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Application of Electron Accelerator for Thin Film in Indonesia

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Introduction

Electron accelerator is widely used for the crosslinking of wire and cable insulation, the treatment of heat shrinkable products, precuring of tire components, and the sterilization of medical products. Research and development the use of electron accelerator for thin film in Indonesia covered radiation curing of surface coating, crosslinking of poly (butylenes succinate), crosslinking of wire, cable and heat shrinkable, sterilization of wound dressing, and prevulcanization of tire.

In general, comparing with conventional method, electron beam processing have some advantages, such as, less energy consumption, much higher production rate, processing ability at ambient temperature and environmental friendly.

Indonesia has a great potential to develop the application of electron accelerator, due to the remarkable growth industrial sector, the abundant of natural resources and the increasing demand of the high quality products.

This paper describes the activities concerning with R & D, and application of electron accelerator for processing of thin film.

Electron Accelerator Facility

There are four electron accelerators have been installed in Indonesia. Three accelerators belong to the low energy, and one is medium energy. The first electron accelerator (300 keV, 50 mA) was installed in 1984 at Center for Research and Development of Isotopes and Radiation Technology (P3TIR), as a pilot plant for radiation curing of surface coating of wood products. The pilot–plant was designed for research and development, training and demonstration, technical and economical aspect, and also for radiation services [1]. In 1993, the second accelerator from China, was installed in the same facility (2 MeV, 10 mA) for R & D of crosslinking process of wire and cable, heat shrinkable tube and sheet, and other radiation processes. A private company (PT. Gajah Tunggal) installed a low energy accelerator (500 keV, 20 mA) for crosslinking tire components in 1998. In 2002, the Bridgestone Indonesia Company has installed two electron accelerators with energy of 350

keV and beam current of 150 mA, at Karawang, West Java. The equipments were used for precuring of tire. Nissin High Voltage Company, Japan, made all of the low energy accelerators.

In 1997, the project for construction of electron beam machine of 350 keV/ 10 mA for multi purpose applications especially for thin samples for duration of five years was assigned to the Yogyakarta Nuclear Research Center (Now: R & D Center for Advanced Technology) by top leader of BATAN. In general, the main objective of the project is the capacity building of the human resources development of the accelerator technology, especially for handling electron beam technology. The output of the project is one prototype of EBM 350 keV/10 mA for training and demonstration purposes especially in operation and maintenance.

Research and Development:

Radiation Curing of Surface Coating

The activities on radiation curing of surface coating using pilot-plant for wood products cover synthesis of radiation curable materials, radiation surface coatings of several substrates, and economic evaluation. The pilot-plant have two radiation sources i.e. electron beam machine of 300 keV, 50 mA and one lamp of 80 W/cm intensity UV source. Research and development of the technology have been focused on various kinds of wood panel substrates such as plywood, particle board, parquet flooring, and some commercial timbers [2-4]. This is due to the reason that Indonesia is the world's leading wood producing country an a big markets of wood finished products such as rattan based products, furniture and handicraft products and other wood working products either for domestic or export.

Several companies have already used the pilot plant for their coating process of plywood, particle board, parquet flooring, ceiling etc. UV-curing are widely used commercially in industry for surface coating of wood based products i.e. parquet flooring, table top, fancy plywood, fancy veneer and other furniture components. In addition for wood based products, UV-curing was used for printing industries such as to cure overprint varnish for magazine, printing inks for labeling, cigarettes papers, packaging materials, printed circuit board (PCB) and dental materials.

Electron beam curing is still in a pilot scale. For many applications, production cost of EB-coating is higher than UV-curing. The high production cost is mainly due to the several reasons, such as high cost of equipment, inert system, and radiation curable materials. Almost of thus items should be imported. The development of radiation curing of surface coating is strongly depend on the innovation of new radiation curable materials and their equipments, and an efficient and friendly-environmental process. Entering the globalization market in the near future, this technology will be considered as an alternative and promising technology for processing many kinds of products.

Radiation Crosslinking

The biggest application of accelerator is occupied by the process of crosslinking, such as crosslinking of plastics, wire and cable, heat shrinkable tube and sheets, precuring of tire, and special products. Some activities concerning with the use of accelerator for thin film which was usually based on crosslinking process can be described briefly as follows.

Crosslinking of Poly (butylene succinate)

The study of radiation crosslinking of three kinds poly (butylene succinate) in the presence of different molecular weights, was conducted in the presence of five polyfunctional monomers and fourteen different inorganic materials at ambient temperature. Poly (butylene succinate-*co*-adipate with high molecular weight (PBS 1), poly (butylene succinate-*co*-adipate) with low molecular weight (PBS 2) and poly (butylene succinate) (PBS 3) were used for experiment. Irradiation was conducted using electron accelerator of 2 MeV and a beam current of 1 mA.

Trimethalyl isocyanurate (TMAIC) was better at enhancing the formation of gel in the irradiated PBS than did the other polyfunctional monomers, i.e., polyethylene glycol dimethyl methacrylate (EGDM), trimethylol propane trimethacrylate (TMPT) and tetramethylol methane tetra acrylate (A-TMMT) The amount of TMAIC blended with PBS influenced the amount of gel resulting after irradiation. The most efficiently crosslinking was achieved for PBS that contained 1 % TMAIC. The crosslinked PBS in the presence of TMAIC exhibited considerably improved heat stability. The biodegradation rate of the modified polymers was slightly diminished with an increasing gel fraction; however, the polymers were still biodegradable.

The presence of some inorganic materials inside crosslinked PBS samples enhance the yield of gel formation and 2 % of carbon black and 2 % of silicone dioxide respectively, give optimum yield of crosslinking at irradiation dose of 160 kGy. The Irradiated PBS 1 containing 2 % silicone dioxide and 2 % carbon black, elongated lowest than that of unirradiated and irradiated pure PBS 1 as shown by creep test and thermomechanical analysis (TMA). This is due to the formation of inorganic-polymer network during irradiation that improves the heat stability. Investigation using enzymatic and soil burial test showed that the rate of biodegradability of irradiated PBS 1 containing 2 % of silicone oxide and 2 % of carbon black much faster than that of irradiated pure PBS 1. This phenomenon is due to the enlargement of the sample's surface caused by the presence of inorganic material in the sample and so enzymes are easier to enter inside polymer [5,6].

Indonesian researcher at TRCRE, JAERI-Takasaki, performed the research.

Wire and Cable

Cable and heat shrinkable are the main component in the electricity, telecommunication, automobile and related industry. According to Indonesian Electric Cable manufacturers' Association (APKABEL), total capacity of cable production is 445,090 MT, which consist of telecommunication cable, power cable, special cable and enameled wire.

In general, insulating cable was prepared of polyethylene and polyvinyl chloride. Center for research and Development of Isotopes and Radiation Technology and Kabelindo Murni Comp., have carried out the joint research preparing master-batch for heat shrinkable compound. The preparation of heat shrinkable compound and blowing process were conducted at Kabelindo Murni, whereas irradiation, and physical/mechanical testing were carried out at Center for Research and Development of Isotopes and Radiation Technology. The best result regarding the physical/mechanical properties and performance before and after blowing & heating are achieved at the dose of around 250 kGy. The experiment will be continued in the design for efficient process of heat shrinkable.

Crosslinking of low density polyethylene (LDPE) and polyvinyl chloride was performed by irradiation using electron accelerator. The highest value of the gel fraction of XLDPE, tensile strength, and elongation at break were achieved at the energy of 2 MeV, current of 1.0 mA and irradiation dose of 300 kGy [7]. Heat- and oxidative-resistance of LDPE for cable insulation increase significantly by addition of antioxidant after crosslinked using 300 keV electron beam. Addition of 0.2 % of antioxidant gave the optimum result at the dose of 300 kGy Antioxidant of Irganox 1076 resulted better film properties as compared to the use of Irganox 1010 and Santowhite powder [8]. The rate of flammability of polyethylene was influenced by addition of flame retardant. The flame retardant used were halogen compounds i.e. chloroparafin (CP), tetrachloro-bisphenol-A (TCBA), polyvinyl chloride (PVC) and antimony trioxide (Sb_2O_3). Linear burning rate of the sample without irradiation is lower than that of irradiated one, but the flame retardant could not retard the burning rate of the irradiated compound [9].

Wound Dressing

In order to develop the application of irradiation for treatment of natural polymers, the synthesis of polyethylene oxide (PEO) – carrageenan hydrogel by using electron accelerator and the effect of poly (ethylene glycol) (PEG) on the physicochemical properties have been studied. The physicochemical properties of the hydrogel such as gel fraction, water adsorption, water loss, and tensile strength were observed. Increasing irradiation dose, decreases gel fraction of the hydrogel. Increasing PEG concentration decreases gel fraction. The ability of hydrogel to adsorb and reduce water evaporation increases with increasing PEG concentration. Irradiation dose up to 40 kGy increases tensile strength. The appearance of PEO-carrageenan blend hydrogel can be used for wound dressing.

Prevulcanization of Tire

The main application of electron beam radiation in the rubber industry is in crosslinking (precuring) compounds requiring higher green strength. Tire manufacturing process can be improved by the use of precured rubber sheet through electron beam irradiation. The inner liner of tire compound can be rapidly processed using accelerator.

Now, there are two private companies, namely, PT. Gajah Tunggal at Tangerang (near Jakarta) and PT. Bridgestone Indonesia at Karawang (West Java) have already used electron beam for prevulcanization (precuring) of tire compound.

Radiation

Accelerator electron 2 MeV, 10 mA at P3TIR has already used for sterilization of wound dressing from medical company. Radiation services was performed using 2 MeV and 10 mA of accelerator to sterilize 20 boxes / week. One box contains of 350 plastics packs, and each pack contains of 16 pieces with the size of 16 cm × 16 cm and irradiation was conducted in a plastics pack with the dose of 25 kGy, voltage of 2 MeV and beam current of 5 mA.

Conclusion

Most of electron accelerator for processing of thin films is based on the crosslinking process such as, radiation curing of surface coating, crosslinking of poly (butylene succinate), crosslinking of wire and cable, wound dressing and precuring of tire. Some of the significant progress and development on the application of electron beam processing in Indonesia have been achieved. Crosslinking for prevulcanization/precuring of tire compound is an example for the application of electron accelerator commercially by two rubber tire companies. Improvement and advancement in the materials to be processed and electron beam processing technology are the important factors in the growth of application for thin film processing. Economical aspect is still a dominated factor for the development the use of electron accelerator for thin films.

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