ACTIVITY MEASUREMENT OF THE GOLD FOIL ACTIVATED BY THERMAL NEUTRONS USING NAI BOREHOLE DETECTOR AND ITS EFFICIENCY DETERMINATION USING GEANT4 MODELLING

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The radioactivity measurement for gold foil irradiated by thermal neutrons was performed using NaI borehole detector. The measurement efficiency was determined by GEATN4 modelling which is about 93 % of 15 keV threshold. The verification of GEANT modelling was carried out with point sources certified by KRISS reference ion chamber. The measurement uncertainty of radioactivity of gold foil is about 0.5 % which is enough for the neutron fluence determination.

I. INTRODUCTION

Gold foil activation method is one of the popular techniques to determine the neutron fluence of thermal neutron field. The saturated activity of gold foil activated in the thermal neutron field can provide the thermal neutron fluence after the various calculations and corrections.(Ref. 1) The activity of ^{198}Au in gold foil can be measured in the various ways, gamma detection with NaI borehole detector or 4πβ counting calibrated by 4πβ-γ coincidence counting method, or 4πβ-γ coincidence counting directly.(Ref. 2)

KRISS has recently constructed the thermal neutron field, the thermal neutron fluence of which is about 2300 n/cm^2/s. We adopted the gold foil activation method to determine the neutron fluence rate and NaI borehole detector system was constructed to determine the activity of gold foil.

In order to determine the radioactivity using NaI borehole detector, its counting efficiency should be evaluated or calibrated. The gold foil whose activity is measured by 4πβ-γ coincidence counting method can be used for the efficiency calibration of the detector. 4πβ-γ coincidence counting method is well established method for the absolute measurement of radioactivity. However, its procedure is quite complicated and there should be some serious modification of detection system. Also, the activity should be high enough because of the low efficiency and the limited time due to the short half-life.

In order to avoid these difficulties, we have evaluated the counting efficiency of NaI borehole detector using GEANT4 simulation instead of calibration and determined the radioactivity of gold foil.

II. ACTIVITY DETERMINATION OF GOLD FOIL WITH NAI BOREHOLE DETECTOR

We modelled NaI borehole detector using GEANT4.(Ref. 3) We included the full geometries and materials as many as possible, like NaI crystal, reflector, casing, glue, and quartz window for PMT attachment which are all supplied by the manufacturer. The gold foil geometry and the density were measured and included in the modelling. The radioisotope of ^{198}Au is assumed to be uniformly distributed inside gold foil and decayed through beta minus transitions to ^{198}Hg. That is, the full decay processes of ^{198}Au to the ground state of ^{198}Hg is simulated including gamma emission from the excited state of ^{198}Hg and also the X-ray emissions and internal conversions.

The energy calibration and the energy resolution determination of NaI detector have been done with mixed gamma sources from about 25 keV (X-rays from ^{113}Sn) to 1173 keV (gammas from ^{60}Co). The counting efficiency determined by GEANT4 modelling is about 93 % with the counting threshold of about 15 keV. The exact values are depending on each measurement geometries and radionuclides.

In order to verify the modelling, we used the point sources whose activities were certified with reference ion chamber measurement at KRISS. ^{65}Zn, ^{113}Sn, and ^{137}Cs were chosen because of its gamma energies. The same

procedures with foil measurement including efficiency calibration (GENAT4 modelling) and gamma measurement were applied and the final radio-activities are consistent with the certified values within measurement uncertainty.

We used two gold foils. The diameters are both 2 cm and the thicknesses are 25 μm and 50μm each. For the neutron fluence measurements, 50 μm thick foil is usually used. But to check the thickness dependence due to the high density of ^{198}Au, we tried two different thicknesses.

The measurement uncertainty of radioactivity could be about 0.5 % which is enough to the thermal neutron fluence measurement. The measurement comparison with 4πβ counting method which is calibrated by 4πβ-γ coincidence counting method was also performed and consistent with each other.

III. CONCLUSIONS

The radioactivity of ^{198}Au inside gold foil produced in the thermal neutron field was determined by NaI borehole detector. The detection efficiency of detector was calculated using GEANT4 modelling. The verification of the procedure has been performed using point source with certified radioactivity and the value of radioactivities are consistent within measurement uncertainties. The comparison with 4πβ counting method which is calibrated by 4πβ-γ coincidence counting method is planned was also performed and consistent with each other.

The procedure for the efficiency calculation of NaI borehole detector using GEANT4 codes and for the radioactivity measurement using NaI borehole detector are well established.

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