Nuclear Instruments and Methods in Physics Research B 318 (2014) 292–296

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research B

journal homepage: www.elsevier.com/locate/nimb

Stopping power of palladium for protons in the energy range 0.300–3.100 MeV

P.A. Miranda *, A. Sepúlveda, J.R. Morales, T. Rodriguez, E. Burgos, H. Fernández

Departamento de Física, Facultad de Ciencias, Universidad de Chile, Casilla 653, Santiago, Chile

ARTICLE INFO

Article history:
Received 12 October 2012
Received in revised form 22 October 2013
Available online 8 November 2013

Keywords:
Stopping power
Palladium
Ionization potential
Barkas effect

ABSTRACT

The stopping power of palladium for protons has been measured using the transmission method with an overall uncertainty of around 5% over the energy range $E_p = (0.300\text{–}3.100)$ MeV. These stopping power data are then compared to stopping power values calculated by the SRIM-2010 code and to those derived from a model based on the dielectric formalism. Subsequently, and within the framework of the modified Bethe–Bloch theory, this stopping power data were used for extracting Pd target mean excitation and ionization potential, ($I = 468 \pm 5$ eV), and Barkas effect parameter, ($b = 1.51 \pm 0.06$). A good agreement is found between the obtained results and values reported in literature.

It is worth mentioning that these are the first reported results for protons on palladium over this energy range, which is often used in IBA applications, such as Rutherford Backscattering Spectrometry (RBS) and Proton Induced X-ray Emission (PIXE).

1. Introduction

It is well known that the stopping power of charged particles in matter S (E) not only is an important quantity in atomic and nuclear physics, but also has important applications in other fields of Science and Technology [1,2]. Moreover, in recent times there has been a renewed interest in increasing the accuracy of these values, particularly for light ions, in order to better determine some key parameters included in the theory of stopping power [3–5]. However, surveying the available literature it turns out that experimental data of stopping power for certain materials are absent. For instance, in the case of palladium the available data for protons is rather scarce [6–11], though this material is no less crucial in a number of important applications. Nowadays, palladium is used as the active ingredient in catalytic converters and it is also found in many electronic devices including multi-layer ceramic capacitors and low voltage electrical contacts. It is in this respect, that within a long-term research project, we propose to measure the stopping power curves for different materials of technological interest over the energy range between 0.3 and 3.1 MeV, which is often used in Ion Beam Analysis.

2. Experiment

The stopping power measurements were performed at the 3.75 MV Van de Graaff accelerator of the Faculty of Sciences of University of Chile [12]. Its absolute energy calibration was carried out over a wide energy range using the 872, 974 and 1370 keV resonances of the $^{19}F(p,(\alpha\gamma))^{16}O$ reaction, the 1735 keV resonance of the ^{12}C (p,p)^{12}C reaction and the 2085 and 3103 keV resonances of ^{28}Si (p,p)^{28}Si reaction.

In order to achieve a high accuracy in the stopping power data a stainless steel 600 series ORTEC scattering chamber was used during the acquisition, which allows a precise positioning of the detector ($150.0^\circ \pm 0.1^\circ$) in relation to the beam direction. This facility also features two collimators (antiscattering) which define a beam spot that can varied from about 3 to 0.5 mm in diameter. A goniometer is used to position and orient the samples with respect to the beam (±0.5 mm) and to select the tilt angle (±0.5°). The data acquisition system includes an ORTEC surface-barrier detector Model BA-014-50-100 with 14 keV nominal resolution FWHM for a ^{241}Am alpha source (5.486 MeV). Pulses were analyzed with proper electronic circuitry (preamplifier ORTEC Model 142E, an ORTEC amplifier Model 572) and collected by an ORTEC PC MCA Model Trump-8K. The acquisition system was periodically calibrated in energy by using ^4He backscattering spectra of a thin Al/Ti/Ta multilayer deposited on a carbon substrate with a well-known concentration. High-vacuum conditions 10^{-6} torr were achieved during the measurements by using two turbo-molecular pumps. The beam current on target was kept relatively constant at around 5.0 nA in order not only to attain sufficient statistics in each RBS spectrum, but also to prevent any further damage of the target.

The stopping medium was a single palladium foil with nominal thickness of 0.5 μm supplied by Goodfellow [13]. However, the

* Corresponding author. Tel.: +56 29787281.
E-mail address: pjmirand@gmail.com (P.A. Miranda).

0168-583X/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.nimb.2013.10.020