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Mass spectrometry improvement on an high current ion implanter

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ABSTRACT

The development of accurate mass spectrometry, enabling the identification of all the ions extracted from the ion source in a high current implanter is described. The spectrometry system uses two signals (x–y graphic), one proportional to the magnetic field (x-axes), taken from the high-voltage potential with an optic fiber system, and the other proportional to the beam current intensity (y-axes), taken from a beam-stop. The ion beam mass register in a mass spectrum of all the elements magnetically analyzed with the same radius and defined by a pair of analyzing slits as a function of their beam intensity is presented. The developed system uses a PC to control the displaying of the extracted beam mass spectrum, and also recording of all data acquired for posterior analysis. The operator uses a LabVIEW code that enables the interfacing between an I/O board and the ion implanter. The experimental results from an ion implantation experiment are shown.

1. Introduction

Nuclear physics applications in materials science using combined methods of hyperfine interactions for the observation of the magnetic and electric interactions between nuclear moments of excited states in specific radioactive probe nuclei as well as the internal fields of the material and ion channeling for lattice location investigations can be excellent and unique tools for basic studies of defects in single crystals [1]. The high current ion implanter installed at Nuclear and Technological Institute (ITN) is dedicated to materials research which makes isotope selection an important requirement. Being also specially oriented for surface engineering studies, the ion implantation facility has been optimized to implant the isotope ^{186}W. Then the ^{187}W radioactive probe is obtained using the thermal neutron flux of the Portuguese Nuclear Research Reactor. The selectivity of the implanted chemical species is one of the most relevant advantages of ion implantation. In order to guarantee beam purity avoiding the contamination of the implanted samples, the mass spectrometry is essential in this process [2–5].

A new system, that was not included in the original configuration of the equipment, was developed in order to obtain precise identification and recording of all elements extracted from the ion source. This system allows the user to control and analyze the mass spectrometry through a developed PC application, using the program LabVIEW, allowing an instantaneous correction of the experimental parameters in order to maintain the beam purity, and enabling the export of the data acquired. Nowadays, Danfysik implanters are fully computer controlled with increased mass spectrometry performance. In this work details are given about the implantation of $^{186}W^{+}$ and $^{186}W^{++}$ and the respective characterization of the samples using neutron activation analysis (NAA) used to prepare radioactive samples for hyperfine interactions studies.

2. System description

The high current ion implanter installed at ITN, represented in Fig. 1, is the Danfysik model 1090 [6,7]. The ion source, gas and sputter version, operating flexibility makes it possible to produce ion beams from nearly all elements of the periodic table [8]. This high current ion implanter is equipped with a beam profiler, an analyzing magnet and x–y analyzing slits, enabling a beam envelop imaging and coarse mass analyses of the extracted ion beam. This device, located between the exit of the 90° analyzing magnet and a pair of analyzing slits consists of a probe that intersects the beam, giving an image of the beam horizontal and vertical contours and its position relative to the beam line.

The application of a magnetic field to the ion beam, as show in Fig. 2, ensures that ions of different masses extracted from the same source spot hit the analyzing slits in different spots. This physical separation, Δy, between two adjacent ion beams with

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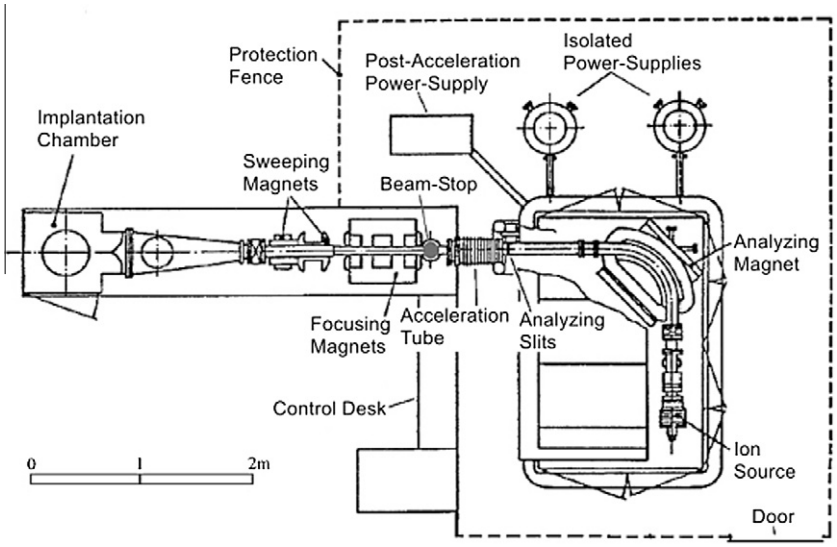

Fig. 1. Layout of the high-current ion implanter installed at the Nuclear and Technological Institute, Sacavém, Portugal.

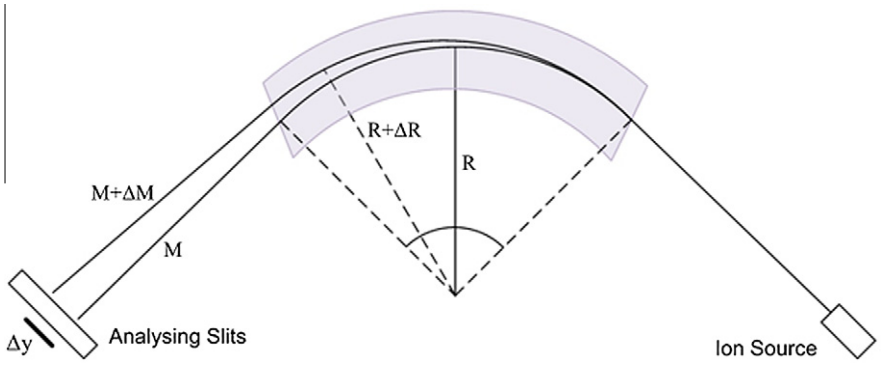

Fig. 2. Schematic of the analyzing magnet ion mass dispersion.

masses M and $M + \Delta M$, in the analyzing slits, due to the analyzing magnet defection, is known as the magnetic dispersion D [8]

$$D = 2R\frac{M_2 - M_1}{M_1} \quad (1)$$

where M_1 and M_2 are two adjacent masses (in a.m.u.) and R is the magnet deflection radius.

The dispersion is measured in the analyzing slits, comprising two L-shaped copper bars that are simultaneously moved, having a 0–25 mm variable horizontal aperture and 25 mm constant vertical aperture. It can be seen from Eq. (1) that the dispersion depends only on the magnet geometry and the ion mass.

With the beam profiler is possible to observe the physical separation between the different beam masses, with the possibility of calibration to obtain the mass separation in length units that corresponds to the dispersion value.

The final width, L, of the beam image in the analyzing slits, which depends on: (i) the extraction power supply stability (dE/E); (ii) the magnet current power supply stability (dB/B), (iii) the beam divergence α; (iv) the initial object width S, is given by [9]:

$$L = R\frac{dE}{E} + R\frac{dB}{B} + R\alpha^2 + S \quad (2)$$

where $dE/E = dB/B = 5 \times 10^{-4}$, $R = 500$ mm, $\alpha = 20$ mrad and $S = 4.5$ mm (according to [10] for the extraction configuration used, the initial object width, S, for a focus beam is about half the extraction electrode aperture), resulting in a beam width of approximately 5.5 mm.

Experimentally, the beam width can vary depending on the system operating conditions, where the α and S parameters change in every run. The beam divergence depends on the ion source optimization and the initial extraction aperture width, of 9 mm, which becomes wider and loses its circular shape due to the ion bombardment. All these factors result in an increasing image size and a decrease in the mass separation. Hence, a slit aperture of 7 mm is usually required to transmit about 90% of a mono isotopic beam to the target.

In order to obtain a mass spectrum, two signals are required, one proportional to the analyzing magnet magnetic field (x-axes) and another proportional to the beam current intensity (y-axes). The first signal is taken from a voltage proportional to the analyzing magnet, available from the magnet power supply. The use of this signal comprises two difficulties: (i) the magnet current has hysteresis, thus it is advisable to continuously scan the current during a mass spectrum; (ii) the analyzing magnet is located on the post-acceleration potential. Therefore, an optic-fiber based circuit was developed to send the magnet current signal to the ground potential.

Whereas, on the post-acceleration potential, the d.c. voltage proportional to the magnet current is converted through a voltage-to-frequency (V/F), in a number of voltage pulses with a frequency proportional to its amplitude.