CR-39 Based α Spectroscopy for Internal Radiation Dosimetry

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Introduction

Internal Radiation Dose formalism, derived from the equation of continuity, is one of the formalisms for interpreting radiation stress corrosions in critical systems, radiotherapy using α emitting isotopes etc. Implementation of this formalism requires the measurement of α spectrum at the points of interest[2]. This is challenging for practical situations as the source is spread in the medium. This is the situation for the α therapy and molten salt type critical systems. The spectroscopy using an active detector has limitations, as it cannot be used in a liquid medium. Further,it doesn't obey the radiation equilibrium requirement for dosimetry, as they are sensitive to direction. The other passive methods like radiochromic films are not linearly sensitive to the dose for alphas, and cannot produce the energy specific information corresponding to each event.

Conventional passive detectors are not often used for studying alpha particles in this environment, especially when the source is in the form of a liquid. This is due to the formation of unreal tracks, by improper etching, cosmic ray events, track detector aberrations,etc. These will produce a significant level of wrong biasing and resolution broadening in the measurements. The present work introduces the development of the alpha spectroscopy method with CR-39 solid state nuclear track detector (SSNTD), by removing the unreal tracks and aberrations. The α spectrum resolving capability of CR-39 has been investigated in this study, by introducing the computational tool for analyzing the track profiles. The CR-39 is immersed in the liquid source, which measures the alpha spectrum at the point of interest, by satisfying radiation equilibrium, to explore the capability of measuring the α spectrum in a liquid medium. The Measured spectrum has been compared with Geant4 simulated α spectrum for the alike contribution, for validation. The details are presented in the following sections.

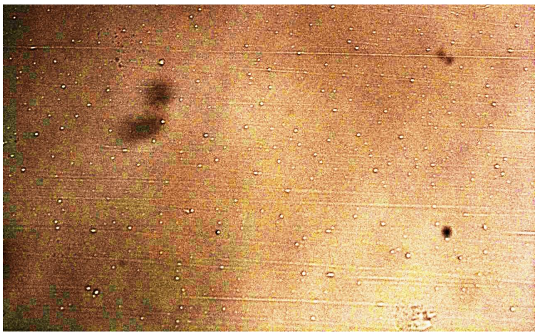

Figure 1: *Figure show perticular image of alpha tracks for 5.48 mev alphas*

Materials and Methods

250 μm thick CR-39 film were calibrated by measuring the track diameter- energy response function. The CR-39 SSNTD were exposed to 5.48,4.87,4.28 MeV alphas generated using ^{241}Am radioactive source, followed by Mylar degradation. The irradiated films were chemically etched with 6N NaoH solution, kept at 60 °and for a etching time of 4 hours, under continuous stirring. The etched film were imaged using optical microscope under 40x magnification. The α tracks on CR-39 is illustrated in figure1. The obtained images, then analysed by fitting hough transform followed by elliptical paraboloid, which returns the major and minor axis of the elliptical tracks. The average diameter (equivalent circular diameter) of the elliptical track has been estimated. A track diameter - brightness (corresponding to the depth of

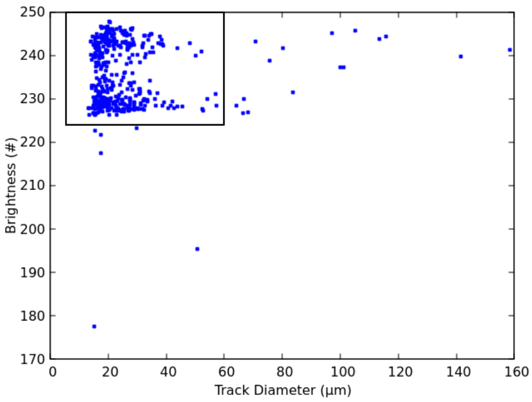

Figure 2: *Track Diameter - Brightness correlation with gate for the real events*

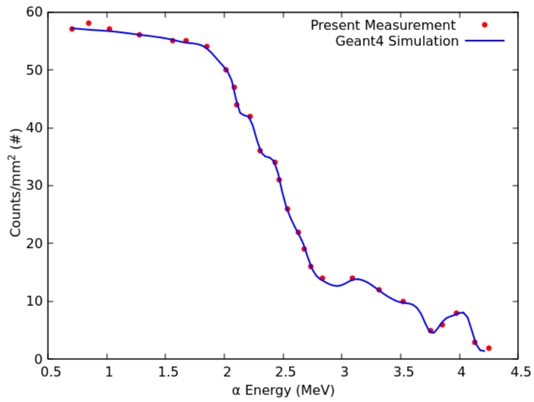

Figure 3: *The energy spectrum of the alpha particle reaching on CR 39 corresponding to the lattice of interest and the Geant4 Simulated spectrum*

the track) correlation has been generated and the real track events were gated by removing the aberrations and unreal tracks. The typical track diameter-energy correlation with gate for real α tracks are illustrated in figure 1. The gated area is projected on diameter axis. The centroid of histogram is estimated through Gaussian fitting and the diameter energy plot has been constructed. This has been fitted with quadratic polynomial for reproducing the calibration function.

A Thorium Nitrate solution has been prepared upto a volume of 10 ml under saturated condition.The CR-39 films are placed in the center of the solution to achieve the charge particle equilibrium condition. This films has been exposed for a time duration of 2 hours and etched for 4 hours under the same condition used the calibration .The optical images has been taken under 40x magnification and the tracks were analyzed using the TRIAC[1]. Tracks were fitted using the brightness v/s track diameter correlation by appropriate gating. The gated events were binned in to histogram based on the tracks diameter and calibrated using previously obtained calibration function, which produces the energy spectrum of alphas at the points of interest. Further a Geant4 Simulation is performed for the same condition to validate the experimentally observed α spectrum. The simulated spectrum is then compared to the experimental results.

RESULTS AND DISCUSSION

From the track diameter-brightness correlations, illustrated in figure 2, it is clear that the α tracks are well isolated from the patches produced by the aberrations and other cosmic ray interactions. This provides an accurate event selection for the spectroscopy. The current method is providing an energy resolution of 250 keV FWHM corresponding to 5.54 MeV α peak from ^{241}Am alpha source. The currently measured alpha spectrum at the center of the thorium nitrate solution along with Geant4 simulation is shown in figure 3. This shows the 4.04 MeV α peak is well resolved and the continuum transition of α in the flood medium is well identified. Further the Geant4 simulation is also showing a well agreement with the current measurement. This shows the current spectroscopy method provides an accurate spectral information and is well acceptable for the internal dosimetry, which can be applied in the fields of medical, and other radiation-critical situations.

REFERENCES

[1] Rajesh K R et al., AIP Conference Proceedings , 2100,020137 (2019).

[2] Allen, Barry J et al Clinical trials of targeted alpha therapy for cancer,3,185 (2018)