Validation of alanine dosimeter measurement using electron paramagnetic resonance spectroscopy

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1. Introduction

Alanine dose measurement using electron paramagnetic resonance technique is widely recognized as one of the most accurate methods for high-dose radiation, and the use of the Alanine/EPR system is recommended as one of the evaluation methods for high-dose radiation through IAEA TECDOC-1188. [1].

The EPR dosimetry allows to obtain information on the dose of irradiation of a material by measuring the concentration of free radicals produced by ionizing radiations. Alanine EPR dosimetry has many advantages such as the linearity of the EPR response in a wide range of doses, the high stability of the radiation induced free radicals under normal conditions, tissue-equivalence for photon beams, ruggedness and ease of handling, low cost for individual dosimeter samples, sufficiently small size for use in mapping radiation dose distribution. [2].

Validation is performed to accurately measure the dose of alanine dosimeter, comply with international standards, ensure reliability and reduce measurement errors, and use alanine dosimeter effectively.

In this study, the effectiveness of alanine dosimetry was verified using electron paramagnetic resonance spectroscopy. Dose response curves from 1Gy-10Gy were produced, and linearity, precision, and accuracy were evaluated..

2. Methods and Results

2.1 Alanine dosimeter

The alanine dosimeter utilizes the property of alanine, which generates free radicals when exposed to radiation. The dose is calculated by measuring the amount of free radicals generated in proportion to the radiation dose through electron paramagnetic resonance (EPR) analysis. Alanine Pellet reference dosimeters were requested to be irradiated by Aerial Laboratory, an internationally recognized calibration laboratory. The dose to water absorbed by the dosimeter is determined with Aerial laboratory ion chamber transfer dosimetry system according to ISO/ASTM 51261: *"Practice for calibration of routine dosimetry systems for radiation processing"*. Dosimeters are irradiated with 7MV X-rays at a calibrated absorbed dose to water rate. Four Alanine pellets are irradiated at the same dose rate. The delivered dose is adjusted by varying the exposure time of the alanine dosimeters to X-rays

2.2 electron paramagnetic resonance (EPR)

The EPR measurements were performed using a Bruker EleXsys E500 X-band spectrometer. The Alanine pellets were evaluated individually, with each having a single orientation while being held in a quartz tube with a sample support system for reproducible positioning in the cavity. The dose-dependent parameter of the sample spectrum of the Alanine pellet was evaluated as the vertical peak-to-peak intensity of the dominant peak.

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2.3 Validation

Method validation was measured based on ISO 51607 (2013) "Practice for use of the alanine-EPR dosimetry system" [3] and "Guidelines for validation of test methods for pharmaceuticals, etc." (MFDS, 2015). The validation of the alanine dosimeter evaluated linearity, precision, and accuracy, and calculated the limit of detection (LOD) and limit of quantitation (LOQ) through the slope and standard deviation obtained through linearity verification.

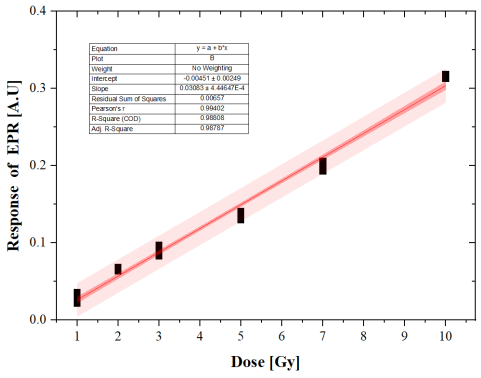

Figure 1. EPR dose-response curve of Alanine dosimeter. The response is linear from 1 to 10 Gy

Linearity: The linearity of the dose response curve was evaluated after 10 repeated measurements with the irradiated alanine dosimeter. As the dose increased from 1 to 10 Gy, the EPR signal increased in proportion to the dose. The dose-response curve for the peak-to-peak EPR signal intensity with the increasing dose is shown in Figure 1. The dose-response curve showed a coefficient of determination, R^2, of over 0.988 when calculated using the linear fitting equation.

Precision: Four dosimeters irradiated with the same radiation were repeatedly measured, and precision was judged by the relative standard deviation (RSD%), which was obtained by dividing the standard deviation of each result by the average of the results.

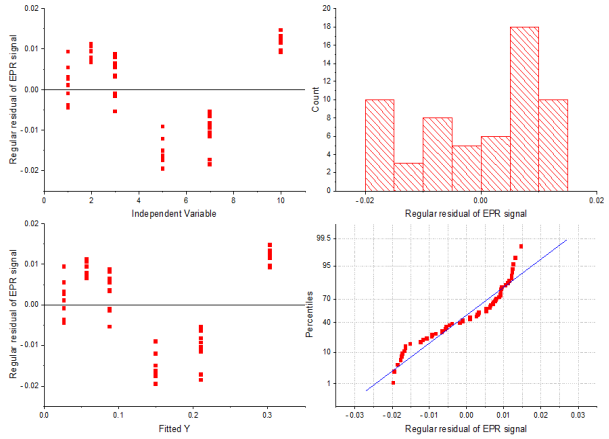

Figure 2. Alanine dosimeter measurement precision evaluation

Accuracy: Accuracy is based on measurements and known standard values. As a method of checking how close the actual measured value was to the theoretical value, the measured value was repeated three times and then an evaluation of the actual measured value and theoretical value was performed.

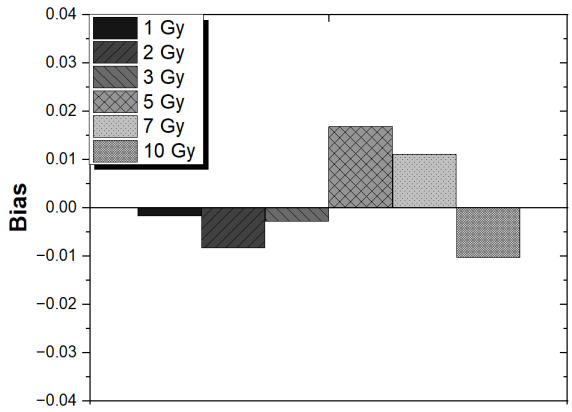

Figure 3. Alanine Dosimeter Bias Results

Detection limit and quantification limit: Detection limit refers to the minimum detectable amount of the analyte present in the sample. Quantitation limit refers to the minimum amount of an analyte in a sample that can be expressed as a quantitative value with appropriate precision and accuracy.

As a result, a calibration curve was created and the slope and y-intercept of the calibration curve were calculated. The detection limit and quantitation limit were calculated using a method based on the standard deviation of the response of y-intercepts and the slope.

The detection limit of the alanine dosimeter was calculated to be 0.66 Gy, and the calibration limit was calculated to be 2.01 Gy.

3. Conclusions

Validation was performed to establish measurement reliability and measurement procedures of the alanine dosimeter using electron paramagnetic resonance spectroscopy. The validation of the analysis method confirmed linearity, accuracy, and precision, and the measurement results will be used as basic data that can contribute to the development of standard measurement procedures for standard radiation-irradiated alanine dosimeters. Additionally, measurement uncertainty will be evaluated to ensure measurement reliability.

Acknowledgment

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