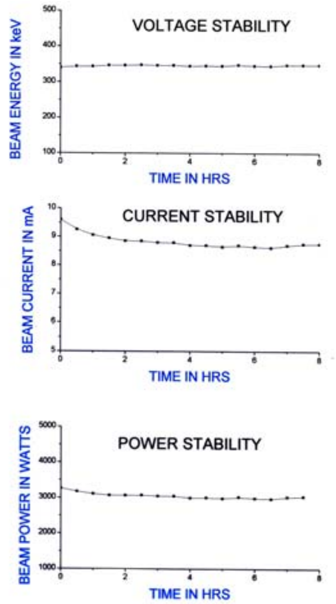

Figure 2: Performance of the 500 keV Accelerator

Design & Development of a 3 MeV, 30 kW DC Accelerator

Most of the radiation processing applications lie in this range of energy & power. The accelerator with this energy and power can be considered as the work horse for radiation processes. A detailed 3D layout [6] of the accelerator is shown in figure 3. Except for the voltage generation part, most of the components are similar to the 500 keV accelerator. The high voltage column comprises of corona rings which are interconnected by rectifier diodes. The split RF electrodes are energized by high frequency electronic oscillator. The self capacitances formed between the corona rings and the RF electrodes, serve as filter capacitors. There are 70 stages & each stage is designed to give an effective voltage of 50 kV. The tank houses the electron gun, acceleration tube, high voltage column, the dome , motor alternator drive assembly etc. The voltage insulation is provided through SF_6, maintained at a pressure of 6 atmosphere. The tank is approximately 7 meter long and has a diameter of 2 meters and will be built in three sections. To keep a track of the beam transportation, thermistor type beam sensing devices have been incorporated.

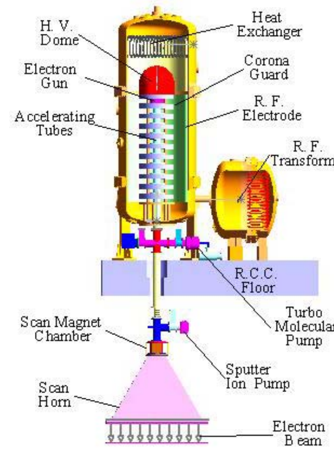

Figure 3: Layout of 3 MeV, 30 kW DC accelerator

There are quite a few technological challenges being faced in building this accelerator. The high power 120 kHz oscillator with ratings as 150 kV-0-150 kV, is one of them. The corona guards, RF electrodes and the HV dome, require a highly complicated configuration. The whole assembly requires a mirror finish. Most of its sub systems are in the advanced stage of completion.

10 MeV, 10 kW RF Linac

The on axis coupled cavity, constant geometry, standing wave types of linacs operated in the ∏/2 mode, has been adopted for this purpose [7]. A 50 keV electron beam injected into the linac is accelerated to the desired energy of 10 MeV. The energy analysis is accomplished through a magnetic analyzer. A 5 – 10 Hz magnetic scanner is used to scan the beam. Klystron based RF source is used for generating the field in the cavity. The design has been conceived for a RF frequency of 2856 MHz. The dimensional tolerances and the surface finish of the cavity have been strictly controlled within ± 10 μ and 1 μ respectively. A 33 cell cavity is shown in figure 4 and its field distribution in figure 5.

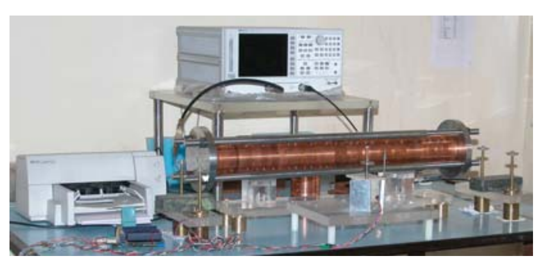

Figure 4: Characterisation of the Linac Cavity

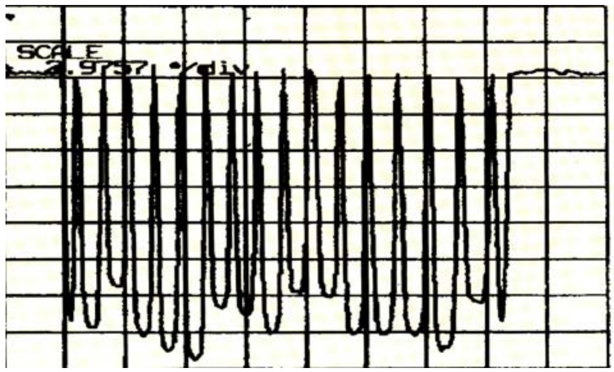

Figure 5: Electric field distribution inside the cavity

Figure 6: Assembly of 10 MeV Linac

For braising the cavity, we had to face quite a few technical problems, because the infrastructure & facilities needed for this, do not exist at BARC. For accomplishing the task, the cavity had to be splitted into three segments. Only then the job could be accommodated into the vacuum furnace for braising. After braising, the difference in RF frequency was found to be within 0.8 MHz of the original value. The Q value was measured as 12000 and the vacuum leak tightness was found to be better than $1*10^{-10}$ mbar-lit/sec. Most of the sub systems of 10 MeV linac are ready. The trial assembly is shown in figure 6.

ELECTRON BEAM CENTRE (EBC)

An Electron Beam Centre (EBC) at Kharghar, Navi Mumbai, in collaboration with SAMEER, is being set up for this purpose. The centre spans an area of about 5 acre and is located at a distance of about 25 km from BARC. It will house both, 3 MeV & 10 MeV accelerators. EBC is planned as a self sustained centre. It will totally be dedicated to the cause of research and development in the area of electron beam accelerators and their applications to the industry.

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