

# ACCELERATOR TECHNOLOGY AND ITS APPLICATION IN INDONESIA

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### Abstract

In Indonesia, activities on the development and application of particle accelerators have been carried out by the National Nuclear Energy Agency (BATAN) on a modest scale since 1979. It consists of a 200 keV ion implantor and a 150 keV deuteron accelerator as part of a neutron generator were located in the Research and Development Center for Advanced Technology (RDCAT), Yogyakarta. At present the research and development activities on ion implantation technique are carried out with emphasis on the surface modification of semiconductor materials and metals; while the neutron generator has been utilized for biological and environmental research. BATAN has also acquired, installed and operated two electron accelerators : 300 keV and 2 MeV, which are primarily used as electron irradiators at the Research and Development Center for Isotopes Technology and Radiation in Jakarta, and a fixed low energy cyclotron mainly for radioisotopes production at the Radioisotope Production Center in Serpong. Activities to plan the development of a modern accelerator based laboratory at the RDCAT are also currently being carried out. This paper presents a brief overview of the status and future prospects of the activities on particle accelerators in Indonesia.

## 1. INTRODUCTION

The activities connected with the technology and applications of particle accelerators were started by BATAN on a modest scale in 1979. At the Research and Development Center for Advanced Technology (RDCAT) of BATAN, the scientists and engineers primarily through the method of learning by doing and spite of very limited funds have succeeded step by step to upgrade their scientific and engineering capability to design and construct most of the components of a Cockcroft-Walton type 200 keV ion accelerator for ion implantation. Similar activities were successfully performed on a 150 keV deuteron accelerator as part of a

neutron generator. The research and development activities can be classified into two subjects :

- 1) Design and construction of an ion accelerator for ion implantation and its application for research activities
- 2) Design and construction of an deuteron ion accelerator for neutron generator and its application for research activities.

Two electron accelerator have been installed and operated at the Research and Development Center for Isotopes Technology and Radiation (RDCITR), i.e. 300 keV electron beam machine (EPS 300) installed in 1984, and a 2 MeV electron accelerator GJ-2 type installed in 1993. BATAN has also installed and operated a fixed low energy cyclotron model CS-30 at the Radioisotope Production Center in Serpong. The cyclotron facility has six beam tubes of switching magnet, two beam tubes are used for Ga-67 and Tl-201 production, and other tubes for research activities.

Currently BATAN is planning to establish an accelerator based laboratory at the Research and Development Center for Advanced Technology. The establishment and operation of the laboratory is expected to provide significant contributions in *solving various scientific-technical problems*, primarily those related to human health and medicine, industrial techniques, environmental care and biotechnology; and also for *developing and acquiring a wide spectrum of modern technologies*, such as those related to ion sources, particle acceleration techniques, beam handling and diagnostics, magnet technology, vacuum techniques, detector technologies, nuclear electronics, and data acquisition as well as processing techniques.

This paper presents a brief overview of the research and development activities in accelerator technology and applications in Indonesia, and a glimpse into the future describing the essential ideas involved in the development of the envisaged accelerator based

laboratory in the Research and Development Center for Advanced Technology, Yogyakarta.

## **2. COCKCROFT-WALTON TYPE ION ACCELERATORS**

Research and development activities of accelerator technology have been conducted by RDCAT on a modest scale since 1979. There are two main research and development activities of accelerator technology, i.e. design and construction of 200 keV ion accelerator for ion implantation, and similar activities were successfully performed on a 150 keV deuteron ion accelerator as part of a neutron generator.

### **2.1. The Ion Implantor**

The ion implantation accelerator constructed at RDCAT consists of ion source system, a Cockcroft-Walton high voltage generator with a maximum of 200 kV, an acceleration tube system, a quadrupole lens, a mass separator system, a beam sweeping system, a vacuum system, and a target chamber.

The beam currents necessary for implantation amount to between a few microamps and several milliamps. Although low currents are adequate for MOS devices (e.g. threshold-voltage adjust), high beam currents are needed for applications involving bipolar transistors or an alteration of physical or mechanical material properties, if relatively short implantation times are to be achieved [1]. Based on this condition the ion implantor was equipped with cold-cathode (Penning) and hot-cathode ion source systems which can produce many kind of ions from gaseous and solids substances.

#### **1) Implantation into semiconductor materials**

In recent years, ion implantation has been developed as a new process for the doping of semiconductor crystals. The most common processes used in the past have been doping during epitaxy, diffusion, and alloying. In the case of epitaxy, layers having the desired doping are grown on a wafer; during the diffusion process, doping atoms are diffused from the surface into the semiconductor. In the case of alloying, the semiconductor layer nearest to the surface is dissolved and doped during recrystallization. According to its nature, the process of implantation is basically independent of chemical solubility limits, the temperature during implantation, and the concentration of the dopant at the surface of the semiconductor.

At present the research and development activities on the techniques of implantation are focused on the surface modification of semiconductor materials

and metals or non-semiconductors. The research and development activities on ion implantation technique into semiconductor materials are concentrated on :

- The study of dopant behaviour in implanted semiconductors
- The determination of the range distribution of dopant species, lattice disorder, location of dopant species on substitutional and interstitial sites in the lattice
- The study of ion implantation into II-VI and IV-VI semiconductors for solar cells.

#### **2) Implantation into metals**

The use of ion implantation is not restricted to the field of semiconductors, it is also coming into application in other areas of physics and chemistry of solids, though efforts here are still in the research stage. With the development of high-current implantation machines, it has become possible not only to dope semiconductors, but also to alter physical, chemical, mechanical and optical properties of solids or metals. Using implantation with high doses, a transformation of the layer near the surface into another chemical compound is possible.

Small additions of reactive elements (e.g. yttrium, cerium, hafnium or their oxides), when added to chromia or alumina-forming alloys, have been shown to cause considerable improvements in high-temperature oxidation behaviour [2]. The addition of small amounts of reactive elements can be performed by alloying or by ion implantation. The latter technique offers the advantage of adding one or more elements to the alloy in a near surface layer in a well controlled and reproducible manner. Based on these advantages of ion implantation technique, the activities on ion implantation technique into metals or non-semiconductor materials are carried out with emphasis on :

- To modify the mechanical properties of metal surfaces : surface hardness, friction coefficient, fatigue behaviour and adhesive properties
- To increase the corrosion resistance, especially the high temperature oxidation corrosion resistance.

### **2.2. The Neutron Generator**

In the beginning of 1979 the RDCAT has developed the program to design and construct the low energy deuteron ion accelerator for a neutron generator. The RDCAT neutron generator which has been constructed consists of a RF ion source, a Cockcroft-Walton high voltage generator with a

maximum voltage of 150 kV, an ion optical system, a vacuum system, a target and cooling system, as well as a pneumatic transfer system.

The ion optical system consists of a primary beam focusing unit, an accelerating system and an accelerated beam transport system. The target unit is constructed in form of a Ti-T fixed target using an intensive cooling. A maximum deuteron beam current of 2.5 mA is obtained.

At present the RDCAT neutron generator has been utilized for research and development programs, with emphasis on the biological and environmental research, namely

- The determination of protein content of corn, soybean and peanut
- The determination of nitrogen and phosphor content in the fertilizer
- The qualitative and quantitative analysis of element composition of aerosol pollutions.

### **3. ELECTRON ACCELERATOR**

Two electron accelerators have been installed and operated at The Research and Development Center for Isotopes Technology and Radiation, i.e. a 300 keV electron beam machine (EPS 300) installed in 1984, and a 2 MeV electron accelerator GJ-2 type installed in 1993.

#### **3.1. The EPS 300 Electron Accelerator**

The EPS 300 was from Nissin High Voltage Co., the maximum electron energy is 300 keV with a variable beam current of 50 mA maximum, the scanning width is 120 cm and the speed of conveyor is between 2.5 m and 25 m/minute. This machine is a pilot plant for radiation curing of surface coating on wood products under UNDP/IAEA-RCA Project and government of Indonesia. The main objectives of this plant was for training course, demonstration as well as for studying both technical and economic aspect of radiation curing of surface coating technology [3].

Radiation curing of surface coating technology is a modern technology of surface coating where no volatile diluent was used. This technology was based on using a coating material called radiation curable materials, a material which is able to cure under a high energy radiation such as electron beam. This material is a moderately viscous liquid which basically consists of a mixture of oligomers and monomers. Under a high energy radiation this material will react each other forming a three dimensional molecular structure, a hard substance physically. A typical physical characteristic of the cured materials : high hardness, chemical

resistance, abrasion resistance and heat resistance. Due to that reason, the research activities were focused on :

- a) Formulation / synthesis of radiation curable materials
- b) Development of an optimum process for typical application
- c) Economic evaluation of the process / technology.

#### **3.2. The GJ-2 Electron Accelerator**

The GJ-2 electron accelerator was from China is characterized by maximum electron energy of 2 MeV with maximum electron beam current is 10 mA, and the scanning width is 120 cm. This machine is primarily used :

- a) As a pilot-scale demonstration plant for radiation cross-linking of wire and cables.
- b) For training course, demonstration as well as for studying both technical and economic aspect of cross-linking of wire and cables.
- c) To increase awareness of the industries on the potential applications of electron radiation technology including its benefits.
- d) To promote radiation as a means of rubber vulcanization, curing of surface coatings and cross-linking of wire and cables [4].

The advantageous properties caused by cross-linking are solder resistance, heat resistance and good mechanical properties. Many customers use solder to connect wire and equipment. In order to remove the soldering liquid, the equipment connected wires are passed in high temperature oven. So a lot of non-melt type wire and cables such as electron beam cross-linked wire and cable are used in this field.

### **4. CYCLOTRON FACILITY**

BATAN has installed and operated a fixed low energy cyclotron model CS-30 at the Radioisotope Production Center in Serpong. The cyclotron facility has six beam tubes of switching magnet, two beam tubes are used for Ga-67 and Tl-201 production, and other tubes for research activities. The main characteristic of the CS-30 cyclotron is as follows :

- Diameter of magnetic poles : 96.52 cm
- Gap between hills : 5.08 cm
- Gap between valleys : 10.16 cm
- Magnetic field (hills) : 22,500 gauss

- Magnetic field (valleys) : 14,400 gauss
- Magnetic field (average) : 17,500 gauss
- Radio-frequency : 26.901 MHz (for H<sup>+</sup> ion)
- Resonator : moving short type
- Ion source : Ionization Gauge (PIG) type
- Extraction beam current : 78  $\mu$ A of proton
- Energy : 26.5 MeV (proton) on extraction radius of 41.5 cm.

The main application areas of this facility involve the production of Ga-67 and Tl-201 short-life radioisotopes used for medical diagnostics. Other activities performed using the CS-30 cyclotron are to develop a solid target station and a manipulation system, as well as an irradiation facility development outside the vacuum system.

## 5. THE FUTURE ACTIVITIES

In the era of industry and globalization in entering the 21<sup>st</sup> century many problems of national development will be encountered, for instance in the field of industry and R & D (research and development) of new material engineering, medical and health services, biotechnology, and in solving of environmental problems. In the field of industry, development and improvement of product quality are needed, and R & D of new materials requires creation of high speed electronic devices and microelectronics which will support development in communications and informatics, manufacture of high quality optical components, new materials with new mechanical properties and superiority, and high temperature superconductor materials. In public medical and health services, an accurate technique for diagnostics, clinical evaluation, and therapy for cancer is required. In biotechnology into the 21<sup>st</sup> century, one of the principal national problems is food sufficiency, from agriculture (rice, corn, soybean, etc.), livestock, and fishery. Also the problem of raising the national revenues by exporting agribusiness, forestry, and plantation commodities. In the 21<sup>st</sup> century industrial era, one of the negative aspects is pollution which degrades human health and environmental safety, requiring monitoring of environmental quality as early as possible.

In order to enhance its participation in the national development, BATAN is currently planning to establish an accelerator based laboratory at the Research

and Development Center for Advanced Technology. The establishment and operation of the laboratory is expected to provide significant contribution in :

- Solving various scientific-technical problems, primarily those related to human health and medicine, industrial techniques, environmental care and biotechnology.
- Developing and acquiring a wide spectrum of modern technologies, such as those related to ion sources, particle acceleration techniques, beam handling and diagnostics, magnet technology, vacuum techniques, detector technologies, nuclear electronics, and data acquisition as well as processing techniques.
- Developing and upgrading of Human Resources in various branches of nuclear sciences and technology, in particular in collaboration with the local universities and foreign institutions.

The envisaged laboratory is planned to have an accelerator system, equipped with several experimental stations and supporting facilities. From the user point of view the laboratory may be divided into two areas, namely the Low Energy and the Medium Energy Areas.

### 5.1. The Low Energy Area

This area is foreseen to accommodate a low energy ion accelerator. The choice of the accelerator type could be made among the three available types, namely the electrostatic, RFQ (radio-frequency quadrupole) or cyclic (e.g. cyclotron). Optimization will be made with respect to the ion types (light, medium and heavy), achievable beam current, beam phase space quality and time structure. It is envisaged that the low energy accelerator may be used not only as a stand-alone machine to serve several experimental and application facilities, but should also be able to serve as an injector into a higher (medium) energy machine for further beam acceleration and handling.

The ion accelerator facility shall have several experimental stations equipped with appropriate scientific instruments to perform R & D and application oriented activities. In addition, the low energy ion accelerator will also serve as an injector to the intermediate energy facility. The various different beams shall be used among others in activities in the following fields :

- 1) Industrial applications, such as :
  - Ion implantation technique for development of semiconductor devices
  - Ion implantation technique is used to modify the mechanical properties of material surfaces to

achieve special effects connected for instance with electrical conductivity, surface hardness, corrosion resistance, friction coefficient, fatigue behaviour, adhesive properties or catalytic behaviour

- Implantation into optical materials, such as for the fabrication of light guides by alteration of the refractive index.
- 2) Biotechnology, such as creation of new plant varieties through genetic mutation induced by particle beams.
  - 3) Health and medicine, primarily for diagnostic and therapeutic purposes.
  - 4) Environmental care, primarily as an analytical tool in the identification of various types of pollutants in air, water or soil samples.

## **5.2. The Medium Energy Area**

The injected beam from the low energy ion accelerator will further accelerated by an intermediate energy accelerator (e.g. synchrotron) and manipulated in its phase space and/or time structure to meet different user requirements. Envisaged are primarily light ion beams with medium energy (200 – 300 MeV/nucleon) for medical and other scientific applications. In the intermediate energy area, scientific facilities are foreseen among others for the following activities :

- Health/Medical research and therapy
- Application oriented as well as fundamental research
- Development of special techniques and analytical methods.

Planning and promotional activities are currently in progress. In an attempt to optimize the benefits-costs ratio, careful considerations based among others upon user requirements shall be given to the selection process to obtain the most suitable type of accelerator (linear, cyclic or electrostatic) among those commercially available. The basic overall conceptual design, including the specification of the laboratory, the arrangement of experimental stations, as well as detailed technical specifications and the project implementation strategy shall follow thereafter.

## **6. CONCLUSION**

The particle beams have found a multitude of applications, ranging from basic and applied sciences, industrial processes, health and medicine, the development of analytical techniques used for instance in the environmental studies. The role of particle accelerators is expected to give significant contributions in the national development in Indonesia, especially in the acquisition of technology, in the solution of various

scientific-technical problems in many branches of development activities (agriculture, industry, health/medicine, environmental care), and in the human resources development.

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