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Elastic recoil detection analysis of hydrogen with ^{7}Li ions using a polyimide foil as a thick hydrogen reference

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Abstract

Elastic recoil detection analysis (ERDA) with an absorber foil using a 4.2 MeV $^{7}Li^{2+}$ beam was utilized for evaluation of hydrogen depth profiles. Since recoil cross-sections when using Li ions as projectiles are not well known, the energy dependent ratio between the experimental yield and the yield calculated using the Rutherford recoil cross-section was obtained from an ERDA spectrum of a thick polyimide (Kapton) sample. It was estimated that this ratio does not significantly depend on sample composition. Therefore it was used for correction of measured spectra analyzed by existing simulation and evaluation programs in which the Rutherford recoil cross-sections were applied. The correction procedure has been verified in round-robin measurements of well-characterized Si:H thin layers. Application of the method for determination of a hydrogen depth concentration profile in hydrogen-containing graphite samples is presented.

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Keywords: Thin films; Ion beam analysis; Elastic recoil detection analysis; Recoil cross-section

1. Introduction

Elastic recoil detection analysis (ERDA) with an absorber foil is a well established technique for measuring hydrogen depth profiles in samples [1]. Conventionally, helium ions are used as projectiles. The possibility of employing lithium ions has recently been explored to achieve better depth resolution and enhance separation of hydrogen isotopes [2]. Besides, lithium ions can easily be obtained using sputtering negative ion sources available at most tandem accelerator facilities. The major drawbacks of hydrogen-ERDA with a Li beam, as pointed out by Mayer et al. [2], is the lack of recoil cross-section data and increased background in the spectra due to nuclear reactions.

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In this work, we present a quantitative hydrogen depth analysis using polyimide (Kapton) as a reference material for evaluation of hydrogen-ERDA spectra measured with a 4.2 MeV ^{7}Li beam. The accuracy of the procedure has been confirmed in "Hydrogen in Silicon" round-robin measurements, organized by Bundesanstalt für Materialforschung und -prüfung (BAM), Berlin, where Si:H thin films were distributed for hydrogen analysis [3].

The applicability of the method was demonstrated for a graphite sample from the test limiter used in TEXTOR, a research tokamak at IPP-FZ Jülich [4]. This study was initiated in order to determine precisely the depth profiles of hydrogen in typical tokamak material, graphite, that is frequently used as a plasma facing material.

2. Experimental

Measurements were performed at the 2 MV Tandem accelerator at the Jožef Stefan Institute (JSI) in Ljubljana. Lithium ions were obtained from the sputtering source using a mixture of LiOH and Ag powder as a target. The energy of the incident beam was 4224 keV for all the measurements presented in this paper. The beam was collimated by a 1×4 mm rectangular shaping slit placed in front of the entrance of the experimental chamber which was equipped with two conventional silicon detectors; the RBS detector at the scattering angle $\theta = 150°$ and the ERDA one at the recoil angle $\varphi = 30°$ (Fig. 1). The incident beam angle α and the exit angle β as measured from the normal to the sample surface were both 75°. An 11 μm thick aluminum absorber foil was inserted in front of the ERDA detector to separate hydrogen recoils hitting the ERDA detector from scattered Li ions.

A mesh charge collector set behind the shaping slit was used to measure the number of ions hitting the target [5]. It consisted of a tungsten mesh of 80% transmission placed between two cylindrical electrodes at a negative voltage (−800 V) to suppress the secondary electron current from the mesh. The normalization parameter of the measured spectra, i.e. the number N of ions hitting the sample multiplied by the detector solid angle Ω_{RBS}, is proportional to the charge q collected by the mesh charge collector:

$$N\Omega_{\mathrm{ERDA}} = Rq. \quad (1)$$

The coefficient R was calibrated by measuring the RBS yield from thin standard targets.

The ratio of RBS and ERDA detector solid angles $\Omega_{\mathrm{RBS}}/\Omega_{\mathrm{ERDA}}$, which in our case was equal to 0.82, was determined by an ^{241}Am source positioned on the target wheel. The spectra of alpha particles were accumulated simultaneously until the statistical uncertainty in the solid angle ratio $\Omega_{\mathrm{RBS}}/\Omega_{\mathrm{ERDA}}$ was lower than 1%. The normalization parameter $N\Omega_{\mathrm{ERDA}}$ needed for quantitative analysis of spectra was calculated from the accumulated charge on the mesh collector using relation (1).

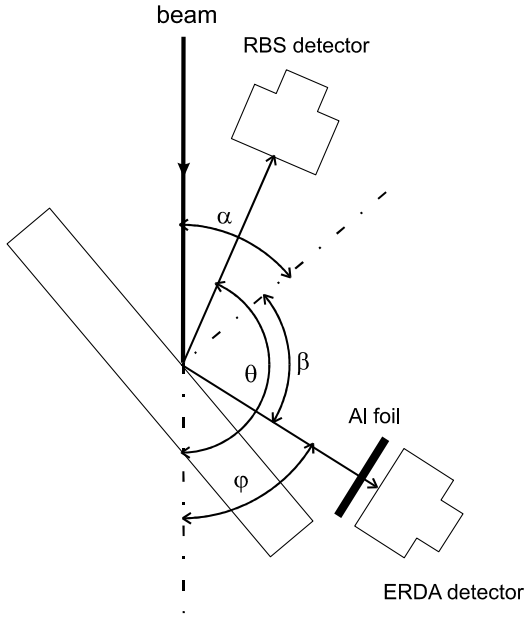

Fig. 1. RBS-ERDA set-up used in this work.

3. Results and discussion

The energy spectrum of hydrogen recoils from a polyimide film measured by the ERDA detector is displayed and compared to a simulated spectrum in Fig. 2. The calculation was done using the SIM-