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Performance Prediction of Coincidence-based Prompt Gamma Activation Imaging System using Geant4 Monte Carlo Toolkit

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The prompt gamma activation imaging (PGAI) using the neutron beam has been used in archeology and cultural heritage researches to obtain the two- or three-dimensional elemental distribution of the volumetric sample. To measure the high-energy prompt gammas emitted by the neutron induced nuclear interactions with the sample, a simple measurement system, which consists of an HPGe detector, a single-slit collimator and a scanning system, have been used. Although the measurement system can visualize the elemental distribution of the sample, it required a time-consuming process to scan the sample.

For the practical use of PGAI, a new imaging system, which determines the 2D elemental distribution of the bulk sample by using the coincidence logic, was proposed. The imaging system consists of a calorimeter for the element identification by measuring the energy and a position sensitive detector coupled with a parallel-hole collimator for the position determination. To visualize the 2D distribution, the imaging system selectively measure the coincident events where prompt gammas emitted by one nuclear interaction interact simultaneously with the calorimeter and the position sensitive detector. In the imaging system, one detector is located at the opposite site of the other detector, and the sample is placed at the center of both detectors.

To estimate the feasibility of the proposed imaging system, in the present study, we performed the Monte Carlo simulation using the Geant4 toolkit for the rectangular iron plate implanted with the nickel. To improve the computational speed, the simulation was separated by two parts. First, we calculated prompt gammas emitted by the nuclear interactions between the neutrons and each sample including the number of generated photons and each energy information. After that, for the detector setup of PGAI, the prompt gammas were generated in the sample by using this information, and the coincidence events was recorded. The emission positions were randomly determined by considering the emission yield of prompt gammas for each element, and the emission angles were also randomly sampled. For the coincidence events, we can identify the characteristic gamma-rays'peaks for the iron (352, 7631 and 7645 keV) and the nickel (465, 8533 and 8998 keV). With the energy gate of 460-470, 8528-8538 and 8993-9003 keV for the calrolimeter, we also recognized the shape of implanted nickel from the 2D image obtained by the imaging system. Base on the results, we expects that the proposed imaging system can be utilized in the elemental analysis of volumetric samples by measuring the prompt gammas.

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