Industrial Application of Electron Beam Acclerators

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Introduction

The interaction of electrons with materials has been studied in the field of "Radiation Chemistry". In recent 10 years, extensive works have been done in this field about the primary processes and the analyses of final products induced after the irradiation. We are now in the position to use the new knowledge of the Radiation Chemistry for new application of radiation processing.

In this paper, it is described how accelerated electrons are useful and powerful tool to induce an expected change in materials, and typical examples of practical applications for the industrial processing using ionizing radiation are shown briefly.

In the last part of this paper. current status of our Electron Beam Service and Application Research Center located in Tsukuba is also described.

What is the electron?

Ever since J.J.Thomson identified electrons through his experiments on cathode ray in late 19th century, electron has been important items(or objectives) for studies of quantum physics.

After the World War II, electron technology has become more and more faimiar to us through the devices such as television sets and oscilloscopes. In the field of chemistry, such electron beam accelerators as Van-De-Graafs, Dynamitrons®, Cockcloft-Waltons and linear accelerators(Linac) have become tools for study.

Now we can expect that we are in threshold of promising age of EB applications using these electron beam accelerators.

Why electrons are convenient for us?

Generally, materials which are to be modified are composed of many molecules, which are combined and characteristics are dominated by the electronic interactions. Hence, the materials can be modified by inducing change of electronic states by interaction of electrons of the energy around several eV.

The methods to give chemical changes onto the materials are heating, chemical reagents, photons and electrons. Among them the most direct method to induce changes on molecules is the injection of electrons into materials. With this method, one can get very quick and effective modifications of materials and the modification efficiency is much higher than other conventional methods, such as heating and chemical reagents.

What is the radiation chemistry?

The knowledge obtained in the studies of radiation chemistry gives us very valuable information for the understandings of "primary processes of electron-molecule interactions", "the successive reaction mechanism", and "the final products", Therefore, understanding of the radiation chemistry is very important for achieving a desired new radiation process successfully.

The radiation chemisty gives us following important knowledge such as :

- Physics of primary processes of reactions in the chemical system such as geminate ion recombination.
- Ion-Molecular reactions
- Processes of polymer crosslinking and degradation
- Polymerization mechanism
- Reaction rate constants of above reactions
- Identification of reactive intermediates
- Identification of final products.

What happens in materials after the electron irradiation?

The major phenomena after the electron irradiation are ionization and excitaion. Injected primary electrons with relatively high energy (in the industrial processing, the energy of electrons are between 150 keV and 10 MeV) will generate a number of secondary electrons.

The major initiators for inducing chemical reactions are not the primary electrons but these secondary electrons.

Energy absorption of electrons are almost proportional to the electron density of materials. This is completely different from photon (not X-ray but UV and Visible lights) energy absorption. In the case of electrons, mass collision stopping power (MeV /(g/cm^2)) dominates the energy absorption, but in the case of photons, the molecular extinction coefficients of molecules dominate the photon energy absorption.

Another aspect of energy absorption of electrons are the depth-dose distribution in the materials. This characteristics are very important and should be taken into account by the processing of relatively thick materials with certain energy electons. The depth-dose relations can be calculated by use of computer code named EDMULT.

Advantages and some Applications of Electron Beam(EB) Processing

Typical EB accelerators and their applications are shown in Fig. 1.

Fig 1. TYPICAL LAYOUT OF ELECTRON BEAM ACCELETOR & APPLICATIONS

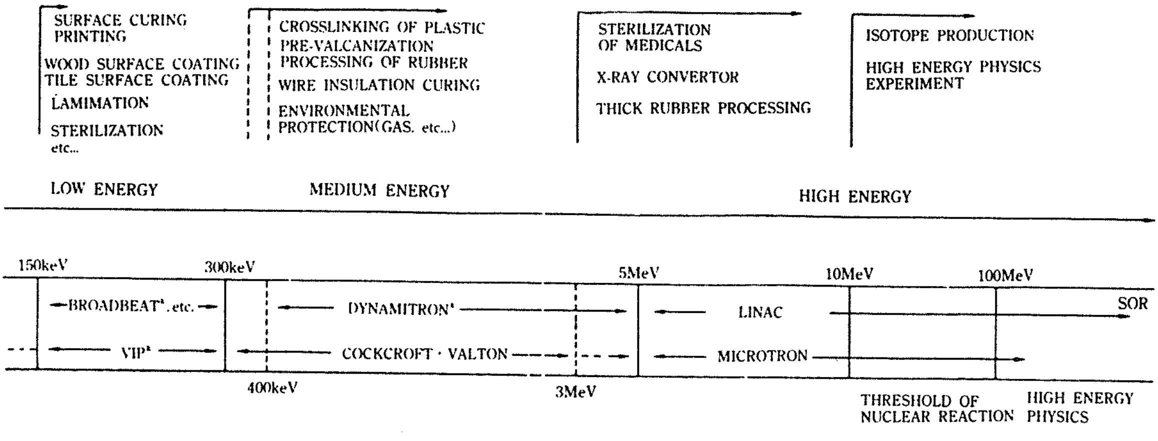

Table 1 shows the list of advantages of EB processing very briefly.

Table 1 ADVANTAGES OF EB PROCESSING

1. REACTION CAN START AT VERY WIDE TEMPERATURE RANGE ➡ REACTION STARTS AT ROOM TEMPERTURE !
2. REACTION CAN START FROM OUTSIDE OF THE SYSTEM : CATALYST FREE ! ➡ CONTAMINATION FREE PRODUCTS, A SIMPLE PROCESS
3. EASY ON/OFF CONTROL OF REACTION ➡ SAFETY SYSTEM, LESS LOSS OF ENERGY
4. EASY REALIZATION OF HIGH SPEED PROCESS ➡ HIGH THROUGHPUT PRODUCTION
5. POISONOUS GAS FREE AT THE STERILIZATION. FOOD PROCESSING ETC. ➡ SAFETY, EASY TO CONTROL
6. NO NEED OF STOCK AREA AFTER PROCESSING ➡ ECONOMICAL FOR PLANT DESIGN

On line productions using EB processing are now widely applied in many field, such as tire manufacturing, wire and cable insulation improvement, and many types of surface treatments, etc.. Other aspect of EB processing is off line or batch production which is convenient for the customers with small production amounts and for the purpose of medical supply sterilization. For these purposes, there are many established facilities in the world. They are tabulated in Table 2 with some typical applications of each facilities listed in the fourth column.

Present Status of EB Service and Application Research Center

The center was established by Sumitomo Heavy Industries, Ltd. in June of 1989 at Tsukuba city in Japan. Irradiation service has been performed by using Dynamitron® accelerator with the power of 200kW(5 MeV, 40mA). The present major items of irradiation services at the center are sterilization of laboratory ware, teflon degradation, modification of semi-conductor, and crosslinking of heat shrinkable tube, etc..

Objectives of establishment of this facility are as follows.

1. Small Scale Production by Contract Irradiation
2. Development of EB Irradiation Oriented Materials
3. Development of EB Irradiation Application Technology
4. Development of new EB processor with high energy and high power
5. Development of new beam source such as X-ray by using converter
6. Development of EB sterilization procedure and quality assurance
7. Training of operation and maintenance for personnel in charge of operating Dynamitron®
8. Better capability for field service in Asia Pacific region by stationing field engineers and stocking spare parts

Recently, the approval that qualifies Tsukuba Center as a facility for sterilizing a medical product (surgical gloves) by electron beam was issued by the Ministry of Health and Welfare

Thus our Tsukuba Center became first facility in Japan to sterilize medical product by EB.

Needless to say, this must be very important milestone in Japan to expand the EB business.

Table 2 ELECTRON BEAM SERVICE FACILITIES

OPERATOR	EQUIPMENT	IN USE	PRODUCT	REMARKS
TELEFUNKEN (HUMBURG, GERMANY)	1.5 MeV, 60 kW	1976	wire, tubing, plastics	
BETA-GAMMA SERVICES (WIEHL, GERMANY) (BRUCHSAL, GERMANY)	550 keV, 11 kW 3.0 MeV, 110 kW 4.5 MeV, 150 kW (DYNAMITRON®)	1980 1983 1986	coatings, thin films wire, cable, tubing sterilization	Former RDI (Germany)
CARIC (PARIS, FRANCE)	6.0 MeV, 7.5 kW (CIRCE) 10 MeV, 10 kW (CIRCE)	1966 1987	sterilization food	
E-BEAM SERVICES (PLAINVIEW, N.Y., USA) (CRANBURY, N.J., USA)	3.0 MeV, 90 kW (DYNAMITRON®) 4.5 MeV, 150 kW (DYNAMITRON®)	1974 1986	wire, cable, plastics sterilization	Former RDI Service Division
ELECTRON TECHNOLOGIES (SOUTH WINDSOR, Ct., USA)	3.0 MeV, 3 kW 3.0 MeV, 3 kW	1965 1972	plastics, molded parts semi-conductors	
IRRADIATION INDUSTRIES (GAITHERSBURG, Md., USA)	2.5 MeV, 45 kW	1965	plastics	
I.R.T. (SAN DIEGO, Ca., USA)	12 MeV, 10 kW 12 MeV, 10 kW	1960 1984	sterilization, gems semi-conductors	
MEDICAL STERILIZATION (SYOSSET, N.Y., USA)	4.5 MeV, 150 kW (DYNAMITRON®)	1986	sterilization	Derived from RDI
RAYCHEM (COPENHAGEN, DENMARK)	10 MeV, 10 kW	1967	sterilization, plastics	
RISO (ROSKILDE, DENMARK)	400 keV, 20 kW 10 MeV, 10 kW	1970 1960	thin films, plastics sterilizationm semi-conductors	
SCAN-CARIC (COPPERBURG, SWEDEN)	10 MeV, 20 kW (CIRCE)	1988	sterilization	
STUDER (DANIKEN, SWITZERLAND)	2.5 MeV, 200 kW	1983	wire, cable, tubing, sterilization	
VIRITECH (SWINDON, UK)	1.5 MeV, 74 kW 4.5 MeV, 90 kW (DYNAMITRON®) 6.5 MeV, 1 kW	1977 1987 1983	wire, cable, tubing sterilization semi-conductors	Former RDL (RDI, UK)
SUMITOMO HEAVY IND. (TSUKUBA, JAPAN)	5.0 MeV, 200 kW (DYNAMITRON®)	1989	plastics, sterilization semi-conductors	
RADIA IND. (TAKASAKI, JAPAN)	5.0 MeV, 150 kW	1991	sterilization etc.	