Applied Radiation and Isotopes 161 (2020) 109168

Contents lists available at ScienceDirect

Applied Radiation and Isotopes

journal homepage: http://www.elsevier.com/locate/apradiso

Sub kGy photon irradiation alterations in graphite

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ARTICLE INFO

Keywords:
Luminescence
Polymer pencil-lead graphite
Trapping parameter
Photoluminescence spectroscopy
X-ray diffraction

ABSTRACT

Present work concerns polymer pencil-lead graphite (PPLG) and the potential use of these in elucidating irradiation-driven structural alterations. The study provides detailed analysis of radiation-induced structural interaction changes and the associated luminescence that originates from the energy absorption. Thermally stimulated emission from the different occupied defect energy levels reflects the received radiation dose, different for the different diameter PPLGs. The PPLG samples have been exposed to photon irradiation, specifically x-ray doses ranging from 1 to 10 Gy, extended to 30–200 Gy through use of a ^{60}Co gamma-ray source. Trapping parameters such as order of kinetics, activation energy and frequency factor are estimated using Chen's peak-shape method for a fixed-dose of 30 Gy. X-ray diffractometry was used to characterize the crystal structure of the PPLG, the aim being to identify the degree of structural order, atomic spacing and lattice constants of the various irradiated PPLG samples. The mean atomic spacing and degree of structural order for the different diameter PPLG are found to be 0.3332 nm and 26.6° respectively. Photoluminescence spectra from PPLG arising from diode laser excitation at 532 nm consist of two adjacent peaks, 602 nm (absorption) and 1074 nm (emission), with mean energy band gap values within the range 1.113–1.133 eV.

1. Introduction

Over the past 90 years and more the various effects of ionizing radiation have been well documented, typically in regard to deterministic and stochastic biological risks and mostly at sub-Gy levels, notably in as much as these concerns reach the public eye. From as long ago as 50 years, irradiations of mammalian tissues have been associated with DNA alterations, not least cancer and genetic mutation stochastics (Hall and Giaccia, 2006). Less well publicized have been the very large efforts, daily carried out, on the development of high-strength highly resilient composite materials via in particular irradiation-promoted cross-linking at tens through to hundreds of kGy, delivered using gamma-ray and accelerated electron sources. With benefits versus risk now being well appreciated and under highly controlled conditions, a wide-range of safe technology applications have evolved, not just in medicine but also in industry, nuclear energy and radiation source utilization included. In regard to the study of structural integrity, major efforts have been made towards the development of lighter materials of greater strength, carbon fibre technology being one such area of thrust, including the carbon fibres used in radiotherapy suite treatment couches, aircraft wings etc. In regard to graphitic materials, the focus of current interest, much less studied have been the possible post-production signs of relatively low dose (sub kGy) irradiation-promoted alterations in the materials. This differentiates present work from the extensive studies that have been carried out on MGy neutron dose material degradations in the graphite moderators of nuclear reactors, impacting on performance and the life-cycle of these media. However, thus said, for dose effects on carbon fibres see for instance Sharp and Burnay (1974).

Key to such irradiated material studies, whether they be in regard to low or high dose, is the ability to evaluate radiation dose, dosimeters and dose simulations playing key roles in radiation protection monitoring and quality control. In present work using external beam x-ray facilities of note is that the doses from these are known through use of ionisation chambers. An acknowledged aside is a potential for dosimetric material performance alteration in long-term use of the graphite-based ion chambers, commonly applied as noted in control of irradiation dose delivery.

With these opening statements, present work concerns the structural

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https://doi.org/10.1016/j.apradiso.2020.109168
Received 24 December 2019; Accepted 27 March 2020
Available online 2 April 2020
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