Gamma-ray Irradiations at the Penn State Radiation Science and Engineering Center

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Service Provided: Gammacell® Irradiator, ^{60}Co Pool

Sponsors: Numerous federal, state, and industrial organizations

Introduction

Gamma-rays from radioactive cobalt-60 are used for a wide variety of applications in many research areas such as sterilization, cryo-reduction, genetic changes, and radiation effects on biological systems, electronics or materials. In addition, gamma-rays cause chemical and/or material changes such as radiolysis, electron trapping, chemical bond changes, cross-linking and polymerization. The RSEC gamma-ray irradiation facilities are used by a diverse number of Penn State researchers including: 5 Colleges, 21 departments and 3 Centers. In addition, numerous outside universities, government agencies, and industries use these experimental facilities.

Sterilization of Materials

Gamma-rays are used to sterilize many medical, pharmaceutical, and consumer products. The gamma-rays penetrate through the packaging, killing the germs inside, but do not make the material radioactive. Many researchers at Penn State who can't use heat or chemicals to sterilize their materials for research use this technique. Penn State researchers sterilize bio-reactors for cancer research, carnation leaf pieces for Fusarium research, pollen and royal jelly for honey bee Colony Collapse Disorder, orthopedic implant material, and matrix material for soil research and environmental engineering studies. A detailed example of this kind of application is included in this book; some other related projects performed at the RSEC include:

- Sterilization of pollen and royal jelly for honey bee research related to colony collapse disorder
- Characterization of the tissue-electrode interface based on electrophysiology, histology, and magnetic resonance imaging
- Compartmentalized bio-reactors for cell cultures
- Evaluation of Fe(II) oxidation at an acid mine drainage site using laboratory-scale reactors
- Role of 15-lipoxygenase in the pathogenesis of artherosclerosis
- Sterilization of biotite materials for research: oxidation of Fe(II) in biotite by a mixed community from a granodiorite weathering front, Rio Icacos Watershed, Puerto Rico

FIGURE 1: The RSEC gamma-ray irradiation facilities have been used to help study the causes of honey bee colony collapse disorder

- The potential for feedbacks between fire and soil fungi and in pyrogenic environments

Chemistry and Bio-molecular Biology

Cryo-reduction, or the exposure proteins or metallo-enzymes to gamma-ray radiation while at cryogenic temperatures (77 K), offers significant information about biochemical mechanisms that are important in substances ranging from antibiotics to industrial process materials. A detailed summary of this work is included in this book.

Chemical and Molecular Changes

As radiation passes through materials and deposits energy, electrons can be shifted to a higher energy state, or removed from the atom entirely, causing ionization. This effect can produce a number of different characteristics depending on the chemical structure. Gamma-rays can break chemical bonds, cross-link large chain molecules, and change material properties such as elasticity, brittleness, and color. Gamma-rays can also cause polymerization or decomposition of large-chain molecules. Experiments of this kind performed at the RSEC include:

- Irradiation to mitigate the acute and indirect effects of high varroacide residues on honey bees
- Radiolytic synthesis of silver nanoparticles in Nafion membranes

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- Cross-linkage of polymers for electrolyte research
- Development of proton conducting members for Fuel Cell applications,
- Polymerization of sugar and amino acid surfactants using gamma-ray radiation.

Radiation Effects on Electronic Materials and Space Applications

For over 40 years the RSEC has provided gamma-ray irradiation testing and services on electronics, components, and materials for radiation environments such as outer space, the nuclear power industry, and other nuclear applications. The projects range from basic research into mechanisms of radiation interactions to qualifying components or materials for specific applications. The facilities can accommodate monitoring of components during irradiation to study effects in-situ. Some examples of work performed at the RSEC are:

- Piezoelectric crystals and radiation effects
- Study of charge-trapping characteristics of HfO_2/Si
- Radiation Hard Thin film Zn-O transistors
- Study of atomic-scale effects of gamma-irradiation in microelectronic materials
- Graphene–oxide radiation sensitivity
- Enhanced low-dose-rate sensitivity (ELDRS) testing
- Radiation detector testing

Genetic Changes

Mutations occur naturally and spontaneously in approximately one out of a million events. Radiation exposure can increase this probability to one in ten thousand, thus seeds, plants, nematodes and cells can be subjected to a radiation environment for the purpose of inducing mutations for study. This means that researchers need far fewer plants in order to have a significant number of mutations. As an example, 91.4% of plant mutations that have been commercially developed have been produced by irradiation, while 7.5% were produced by treatment with mutagenic chemicals. A number of biological mutations have been studied using the gamma-ray resources at the RSEC, including:

- Irradiation of African violets for Dr. Richard Craig and poinsettias to produce different color varieties
- Creation of a strain of *C. elegans* with a transgene integrated on a chromosome for the Department of Biochemistry and Biomolecular Biology
- Quantification of protective compounds induced in response to the irradiation and the role of plant pigment properties for the PSU Agronomy program

FIGURE 2: African violets created from gamma-ray induced mutations

Cosmochemistry

Cosmochemistry research focuses on chemical processes relating to the solar system. A new research project with NASA Goddard was conducted using the Gamma-ray Irradiation facility while the samples were kept in a frozen state, investigating the destruction of the organic matter and isotopic changes in the surface of Martian rocks due to irradiation by simulated cosmic rays.