Measurement Technology for Primary Fission Products

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Abstract: The measurement of primary fission products is very important for the research on fission yields and the fission phenomena. It is necessary to jointly measure the mass, charge and kinetic energy of fission product. This paper mainly introduces the following four aspects: 1) Research on time-of-flight measurement of primary fission products; 2) Developing a Frisch-grid ionization chamber with silicon nitride film for measuring kinetic energy E_k of primary fission products; 3) Using the ^{252}Cf spontaneous fission source to verify the method of measuring the mass distribution of primary fission products; 4) Study on the charge measurement of the primary fission products based on its specific energy losses.

Keywords: Primary fission products, time-of-flight measurement, Frisch-grid ionization chamber, silicon nitride film, ^{252}Cf spontaneous fission, mass distribution, specific energy losses

1. Introduction

There are many programs aimed to investigate the neutron-induced fission, such as VERDI (IRMM) [1-3] and SPIDER (LANL)[4]. Those investigations are very important for inferring the independent yield of fission yield, prompt neutron and fission model about the neutron-induced fission of uranium and plutonium. But now the resolution of flight time and energy are dissatisfactory, and the charge of primary fission products cannot be measured feasible. So this paper will try to measure the charge of primary fission products using the specific energy losses obtained by the Frisch-grid ionization chamber.

2. Experimental

Measurement of primary fission product requires measuring mass, kinetic energy and charge simultaneously. The mass is acquired from the flight time and kinetic energy. The flight time is measured by a couple of time pick-up detectors. The kinetic energy is measured by a Frisch-grid ionization chamber with silicon nitride film. And the charge is measured based on specific energy losses of primary fission product.

A schematic representation of the experimental arrangement is shown in Fig. 1. Two secondary electron detectors [5, 6] are used as time pick-up detector pairs for time of flight measurement. Particle trajectories on the order of 775 mm are determined accurately within 0.5 mm.

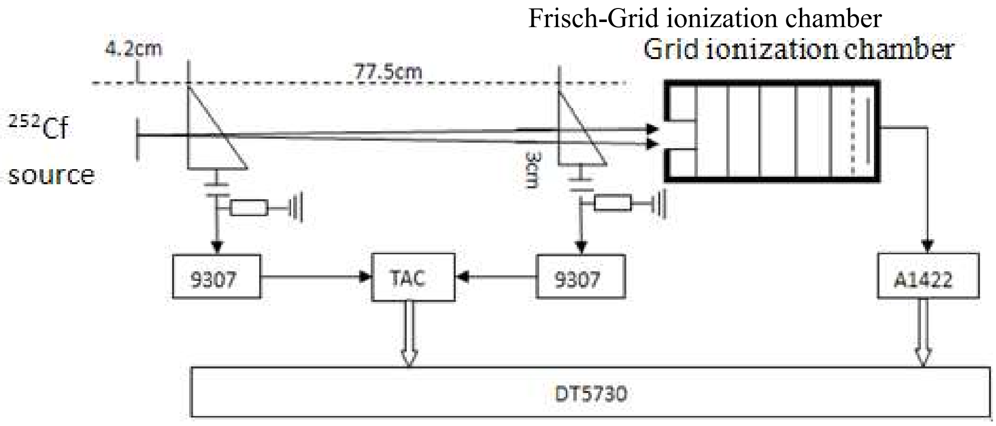

FIG.1. A schematic representation of the experimental arrangement.

Each secondary electrons detector module is comprised of thin electron conversion foil, electrostatic mirror, micro-channel plates. Based on the simulation of the secondary electrons flight time and path in the detector, a secondary electrons detector was designed and its parameters such as the interval of mirror grids, the acceleration voltage and the deflection voltage had been optimized. The performance of the secondary electrons detector was tested by using a ^{241}Am α source. The FWHM of flight time spectrum was about 260ps by using analog timing equipment (ORTEC 9307) (seen in Fig. 2.).

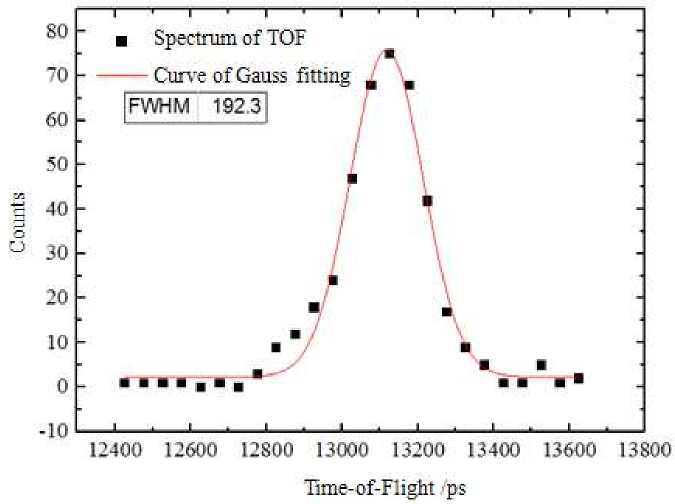

FIG.2. TOF spectrum of α particle emitted from ^{241}Am.

The 200 nm silicon nitride film (seen in Fig. 3, mass thickness: 4.32×10^{-5} g/cm^2) was used to coupling the Frisch-grid ionization chamber with the time of flight measurement system, so that the primary fission products could be incident from the high vacuum flight pipe to the working gases of the Frisch-grid ionization chamber with lower energy losses. The pressure of working gases in the Frisch-grid ionization chamber was about 0.13 atm. After studying the signal characteristics of the Frisch-grid ionization chamber caused by the grid inefficiency, digital signal processing had been used to correct the grid inefficiency, and the deviation caused by the semi-rational formula for the grid inefficiency was avoided.

Measuring ^{241}Am α source, the energy resolution of the Frisch-grid chamber was about 2.2%, and this Frisch-grid chamber had the function of measuring the specific energy losses of primary fission products.

FIG.3. Photos of 200 nm silicon nitride film, (a) only silicon nitride film, (b) silicon nitride film with 20 nm aluminum film, (c) silicon nitride film was irradiated by primary fission products.

3. Results and Conclusions

A ^{252}Cf spontaneous fission source from the Institute of Modern Physics (IMP) had been used to measure mass, charge and kinetic energy of primary fission product. Due to the self-absorption of the ^{252}Cf fission source, light and heavy fission products could not be distinguished from the spectrum of flight time or energy, but they had been distinctly distinguished in the obtained two-dimensional spectrum of time-of-flight and energy (seen in Fig. 4.). By establishing a semi-rational formula that could describe the energy losses of the primary fission products in the thin film, an iterative correction method for the energy losses and mass number had been established and applied to process the measurement data. The mass distribution of fission products from ^{252}Cf was achieved (seen in Fig. 5.) and the relative mass resolution was about 3%.

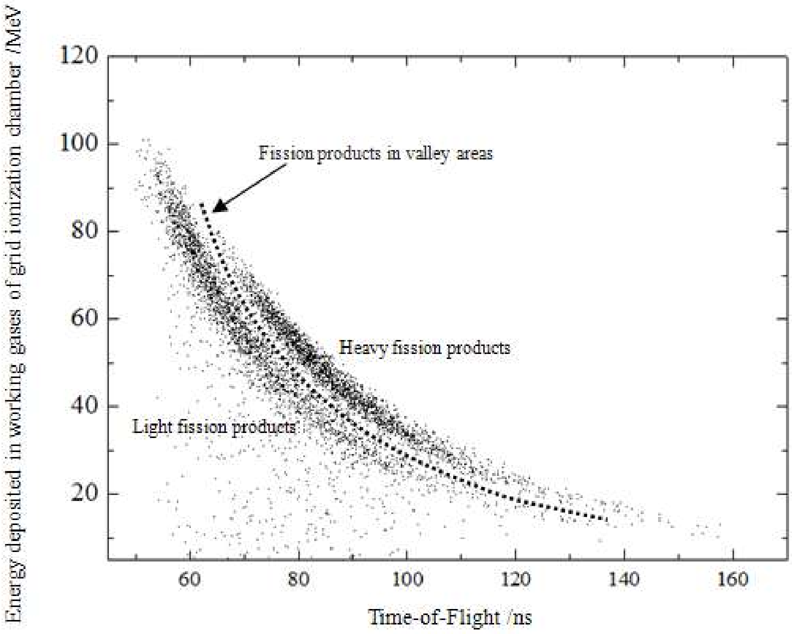

FIG.4. Two-dimensional spectrum of time-of-flight and energy by measuring primary fission products of ^{252}Cf.

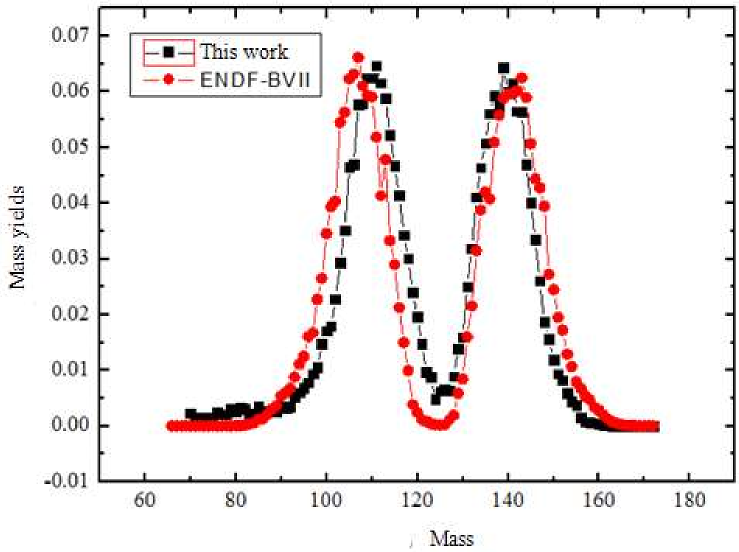

FIG.5. The mass distribution of primary fission products of ^{252}Cf.

As the same principle to a Bragg curve counter [7-9], the current signal (seen in Fig. 6.) output from the Frisch-grid ionization chamber can be used to measure the specific energy losses of primary fission products in working gas. And the nuclear stopping power of the primary fission products in working gas of the ionization chamber has been studied. There was a certain difference in the nuclear stopping power between light and heavy fission products, but the charge number Z could not be measured directly.

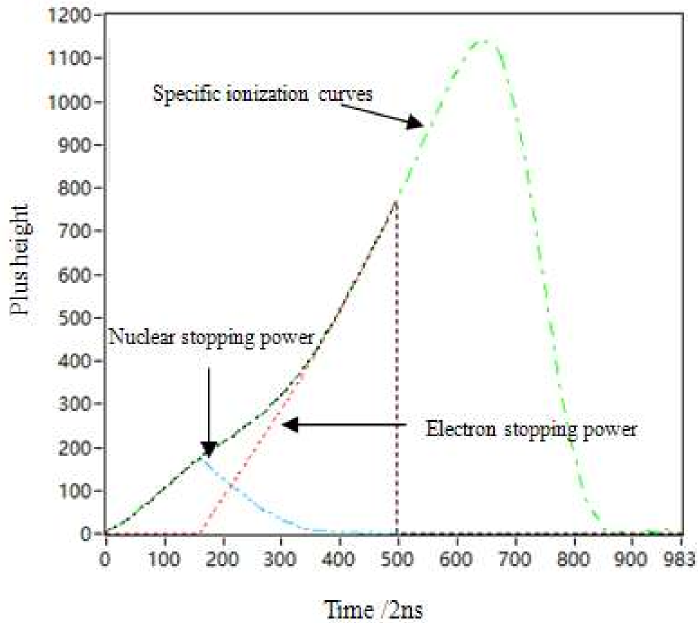

FIG.6. The specific energy losses of primary fission products obtained by the Frisch-grid ionization chamber.

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