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Characterization of LiF thin layer by nuclear reaction techniques

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Abstract

In this work the thickness and the stochiometric ratio of a thin LiF target deposited by vacuum evaporation onto self-supporting Ag foil was measured using Elastic Backscattering Spectroscopy (EBS), Particle Induced Gamma-ray Emission (PIGE) and Nuclear Reaction Analysis (NRA) techniques. The gamma-rays and protons were collected by an HPGe detector placed at an angle of 90° with respect to beam direction and an ion implanted Si detector placed at a scattering angle of 165°, respectively. The results of EBS, PIGE and NRA are in good agreement with each other within the estimeted uncertainties. Carbon and Molybdenium contaminations in the target also were examinated by EBS .

Keywords: thin LiF film, PVD , EBS,NRA and PIGE

Introduction

Lithium fluoride is an interesting material because of its low refractive index and large band gap. LiF has widely been used in many fields of applications, for instance in optic physics [1] and in nuclear physics as a thin-film detector and as a radiation dosimeter [2].

LiF thin target also commonly is used for measuring the Li and F cross section data in low-energy charged particle beams because of its high thermal stability under ion bombardment [3]. The target film thickness plays a crucial role in the quality and reliability of the experimental cross section data [4]. The use of nuclear reactions induced by low-energy charged particle beams provides several most suitable techniques to analyse thin films in the range of tens to hundreds of nanometres thickness. Among these techniques Elastic Backscattering Spectroscopy (EBS), Particle Induced Gamma-ray Emission (PIGE) and Nuclear Reaction Analysis (NRA) are preferably used, due to their high analytical power for accurate and simultaneous determination of several light elements [5].

LiF thin layers have been deposited mostly by physical vapor deposition (PVD) methods such as evaporation or sputtering [6]. It should be noted that when chemical compounds are evaporated the elemental composition and stochiometry of the deposited layer may be not the same as those of the original compound.

The aim of this research work is to determine the thikness and the stochiometric ratio of the thin LiF/Ag target, using proton/deuteron induced nuclear reactions.

Experimental

Preparation of the materials

The experimental work was carried out on the 45° right beamline of the 3 MV Van de Graaff electrostatic accelerator of Nuclear Science and Technology Research Institute (NSTRI) in Tehran. Our experimental setup includes a coaxial type HPGe detector at a right angle with respect to the beamline direction, a silicon charged particle detector at an angle of 165°, an isolated target holder and a Faraday cup electrically connected to the target to measure the incident beam current. More description of the employed experimental setup can be found in Ref. [5].

LiF thin layer was prepared by vacuum evaporation of high-purity LiF powder onto a self-supporting thin Ag film. For this purpose 26 mg of the LiF was evaporated using Molybdenum boat at a distance of 12.5 cm from Ag substrate.

Results and discussion

The LiF/Ag thin target was characterized by implementing the EBS, PIGE and NRA techniques. The the stoichiometry as well as the thickness of the thin target layer were measured by applying simultaneously the EBS and NRA techniques with 2.2 MeV proton beam. By simulation of the spectum with the SIMNRA code [7] and experimental cross sections downloaded through IBANDL [8], composition of the LiF layer was obtained to be 45% natural Li and 55% F. The experimental spectum along with simulation result are shown in Fig.1.

The absolute number of Li and F atoms per cm^2 in the LiF layer was determined by employing the elastically backscattered protons from the $^{7}Li(p,p)^{7}Li$ and $^{19}F(p,p)^{19}F$ reactions and the alpha particles from the $^{7}Li(p,\alpha_0)^{4}He$ and $^{19}F(p,\alpha_{1,2})^{16}O$ reactions. Table 1 presents the measured results from these reactions. As can be seen in this table, two independent analyses are in good agreement within regard to the uncertainties.

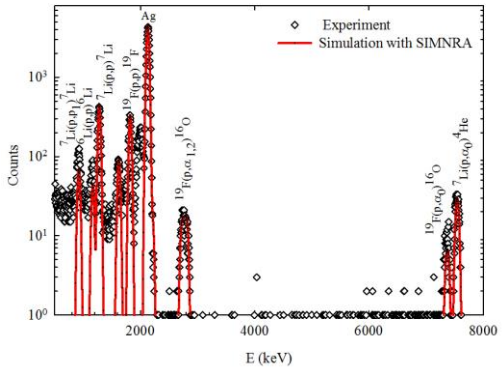

Fig. 1. Experimental and simulated Spectrum obtained at 165° by bombarding the thin LiF/Ag target with E_p = 2.2 MeV. Amount of carbon contamination in target was determined to be less than 2 %.

DIGE (Deuteron Induced Gamma-ray Emission) and p-PIGE (Proton Induced Gamma-ray Emission) measurements with the 1.15 MeV deuteron and with the 2.4 MeV proton beam were also performed on the thin LiF/Ag target. The experimental spectra are shown in Figs. 2 and 3 for $E_{d,lab}$= 1.15 MeV and $E_{p,lab}$= 2.4 MeV, respectively.

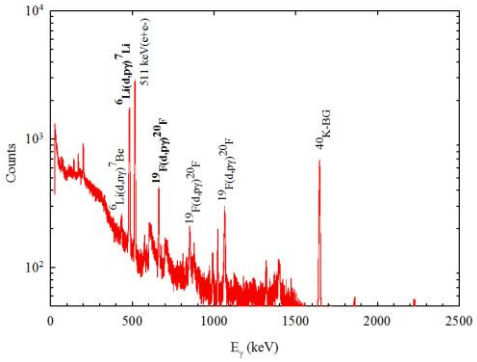

Fig. 2. Gamma-ray spectrum collected at 90° by bombarding the thin LiF/Ag target with a 1.15 MeV deuteron beam.

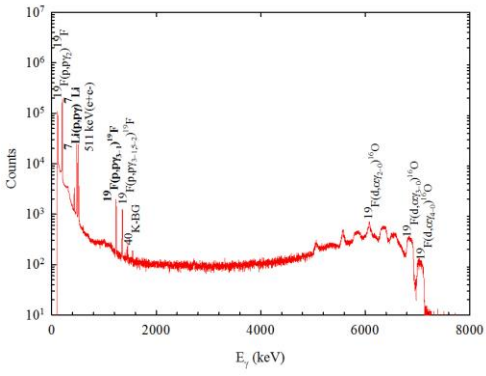

Fig. 3. Gamma-ray spectrum of the thin LiF/Ag targe at 90°, bombarded with 2.4 MeV protons.

In the gamma spectra we focused on utilization of the intense prompt gamma-rays of 478, 656, 478 and 1236 keV from the respective nuclear reactions ^{6}Li(d,pγ)^{7}Li, ^{19}F(d,pγ)^{20}F, ^{7}Li(p,pγ)^{7}Li and ^{19}F (p,pγ$_{3\text{-}1}$)^{19}F.

In figs 2 and 3, the gamma-rays corresponding to the studied reactions are labeled in bold. The results of the DIGE and p-PIGE measurments are presented in tabel 1. It should be noted that the EBS measurement with proton beam did not show any Molybdenium contamination in the target film.

Table 1. Measured LiF thicknesses

	EBS	NRA	p-PIGE	DIGE
Li 10^{18}atoms/cm^2	2.21±0.13	2.49±0.19	2.38±0.21	2.35±0.21
F 10^{18}atoms/cm^2	2.63±0.16	2.95±0.24	2.84±0.25	2.89±0.26

Conclusions

For nuclear reaction cross section measurments, a thin LiF/Ag target was prepared by evaporation of natural LiF powder. the thikness and the stochiometric ratio of the thin LiF/Ag target was obtained using EBS, p-PIGE, DIGE and NRA techniques. The results of these techniques are consistent if the estimeted uncertainties are taken into account.. Based on the result of measurments, the absolute concentration of LiF layer was found to be between 4.84×10^{18} and 5.44×10^{18} (atoms/cm^2) consisting of 45% natural Li and 55% F, respectively.

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