Simulation of Neutron-Induced Prompt Gamma-ray Spectra Emitted from Fake Tungsten Gold Bar

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1. Introduction

Fake gold bars on the market cannot be identified easily without testing because they have the same appearance as a pure gold bar. A non-destructive monitoring method is needed to avoid the trading of fake gold bars on the market. The ultimate goal of this study is to find a fake gold bar detection method using a PGAA (Prompt Gamma Activation Analysis). As a pilot study, the neutron fluence distribution in pure and fake gold bars when thermal and cold neutron beam is irradiated respectively is already calculated [1]. Using existing data, the number of neutron capture for gold and tungsten in fake tungsten gold bar was calculated and a Monte Carlo simulation for the prompt neutron-induced gamma-ray spectra was conducted.

2. Materials & Methods

2.1 Neutron beams from HANARO reactor

The HANARO reactor provides thermal neutron beams with a high flux (5×10^{14}) for characterizing the composition and structure of the target substance. To enhance the utilization capacity of the HANARO reactor, a cold neutron research facility has been developed since 2003, and CONAS (Cold Neutron Activation Station) has been constructed for various applications of cold neutrons [2]. The CN-PGAA (Cold Neutron Prompt Gamma Activation Analysis) facility as one of CONAS component provides cold neutron beams and measurement systems for analysis study.

2.2 Modelling the fake gold bar

The kilo-bar is the most common standard gold bar, measures about $60 \times 110 \times 8$ mm^3. The minimum purity of a standard gold bar is 99.5% gold. However, a fake gold bar is commonly made by filling the bar inside with other substances, particularly tungsten, which has a density (19.3 g/cm^3) nearly the same as gold (19.25 g/cm^3) but with a cheaper price [3]. In this study, tungsten was selected as a representative fake candidate and the common standard size of gold bar was considered for assuming a case of fake gold bar. The fake tungsten gold bar was modeled to be a 6-mm-thick tungsten bar plated with 1 mm of gold.

2.3 Monte Carlo simulation

To calculate the neutron-induced prompt gamma-ray spectra, transportation of photons from gold bar through the surrounding media to the detector was conducted using the Monte Carlo N-particle extended code, MCNPX, which enables one to simulate the transport of neutrons, photons, and electrons in a medium and to define the three-dimensional geometries in an arbitrary way [4]. The photon source for MCNPX input was determined by the number of (n, γ) reactions in gold bar. The existing neutron fluence spectra were multiplied by the number density and the energy dependent (n, γ) cross sections for gold and tungsten in fake tungsten gold bar volume to determine the number of (n, γ) reactions. The energy dependent (n, γ) cross section data for gold and tungsten from the publication database of IAEA (Vienna: International Atomic Energy Agency, 2006) was used [5]. All calculations were carried out using 10^6 particle histories resulting in target relative error R less than 1 %. Relative error R is usually used as a parameter to stop the run, R less than 1 % signify the calculation is reliable.

3. Results

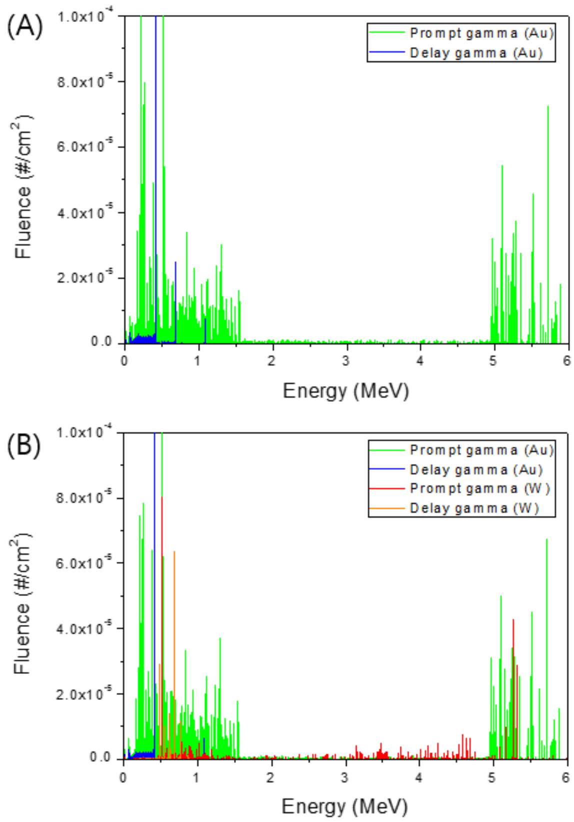

Fig.1 The cold neutron induced prompt and delay gamma-ray spectra simulated by MCNPX code for (A) pure and (B) fake gold bar.

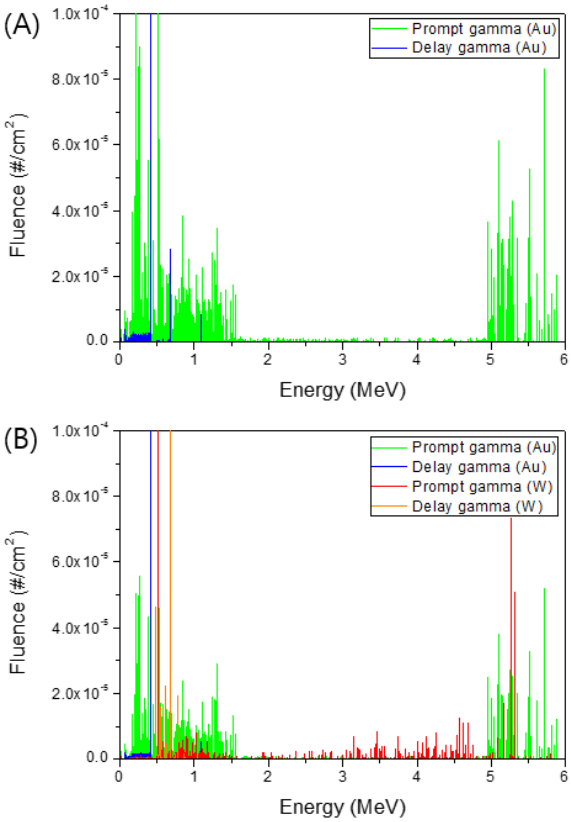

Fig.2 The thermal neutron induced prompt and delay gamma-ray spectra simulated by MCNPX code for (A) pure and (B) fake gold bar.

Each thermal and cold neutron induced prompt gamma-ray spectra emitted from pure and fake gold bars are showed in fig. 1 and fig.2 respectively. The neutron induced prompt gamma-ray spectra of a fake gold bar is obviously different from that of a pure gold bar. Overall, the flux of prompt gamma-rays emitted from the gold of a fake gold bar is lower than that of a pure gold bar. In the 3 to 6 MeV gamma-ray energy region, the prompt gamma-rays emitted from the tungsten of a fake gold bar are observed independently, and in particular, two gamma-ray peaks with a high flux (5.26 and 5.32 MeV) appeared very clearly.

These high energy gamma-rays of the thermal neutron induced prompt gamma-ray spectra for fake gold bar (red line in fig.1 and 2) are more than those of the cold neutron induced prompt gamma-ray spectra for fake gold bar. But the low energy gamma-rays from tungsten are not different between fig.1 and fig.2 in the 0.5 to 1 MeV energy region. Because the transmissivity of thermal neutron is higher than that of cold neutron, the tungsten in the fake gold bar is much more activated by thermal neutron [1]. Most of the low energy gamma-rays emitted from tungsten are self-attenuated, but the high energy gamma-rays are transmitted relatively well. The attenuation rates depending on emission distance for prompt gamma-rays emitted from gold and tungsten are represented in fig.3.

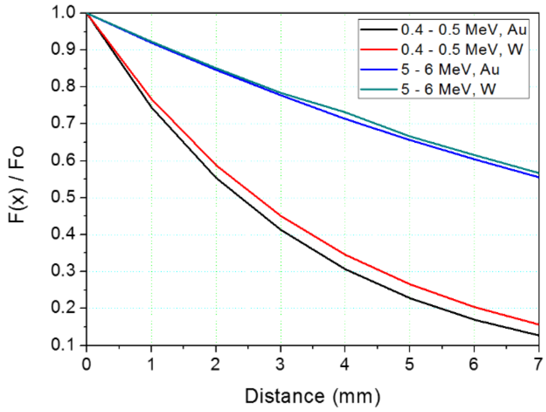

Fig.3 Attenuation rate depending on emission distance for prompt gamma-rays emitted from gold (Au) or tungsten (W).

4. Conclusion

A simulation for neutron-induced prompt gamma-rays spectra when a neutron beam is irradiated onto pure and fake gold bars was successfully conducted. Through a comparison between the prompt gamma-ray spectra of the pure gold bar and those of the fake gold bar, it was concluded that the observation of prompt high-energy gamma-rays from tungsten or a reduction of prompt gamma-rays from gold can be evidence of a fake gold bar. The possibility for detecting a fake gold bar using a PGAA facility was verified.

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