PREPARATION AND TESTS OF THE TARGET FOR PRODUCTION OF ^{134}Nd NUCLEI*

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(Received November 14, 2011)

The ^{134}Nd required for studies of the violation of the K selection rule for electromagnetic transitions in nuclei with mass numbers around 130 can be produced in the reaction of ^{122}Te with ^{16}O. The ^{122}Te target was prepared by the evaporation in a high vacuum. The deposition of the Te isotope on the backing was performed from the very close distance to economize the usage of the isotopic material. The thickness distribution of the target material determined by measurements of the alpha particles energy loss was estimated as 32%. The first test of the target on the ^{16}O beam with energy of 80 MeV and intensity of 40 enA proved that target prepared by the Te deposition on the Au backing in vacuum is stable in the in-beam conditions and in spite of its relatively high inhomogeneity is suitable for the planned studies.

DOI:10.5506/APhysPolB.43.325
PACS numbers: 27.60.+j, 29.25.Bx, 29.25.Pj

1. Introduction

The violation of the K selection rule for electromagnetic transitions in nuclei is not yet well understood [1,2,3]. The K-isomer of interest, described by $I^\pi = K^\pi = 8^-$ appears in nuclei with the mass numbers around 130. It is planned to study the conservation of the K-number of this isomeric state in ^{134}Nd nucleus. The interesting isomer can be populated using the $^{122}\mathrm{Te}(^{16}\mathrm{O}, 4n)^{134}\mathrm{Nd}$ reaction. The best results are expected in experiment

* Presented at the XXXII Mazurian Lakes Conference on Physics, Piaski, Poland, September 11–18, 2011.

with target 3 mg/cm^2 thick. The target thickness was compromising the loss of the energy of the electrons in the target material at the interesting energy range (300 ÷ 1000 keV) and the production rate of the required nuclei.

2. Preparation of the target

Preparation of the tellurium target with required thickness as self-supporting is not feasible because of its properties. The self-supporting foils, with thickness lower than 1 mg/cm^2, can be prepared by Te evaporation on the substrate from which Te is later released, but above of 1 mg/cm^2 the deposit becomes too brittle for handling [4]. Due to high brittleness of the tellurium the rolling technique, very useful for metallic target preparation in this range of the thickness, cannot be applied as well. So it was decided to prepare the target by vapour condensation on the backing using the high vacuum evaporation plant at the Heavy Ion Laboratory of the University of Warsaw. Among the few materials considered as backing, Au seems to be the best choice as assuring the best mechanical properties and stability of the Te layer under the beam [5]. The thickness of the backing was chosen to stop the products of the reaction. The 1.3 μm (2.5 mg/cm^2) gold foil used as backing was prepared in-house (HIL UW) by rolling the gold material between the stainless steel sheets. The target material was deposited on the backing by the procedure of evaporation–condensation in a high vacuum. The tellurium was evaporated from the tube-shaped tantalum crucible with 0.5 cm aperture. The shape and the size of the Te spot was determined by the mask mounted on the backing foil. To reduce the usage of the expensive ^{122}Te isotope, the Te vapour was collected on the backing foil placed at a very short distance (1.5 cm) from vapour source thus, accepting the thickness inhomogeneity of the final product. To enhance the condensation efficiency and to reduce the re-evaporation of the deposited material, the backing was cooled down to about 18°C during the condensation process. The evaporation set-up is presented in Fig. 1. The ^{122}Te target, with thickness of about 3 mg/cm^2 and with 14 mm in diameter, was produced using 12.7 mg of the isotopic material. This was achieved with much better efficiency than for targets prepared at trials with natural material deposited on 5 μm aluminium foil (deposits of $\sim$ 3 mg/cm^2 were obtained from about 18–19 mg of nat-Te). Most probably this discrepancy in efficiency of the Te vapour condensation is related to the different thermal properties of both backings. The heat transfer q is expressed as

$$q = kA\Delta T/s\,,$$

where: k — thermal conductivity coefficient, ΔT — temperature gradient across the material, A — area, s — thickness.

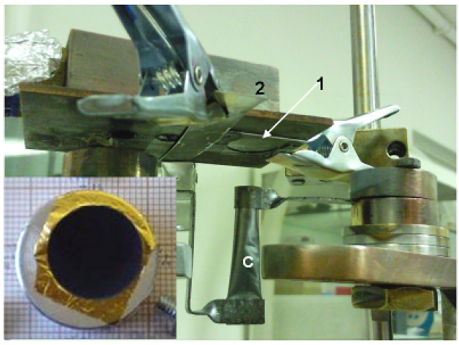

Fig. 1. The Te evaporation set-up. The water-cooled copper block (2) with a backing foil covered by mask (1) determining shape and size of the target spot was placed above the crucible (C) in a distance of 15 mm. The prepared ^{122}Te target on the gold foil backing mounted to the target holder is presented in the photo-inset at the left bottom.

As the temperature difference ΔT across the backings and the area A in both cases are similar, only the thermal conductivity of the backing material and its thickness have to be considered to asses the heat transfer: $q \approx k/s$. A simplified calculation shows that the heat transfer by a 1.3 μm thick Au foil (thermal conductivity $k_{\mathrm{Au}} = 318\ \mathrm{W\,m^{-1}K^{-1}}$) is about 5 times quicker than by a 5 μm aluminium foil ($k_{\mathrm{Al}} = 218\ \mathrm{W\,m^{-1}K^{-1}}$) and thus improving the efficiency of the vapour condensation. The thickness of the Te deposit and its distribution was determined by measurements of the alpha particles energy loss.

3. Determination of the target thickness

3.1. Method

The 2D thickness distribution of the tellurium target material was determined by measuring the energy loss (dE/dx) of the α particles emitted by the triple source ($^{241}\mathrm{Am} + {}^{239}\mathrm{Pu} + {}^{244}\mathrm{Cm}$). The examples of the alpha energy spectrum obtained for the Te + Au target are presented in Fig. 2.

The configuration of the set-up used for the α particles energy measurement is presented in Fig. 3. The position of the target against the collimator and silicon detector was controlled by screws. This allowed the scanning of the Te target surface in 2 mm steps with accuracy of 1 mm. The thickness of the ^{122}Te deposit was also verified by measurement of the energy attenuation of the electrons emitted by the ^{133}Ba (the internal conversion electron calibration source). The examples of beta energy spectra of the source and of the attenuated electrons are presented in Fig. 4.

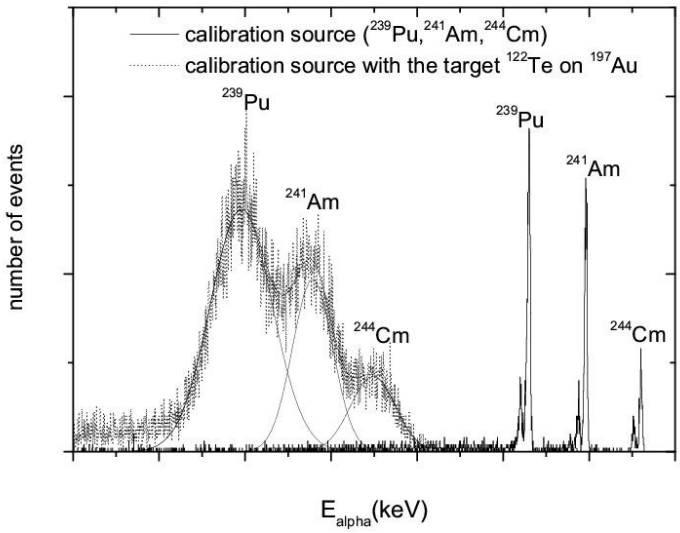

Fig. 2. The examples of the α particles energy spectra. The peaks on the right correspond to the spectrum of the calibration source and the ones on the left correspond to the peaks of the α particles attenuated by tellurium target on the gold backing (dotted line). The three Gaussian fits to the observed alpha spectrum obtained with the Origin software are also presented (solid line).

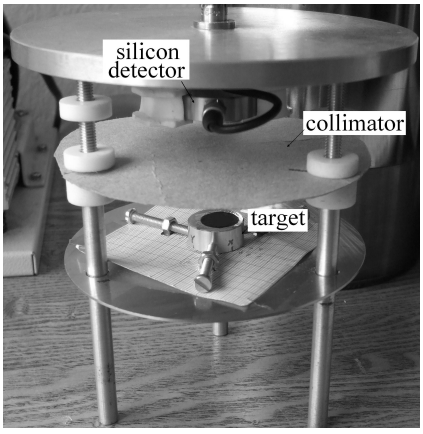

Fig. 3. The experimental set-up used for determination of the energy loss of alpha particles.

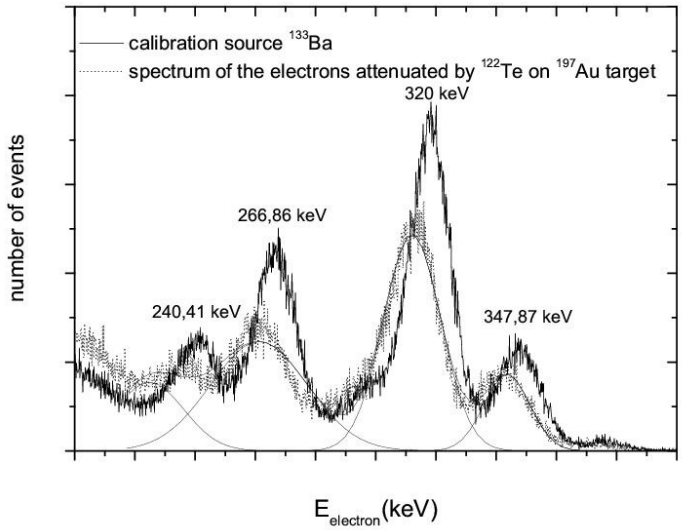

Fig. 4. The examples of electron energy spectra of the calibration source (solid line) and attenuated by the Te + Au target (dotted line). The three Gaussian fits to the observed electron spectrum obtained by the Origin software are also presented (smooth, solid line).

3.2. Results

The average thickness of the tellurium spot determined by the use of the alpha particles energy loss was estimated as 2.7 ± 0.5 mg/cm^2. The thickness was calculated assuming a gold foil thickness as 1.3 μm (2.5 mg/cm^2). The thickness inhomogeneity calculated as a ratio of the difference between the highest and lowest measured thickness values *versus* the mean value amounted to 32%. The average thickness of deposit was as well estimated by measurement of the energy attenuation of the electrons from the internal conversion electron source (^{133}Ba). The mean value of the thickness obtained by this method is equal to 2.27 ± 0.15 mg/cm^2. As can be seen on Fig. 5 the Te deposit is not only inhomogeneous but as well not symmetrical across the spot. This asymmetrical distribution of the Te is most probably caused by the minute shift of the backing centre *versus* crucible. The close distance between crucible and substrate makes the precise positioning of the both items not easy and more attention has to be given to accomplish this task during the next target production run. The Fig. 6 presents the thickness distribution of the target for coordinates $x = 0$ and $y = 0$ (see also Fig. 5). It shows the stalagmite character of the material deposit produced in the applied configuration of the crucible and substrate.

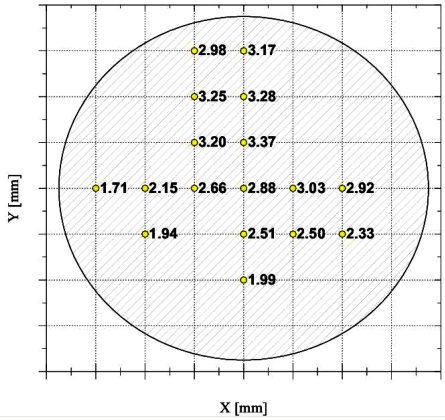

Fig. 5. The thickness distribution of ^{122}Te in the target.

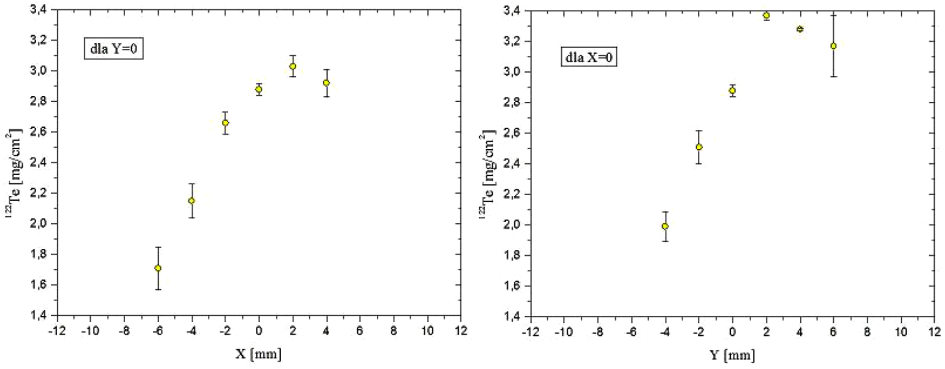

Fig. 6. The distribution of the target thickness for coordinates $x = 0$ and $y = 0$.

4. Summary

The target for two days was exposed to the beam of ^{16}O ions with energy of 80 MeV and intensity of 40 enA. The lines observed in the gamma spectrum recorded from the target after this exposure indicate the presence of the neodymium-134 isotope. The gamma lines characteristic for the decay of the $I^\pi = K^\pi = 8^-$ isomeric state in ^{134}Nd can be observed in the spectrum (Fig. 7) [6].

The tellurium deposit was investigated after the test experiment and its thickness was measured by the method described in 3.1. Neither the peeling of the material nor the changes of its thickness were noticed proving the target stability under the beam. Then, it may be concluded that chosen 'economical method' of Te target preparation resulted with target suitable for the planned studies, having, however, a relatively high thickness inhomogeneity.

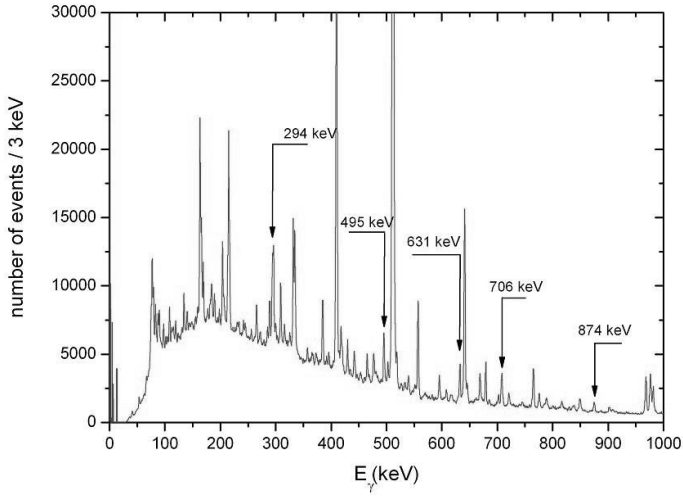

Fig. 7. The gamma lines observed in the Te target after 2 days exposure to the beam of the ^{16}O ions. The gamma lines indicated by arrows are identified as the γ-transitions below $I^\pi = K^\pi = 8^-$ isomeric state in ^{134}Nd.

This project is supported by the grant of the Polish Ministry of Science and Higher Education (N N202 181638) and project EAGLE-GAMMAPOOL, nr. 589/N-G-POOL/2009.

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