Application of Ionizing Radiations

Introduction

The main subject of the Application of Ionizing Radiations Program is to disseminate and consolidate techniques leading to the use of the radiation technology and radioisotopes applications in Industry, Human Health, Agriculture and Environmental Preservation. This Program is divided into four subprograms:

- Food and Agricultural Products Irradiation;
- Radiation and Radioisotopes Applications in Industry and Environment;
- Radioactive Sources and Radiation Applications in Human Health;
- Radioactive Facilities and Equipments for Nuclear Techniques Applications.

After the modernization and implantation of new irradiation systems for the Electron Beam Accelerators 1,200 km of wire and electric cable, 35 km of polyethylene foam and 107,000 powered diodes were processed per year. In this period, two patents were issued, scientific prizes were awarded and the radio sterilization of medical, pharmaceutical and biological products increased around 50%. Furthermore, the production of 240 ^{192}Ir and ^{60}Co sealed sources, the ^{75}Se sources loading services and several inspections in irradiators, command cables and guide pipes have covered all the national demand. Since 2005, the Multipurpose Irradiator has been used as a demonstration facility for manufacturers, who need an economic and logistic in house irradiation alternative system and as support to the local scientific community on the development of process and products using gamma radiation, assisting the traditional and potential users on processes validation, training and qualification of operators and radioprotection officers.

The improvement of the activities of radioisotope technology application in the petrochemical and chemical industries for processing control and sanitation, the distribution of 36,000 ^{125}I seeds per year and activities in the RadTech South America Conference can also be highlighted.

All realizations and achievements were only possible due to governmental financial support, standing out six projects by FAPESP, six by CNPq, two by FINEP and six international projects (ARCAL, TC and RC) supported by the IAEA, as well as, national and international partnership and cooperation with industries, universities and other institutions.

The research and development activities concerning this program are developed at the Radiation Technology Center - CTR. A technical staff of 59 professionals including 20 Ph.D., 8 M.Sc., 5 engineers and 26 technicians are engaged in this Program. Besides that, 15 undergraduate students and 49 graduate students also contributed for the activities development. In the last 36 years, US$ 26 millions were invested in the Center responsible for the Program. During its trajectory of success and achievement, it can be highlighted, in the last three years, the FAPESP, CNPq and IAEA projects for construction and implantation of the ^{60}Co Multipurpose Irradiator, for technological domain of ^{125}I seeds production for prostate cancer treatment; and also, the assembling of industrial tomography equipment for multiphase flow system analyses.

Irradiated food detection laboratory located at the Radiation Technology Center (Nuclear and Energy Research Institute) has been developing different studies in the food irradiation area. These studies embrace many subjects, not only food irradiation detection but also the effects of ionizing radiation on a variety of food stuffs. Works focused on food irradiation detection are based on the application of the microbiological method DEFT/APC and other assays as DNA Comet Assay and germination test. DEFT/APC method and DNA Comet Assay were applied to different minimally processed vegetables. DNA Comet Assay was also used to detect irradiation treatment of soybeans and poultry liver as well as cold chain rupture in food industry control. Moreover, our laboratory research also included the detection of genetically modified food, irradiated and unirradiated. Several works have been performed to evaluate the effects of ionizing radiation on different kinds of food, such as: meat, through lipid peroxidation analysis in salmon and beef burgers; grains, physical, microbiological and sensorial tests in soybean, peanuts, pistachio; herbs, microbiological and sensorial analysis of medicinal herbs; vegetables, effects of gamma radiation on ready-to-eat vegetables. Besides food analysis, other studies evaluated the decontamination of biological ferment by gamma radiation and the radiation degradation of biological residues (aflatoxins) produced in food laboratories.

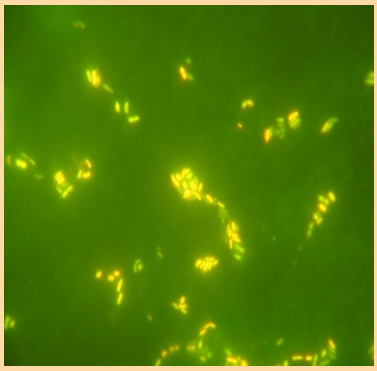

Figure 1. Biological method of food irradiation detection (DEFT/APC), a microbiological screening method based on the use of epifluorescent filter technique (DEFT) and the aerobic plate count (APC). Bacterial cells recovery from irradiated ready-to-eat chicory sample (0,5kGy)

Brazil started the use of radiation technology in food processing in the sixties, with research led to disinfestations and extension of shelf life of fruits. The regulation on food irradiation started in 1969, establishing dose limits for the products; a new version was updated in 2001 without limits and similar to recent modifications introduced by the Codex Alimentarius. Ionizing radiation may be used as a treatment for pest risk management. The adoption of irradiation treatments requires that the efficacy of the treatment be scientifically demonstrated. Application of the treatment requires dosimetry and dose mapping to ensure that the treatment is effective in particular facilities and with specific commodity configurations. The availability of methods for detection of irradiated food contributes to increase consumer's confidence. Tommy Atkins mangoes were from Petrolina, northeastern region of Brazil, harvested at degree 3, on October 7th and sent immediately to the Instituto de Pesquisas Energéticas e Nucleares-IPEN (São Paulo, Brazil) where they were treated. The total quantity was around 630 fruits, which were divided in three batches. One of them was submitted to a hot water dip treatment (46ºC during 110 minutes), that consisted in a control group. The two other groups were irradiated in a Multipurpose Gamma Source (IPEN, São Paulo, Brazil). The delivered doses were 0.4 and 1.0 kGy. After treatment, the mangoes were stored in a conditioned room (11ºC ± 1 and 66,6% RH) until the trip to Canada (October, 17th). Fruits were sent to the Canadian Irradiation Center (CIC, Laval, Canada) by plane at environmental conditions. The storage at CIC was done under environmental conditions (20ºC ± 2; 40% ± 2 RH). The experiment consisted in: Visual observations (mold, rot end or defect occurrence); Mass loss evaluation; Physical and chemical analysis (pH, titrable acidity, total soluble solids, ratio (solids/acidity), texture, color and water activity); Sensory evaluation (color, odor, taste and texture acceptance and overall appearance of whole fruits). Physico chemical analysis showed that gamma irradiation or thermal treatment resulted in similar performances and the main results indicated that irradiation could be a potential disinfestation treatment comparable to thermal treatment, for international purposes.

Figure 2. Irradiated mangoes

Modification and preparation of polymeric materials and composites by ionizing radiation

Electron beam curing using epoxy resin system
The electron beam (EB) curing technology allows the use at room temperature and reduced curing times and this is one of the main advantages over thermal technology. The aim of this work was to investigate electron beam curable epoxy formulations to use in filament winding processes to produce composite material with similar or better properties than thermal curable composites.

Utilization of rice husk ash as reinforcement filler for polyamide 6 irradiated by electron beam
New reinforcement fillers like mineral or fiber are developed to improve the dimensional stability, electrical, thermal and chemical resistance, and strength of many kinds of polymers. The aim of this work was to present, dimensional stability, thermal and strength results of the study of amorphous rice husk ash like reinforcement filler in a polyamide 6 matrix irradiated by electron beam at different doses and compare it with talc, the most utilized mineral filler by the composes producers.

Ionizing radiation effect by electron beam on ultra high molecular weight polyethylene virgin and recycled industrial
Ultra High Molecular Weight Polyethylene (UHMWPE) is an engineering plastic which has several applications, chiefly, in specific areas of the industry and medicine. The goal of this was to recycle the UHMWPE UTEC 3041 and study the properties of this recycled material and of the virgin UHMWPE and compare the results between both with the materials undergone to different radiation doses.

Characterization of crosslinking polyethylene foam by irradiation process with electron beam
The foam of polyethylene obtained by crosslinking process by irradiation performs excellent appearance in the surface, which is formed basically by closed cells. The aim of this work was to study the effect of different radiation doses on the polyethylene of low density that after irradiation it is thermally expanded for foam obtaining. To certify about the effect of the radiation it was studied the mechanical and thermal properties of the foams.

Ionizing radiation effect on the properties of polyamide 6 with glass fiber reinforcement
The aim of this work was to study the effect of ionizing radiation on properties of polyamide 6 with glass fiber reinforcement, undergone to different radiation doses. The properties of the non-irradiated and irradiated polyamide 6 with glass fiber reinforcement were evaluated.

Ionizing radiation effect on composites of wood flour in polypropylene matrix using barium titanate as coupling agent
The composites of wood-polymer are materials that have the combination of a polymeric matrix and a reinforced cellulosic load. These materials are characterized for their versatility, lightness, better resistance to humidity and environmental deterioration, besides their economical advantage in using as reinforcement a cellulosic residual as the wood fiber. The aim of this work was to study the ionizing radiation influence in the properties of the composite of wood fiber reinforced polypropylene using barium titanate with coupling agent to improve the interaction between the interfaces.

Degradation of cellulose from sugarcane bagasse by ionizing radiation to obtain ethanol and natural polymers

In recent years, there has been an increasing trend towards more efficient utilization of agro-industrial residues, such as sugarcane bagasse, as raw materials for industrial applications. Several processes and products have been reported that utilize sugarcane bagasse as a raw material. These include electricity generation, pulp and paper production, and products based on fermentation. Sugarcane bagasse generally contain up to 45% glucose polymer cellulose, 38% hemicelluloses, an amorphous polymer usually composed of xylose, arabinose, galactose, glucose, and mannose and 20% lignin. The main obstacle to produce ethanol bio-fuel from cellulose is how to accelerate the hydrolysis reaction that breaks it down into starches and sugars suitable for fermentation. The major cellulose hydrolysis processes, as chemical or enzymatic reactions, are so harsh that toxic degradation products are produced and can interfere with fermentation. The radiation processing is a powerful technology to accelerate this hydrolysis reaction. The main benefit of ethanol production from sugarcane bagasse is the environmental protection and recovery, reducing greenhouse gas emissions compared to oil derivatives and the increase

of ethanol production per planted hectare. In addition, as a large source of lignocelluloses biomass, sugarcane bagasse is a cheap and annually renewable resource suitable for producing natural cellulose fibers. The preparation and properties of new polymers from hemicelluloses and the use of cellulose and its derivatives in a diverse array of other applications, such as films, plastics, coatings, suspension agents, and composites are another important part of this research program. This project is being realized together with Sugarcane Technology Center, located at Piracicaba, Sao Paulo, Brazil, CTC and has about 200 associated sugarcane farms.

Figure 3. Sugarcane bagasse processed by ionizing radiation

Food polymeric packaging processed by radiation

In this study, the mechanical properties (tensile strength and percentage elongation at break and penetration resistance), optical properties, gas oxygen and water vapor permeability, the overall migration tests into aqueous food simulats (3% aqueous acetic acid) and fatty food simulat (n-heptane), as well as the formation of volatile radiation products tests were used to evaluate the effects of ionizing radiation (gamma irradiation or electron-beam irradiation) on commercial monolayer and multilayer flexible plastics packaging materials. These films are two typical materials produced in Brazil for industrial meat packaging, one of them is a monolayer low-density polyethylene (LDPE) and other is a multilayer coextruded low-density polyethylene (LDPE), ethylene vinyl alcohol (EVOH), polyamide (PA) based film (LDPE/EVOH/PA). Film samples were irradiated with doses up to 30 kGy, at room temperature and in the presence of air with gamma rays using a ^{60}Co facility and electron beam from 1.5 MeV electrostatic accelerator. Alterations of these properties were detected according to the dose applied initially eight day after irradiation took place and new alterations of these values when the properties were evaluate two to three months after irradiation process. The results showed that scission reactions are higher than cross-linking process for both studied films, irradiated with gamma rays and electron beam. The evaluated properties of the irradiated films were not affected significantly with the dose range and period studied. The monolayer Unipac PE-60 and the multilayer Lovaflex CH 130 films can be used as food packaging materials for food pasteurization and in the sterilization process of by ionizing radiation using gamma facilities and electron beam accelerators in commercial scale.

Radiation-induced grafting in polymeric film

On Radiation-induced Grafting research, the Radiation Technology Center at IPEN, CTR-IPEN, approved the project "Development and Application of Chlorinated, Fluorinated and Technological Polymer Films Modified by Grafting Process Using Electron Beam and Gamma Radiation", which begins in October, 2007. This is a Coordinated Research Project from the International Atomic Energy Agency, CRP-IAEA, which includes participants from fourteen countries, and the scope is “Development of Novel Adsorbents and Membranes by Radiation-induced Grafting for Environmental and Industrial Applications”. From 19 to 23 November of 2007, the CTR researcher J.E.Manzoli, coordinator of the project, was in Vienna, Austria, for the first meeting of the participant countries. Preliminary results on grafting of styrene on polytetrafluoroethylene (PTFE), polyvinyl difluoride (PVDF) and polypropylene (PP) were reported. Part of the heating chamber of the project was finished at 2007.

Disinfection and preservation of cultural heritage by ionizing radiation

Cultural heritage on paper and works of art in general made of organic materials in nature are submitted to a constant process of degradation by ageing through physical, chemical, microbiological or insect attacks. The use of ionizing radiation aims the disinfestations of works of art and the preservation of artifacts in their original form or in the state in which they are found, by impregnation with gamma radiation curable resins, avoiding their reinfestation. The effects of gamma radiation on Brazilian paper and wood based cultural heritage have been investigated concerning some specific characteristics.

Biological assays for effluent control

Several effluents are submitted to electron beam irradiation in order to reduce color, surfactants and whole toxicity. In order to measure the efficacy of radiation as a technology for hard effluents, luminescent Vibrio fischeri bacteria have been used, called as biological assays, also applied for toxicity effluent evaluation. Other biological indicator are also studied. As radiation is used for biological control on contaminated paper and materials the radiation doses and its effects on material integrity are being determined.

Gemstones enhancement using Gamma Radiation

Enhancement services through gamma radiation of green quartz and other varieties of gemstones samples for the companies Murta Gems Trade Gemstones (BH), Stoll Precious Stones of Brasil (RS) and Geoscience Institute of USP. Research of processes to induce or enhance the color in several gemstones and their dosimetry using gamma radiation.

Figure 4. Green quartz

Industrial dosimetry in radiation processing

In radiation processing, a well characterized reliable dosimetry system that is traceable for recognized national and international dosimetry standards is the key element of such activities. The Industrial Dosimetry Laboratory/CTR has the responsibility to measure the radiation dose absorbed in the processes induced by ionizing radiation at Co-60 gamma ray irradiation (Gammacell, Panoramic and Multipurpose Irradiator) and electron beam (two Industrial Electron Beam Accelerators of 97,5kW and 37,5kW) facilities of the Center in ordinary services and to develop new products and services by radiation processing. The dosimetry procedures for radiation processing in our laboratory are carried out in agreement with the ISO (International Organization for Standardization) - ASTM (American Society Testing and Materials) standard guides and practices. To establish a reliable dosimetry system, we have participated of the intercomparisons of gamma dose measures organized by International Dose Assurance Service (IDAS) offered by the International Agency Energy Atomic (IAEA) and of the national intercomparisons to check on the entire radiation dose measurement system: dosimeters, measurements equipment, irradiation and data procedures. The dosimetry systems that we use for the quality control of the radiation process are: Fricke solution as reference standard dosimetry system, Alanina as transfer standard dosimetry system and as routine dosimetry system: Red Perspex 4034, Amber 3042, Gamachrome YR, CTA, Gafchromic, FWT and TL dosimeters. The response of routine dosimeters are often influenced by changing dose rates, irradiation temperature, post irradiation time and also environmental conditions, then, studies and evaluations of these parameters are carried out so that the radiation absorbed dose by products may be precisely and accurately measured.

Ionizing radiation application on the treatment of liquid and solids residues and soil remediation

Since 1992 this group has been studying the feasibility to use the Advanced Oxidation Process by ionizing radiation on removing toxic and refractory pollutants (organic compounds) in industrial effluent, drinking water, solid wastes, and on destroying pathogenic microorganisms in wastewater, sludge and in historic documents. These studies are focused to become economically feasible the use of this technology in real industrial effluents that are recalcitrant when treated by conventional methods. As a consequence of pesticides used in agriculture, the human population is constantly exposed to numerous chemical species present in the environment. The Brazilian agriculture activities have consumed about 288,000 tons of pesticides per year conditioned in about 107,000,000 packing with a weight of approximately 23,000 tons. Brazilian Federal law states that the disposal responsibility of the pesticide packing is by attributed to the industry that has search for new technologies to recover and recycle the material. In order to evaluate the efficiency of radiation processing on removal of the pesticides contamination; high-density polyethylene (HDPE) packing were irradiated using Radiation Dynamics Electron Beam Accelerator with 1,5MeV energy and 37kW power and gamma rays. The radiation processing was efficient on removing the pesticides: methomyl, dimethoate, carbofuran, and methydathion, triazine, thiophos, atrazyne, endosulfan, chlorpyrifos, thriazophos), and trifluralin.

Figure 5. Irradiation of pesticides HDPE packing

In the Radiation Technology Center (CTR) there are two Industrial Electron Beam Accelerators of 97.5 kW (1.5MeV-65mA) and 37.5 kW (1.5MeV-25mA), supplied by IBA Industrial Inc. and two Cobalt-60 Irradiators - Gammacell (11,000Ci) and Panoramic (5,000Ci) designs. The Electron Beam Accelerator and Cobalt-60 Irradiators are mainly applied for research, development and services of preservation and disinfestation of food and agricultural products; treatment of industrial and domestic effluents, sludge and hospital waste; paints, varnishes, adhesives and coating cure; preservation of art works and books; radiosterilization of bones and human tissues; Brazilian gemstones enhancement; polymer grafting and modification; radiation processing of composite materials and natural polymers. The gamma rays (electromagnetic energy) and electron beam (EB) are very efficient agents for radiosterilization of medical, pharmaceutical and biological products due to high sensitivity of pathogenic bacteria to radiation. In 2007, 25,600 medical, pharmaceutical and biological products were radiosterilized and 107,000 semiconductors (diodes) were processed by ionizing radiation in these radioactive facilities. Annually, 1,200 km of wire and electric cables for chemical, automobile, aircraft and electro-electronic companies have been irradiated in the Industrial Electron Beam Accelerator. The radiation processing promotes crosslinking among the polymeric chains, increasing electrical, thermal, mechanical and chemical properties. The modernization of the installation promotes the elevation of wire and electric cables processing velocity to 300 m/min and polyethylene foams to 15 m/min, becoming the product prices more competitive in the Brazilian market.

Radiation processing applying industrial electron beam accelerators and gamma irradiators

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Sealed source production for gammagraphy and industrial process control

The gamma writing is an important non-destructive technique to analyze metallic components from small to large ones that need high performance and security in operation. The non-existence of internal failures is checked by gamma rays radiography, because of its great penetration characteristics that allows obtaining the photographic record of failures. This non-destructive analysis is used for quality control of welded components in chemical, nuclear and mechanical industries, such as pipelines, turbines, reservoirs and pressure vessels. According to the IAEA information, the petrochemical and chemical process industries are the mains users and beneficiaries of the radioisotope technology. Radioisotope techniques are very competitive and are largely applied for troubleshooting and process analysis of technically complex, continuously operating industrial plants. Due to this fact, the application of sealed sources becomes more diversified, including for gamma scanning of columns, vessels and pipes, level and interface detection. Since 1983, the Radiation Technology Center (CTR) has supplied industrial gamma sealed sources to more than 20 customers in Brazil and other countries in Latin America and Caribbean. Annually, the laboratory produces 240 sealed sources, with activities ranging from 740 GBq (20 Ci) to 4,444 GBq (120 Ci) of iridium-192 and from 0.37 GBq (10 mCi) to 18.49 GBq (500 mCi) of cobalt-60. The CTR has made several inspections in irradiators, command cables and guide pipes and also selenium sources loading services. These supplies allow taking more then 100,000 radiography per year. The principal CTR's customers are Arctest, ASNDT, Brasitest, CBC, Confab, End Test, Gamatron, Qualitec, Voigth, Tricom and Sertech.

Use of radioisotopes as tracers in the environmental and industrial process control

Radioactive tracer, bromine-82, and dye tracer, rhodamine WT, applications in grounded pipe flow rate measurements. Flow rate order of magnitude: 0,1 m^3/s up to 3,5 m^3/s. Radioactive tracer, iodine-131, applications for mean residence time determinations in tanks and digestors of domestic and industrial waste water treatment plants. Volume order of magnitude: 7,000 m^3 up to 12,000 m^3. This tracer application group took part in the practical activity on radioactive tracer application during the AIEA-ARCAL course held in Santos, S.P. Brazil, with the presence of 12 countries representatives under RLA 8/042 project. Period: October 1 to 5, 2007.

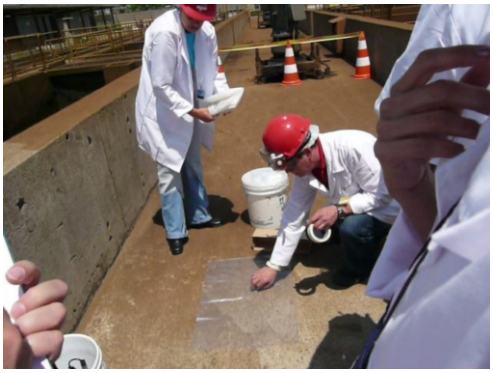

Figure 6. Procedures for radiotracer injection

Radiosterilization for tissue banks

In Latin America, the industrial level ionizing radiation sterilization is used for more than three decades, ever since, foods and medical, pharmaceutical and cosmetics products are treated. Later, this activity extended to the sterilization of human tissues for graft and this activity was reinforced in some countries by the technical cooperation and financial support of the International Agency of Atomic Energy - IAEA. Brazil was incorporated to this project in 1998 through the "Hospital das Clinicas" of Sao Paulo City, where the Tissue Bank was installed and the Institute for Energetic and Nuclear Researches, where the tissues are being irradiated. Most of the tissues transplanted, such as, skin, bone, amnion and other not viable tissues, can be treated with ionizing radiation to minimize the immunogenicity, to kill bacteria and to reduce the contagious diseases transferring risk. Besides implanting the irradiation services routine to the tissue banks of the country, the researchers developed irradiation devices for human tissues, implant dosimetry procedures for irradiation processes control, implant the quality warranty program for tissue irradiation, optimize type and dose to be supplied according to the preservation process of which the tissue was submitted, collaborate with the implementation of quality systems of the Tissue Banks and experimental and clinical applications of irradiated tissues. In the last few years, preserved tissue allograft, such as bone and skin, have been used in reconstructive surgery in many clinical disciplines, like orthopedic and plastic surgery. The risk of transmission of infectious diseases by allograft, however, is a constant concern. To this end, many steps should be taken, including tissue sterilization. Of the available sterilization techniques, the application of ionizing radiation deserves to be considered for its efficiency. Its deployment, nevertheless, is still contested since there is few data on its effects upon the tissue allograft. The skin glycerol preservation has a bacteriostatic effect after certain time. On the other hand, skin sterilization by ionizing radiation may reduces the quarantine period for transplantation in patients and their safety is considered excellent. At the CTR department, we established procedures using two sources of ionizing radiation for sterilization of human skin allograft, and to evaluate the skin after gamma and electron beam irradiation. Skin samples were submitted to doses of 25 kGy and 50 kGy. We evaluated the impact of the irradiation on the mechanical properties through the analysis of stress-strain and they were also accomplished by morphology and ultra-structure studies. Also in the current work, we have started de standardization of the tests that will be used for the characterization of irradiated bones. Initially, two types of analysis have been chosen: biomechanical and histological.

Development and production of radioactive sources for brachytherapy application

The number of prostate cancer cases in Brazil is increasing and only a small part of the patients are submitted to brachytherapy treatment using Iodine-125 radioactive seeds. Nowadays, these seeds are imported at a high cost, restricting this application. The local production of these radioactive sources became a priority in order to reduce the problems of prostate cancer management for end users. Such action will permit to spread the use to a larger number of patients. Due to such reasons, the Nuclear Energy Research Institute established a program, in order to produce Iodine-125 radioactive seeds. In brachytherapy, small seeds with Iodine-125, are implanted into the prostate to irradiate the tumor. The Iodine-125 seeds consist of a welded titanium capsule (diameter = 0.8mm e length = 4.5mm) containing Iodine-125 adsorbed onto a silver rod. During the project execution, the following methods were developed: the seed core (silver) cutting, the titanium tube cutting, the iodine immobilization through its deposition in silver substrate and the sealing of the seeds through welding process, so that the classification of the seeds, as sealed sources, and the leakage tests can be done according to the international norms. In the moment, the routine production line is settling up.

Irradiation facilities

Focusing the development of new irradiators and support the activities on radiation processing the following activities were performed:

- Conception design of a under water gamma irradiator dedicated for gemstones processing.

- Conception design of gamma irradiator and methodology of control for application of good manufacturing practices (GMP) on human blood processing to avoid the transfusion- associated graft-versus-host-disease (TA-GVHD).

- Gamma irradiation activities on samples for food preservation supporting 8 Research Institutions.

- Experiments on gamma processing for validation and routine control.

- Workshop in Petrolina : technical and economical aspects of mango irradiation (commercial scale).

- Training of fellowships from South America on radiation processing and design of irradiation facilities.

- Training of Radiation Protection Officer (06 students).

- Sterilization services (500m^3).

- Gemstone irradiation studies for dose definition.
- Art collection irradiation for decontamination of xylograph wood dye printings and manuscripts from cordel literature (6000 pieces).

Radiation detectors and industrial computed tomography

The evolution of the fundamental and applied research in the nuclear field is entailed to the development of new types of radiation detectors, which have determined different technological applications in several areas, such as, Nuclear Medicine, Industry, Agriculture, Environmental Science and Radiological Protection. Aiming to reach these goals, the following activities were carried out in the period covering the years 2005-2007:

Development of radioguided surgery probe
Intraoperative gamma probes have been widely used in surgery oriented to locate the sentinel lymph nodes in breast cancer and malignant melanoma during the surgery. Two surgical gamma probes were developed, being one with a CsI(Tl) crystal coupled to a PIN photodiode and another with o TlBr crystal as radiation detectors. The TlBr developed at IPEN was used, since the production of this crystal is in development stage and it is not yet commercially available. Both probes, TlBr and CsI(Tl), presented similar performance and met the necessary requirements to be used in radioguided surgery. At present, the probe prototypes are being evaluated concerning their clinical use by Escola Paulista de Medicina - UNIFESP and Hospital Albert Einstein.

Figure 7. Radioguided surgery probe

Study of the long term stability of the TIBr Semiconductor Detector
Thallium bromide is a very attractive compound semiconductor for applications as a room temperature radiation semiconductor detector. However, it is known that the lack of long term stability has limited the use of this kind of semiconductor detectors. The TlBr crystal is being developed at IPEN and, in addition to the improvement carried out in the purification and growth methodology, efforts have been concentrated to investigate the polarization effects and long-term stability of the TlBr crystal detectors. Besides, electronic systems and pulse-processing techniques are being investigated to improve the TlBr crystal detector performance. A good stability over 40 days measurements, carried out at room temperature without removing the bias voltage, was found. The characterized TlBr crystal as a detector has shown good response to gamma radiation and has great potential to be used as a semiconductor detector in radioguided surgery probes.

Development of an industrial computed tomography system for multiphase system
Today, the interest of a wide range of industries, such as chemical and oil sectors, in the use of computed tomography began to grow, for improving design, operation and troubleshooting of industrial processes. To follow this trend, the IPEN laboratory began a study for the development of the computed tomography methodology for multiphase systems. Two computed tomography (CT) systems were developed for industrial applications. The first one was a first generation CT, which use a 5.08 cm NaI(Tl) detector. The second was developed with a 40 cm bar scintillator detector, using two phototubes in its extremities in order to be used as a sensitive position detector. The data acquisition board, the mechanical control interface and the software were specially developed in our laboratory for this project. The tomography systems were tested using a phantom placed between the detector and a collimated ^{60}Co source. The phantom used was a standard polypropylene phantom designed and prepared by the University of Bergen, Norway, granted by the International Atomic Energy Agency. A good resolution was observed for all images reconstructed from the developed CT systems. The attenuation coefficient found for the different density materials used to fill the phantom holes are comparable to the theoretical values described in the literature for these materials.

Scintillator crystals applied in X-ray equipment for inspection in real time
For the industrial inspection and quality control, the artificial vision has appeared as a new and important technique that can provide accurate inspections in pieces, increasing the product quality significantly. The artificial vision has also been used as calibration tool during the production, to correct defective pieces generating processes. In this work, the feasibility of using the CsI (Tl) scintillator developed at IPEN, as a radiation sensor in the X-ray equipment has been studied, aiming its application in artificial vision of dynamic inspection systems for X- ray, with the cooperation of a Brazilian private company. This project has the The State of São Paulo Research Foundation support. This equipment will be used to detect undesirable elements (metals, stones, bones, plastics) in foodstuff and thus meeting the procedures of (a) Alimentary Safety and (b) Public Safety.

Use of a low cost pin photodiode for dosimetric purposes in radiation processing
The silicon PIN photodiode (SFH 00206) has been used as a rotine dosimeter for irradiation processes performed with a Gamma Cell facility in the Centro de Tecnologia das Radiações (CTR) at IPEN/CNEN-SP. Until now, the diode's response as a function of the gamma-ray doses is linear in the interval of 5 Gy to 100 Gy.

MCZ Diode Response as a high-dose gamma radiation dosimeter
A high-resistivity Magnetic Czochralski (MCz) silicon diode processed at the Helsinki Institute of Physics has been successfully used as a high-dose gamma dosimeter in radiation processing, within total doses from 100 Gy up to 3 kGy at a dose rate of 3 kGy/h. In this interval, the dosimetric response of the diode is linear.

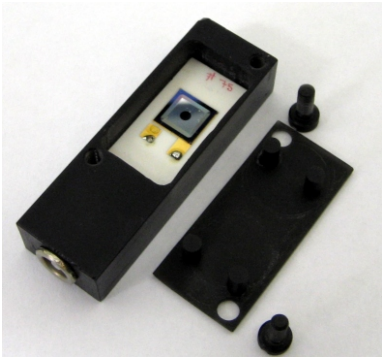

Figure 8. Magnetic Czochralski (MCz) diode

Measurements of electron transport parameters in avalanche regime
The goal of this work is to measure the first Townsend coefficient and the electron drift velocity in high uniform electric fields. The heart of the chamber is an RPC like cell with a bulk aluminium anode and a glass cathode. The signal is readout with a fast digitizing oscilloscope to record the fast signal induced by the electron movement in the thin gas gap. A first set of data with nitrogen and isobutane was collected as part of project FAPESP 02/04697-1.

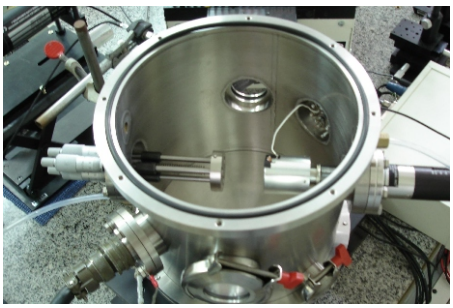

Figure 9. RPC like cell with a bulk aluminium anode and a glass cathode

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