

III. Participation to the JET Experimental Program

TRITIUM DEPTH PROFILE MEASUREMENTS OF JET DIVERTOR TILES BY AMS

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1 Introduction

The project JW9-FT- 3.50 was started 2009 and was devoted to determine the retention properties of tritium in the carbon (CFC) protection tiles of the JET divertor. The detailed knowledge of depth profile of tritium and deuterium content in tiles from JET, tiles that are exposed to the plasma discharges, contribute significantly to improve the understanding of the plasma wall interactions and provide important data on the hydrogen isotope retention. Accelerator mass spectrometry (AMS) [1-2] is a highly sensitive analysing method that provides complementary information to other conventional methods used for analyses or for diagnose in fusion experiments however, is the only method capable to determine low concentrations of Tritium in different substrates. The main goal of the project was to perform AMS experiments of T-concentration depth profiling [3] in divertor tiles from JET. In this way, the retention of T in dependence of depth can be determined in the protection tiles.

2. Experimental upgrading and calibration of the analysing facility.

Since AMS is a relative analysing method it requires standard samples for calibration. Tritium standard samples were prepared, with different tritium concentrations in carbon substrate, adequate to calibrate the concentrations that will be measured in the divertor tiles from JET. The T/C standards were produced with concentrations of 10^{-9} and 10^{-8} . The substrate matrix is close to a CFC structure. Corrections due to the used binding agent were also considered.

Once we had available T standard samples the experimental tests and calibration were performed of the new AMS depth profiling facility in Bucharest. Fig1. shows the new experimental set up and the new tritium detection system.

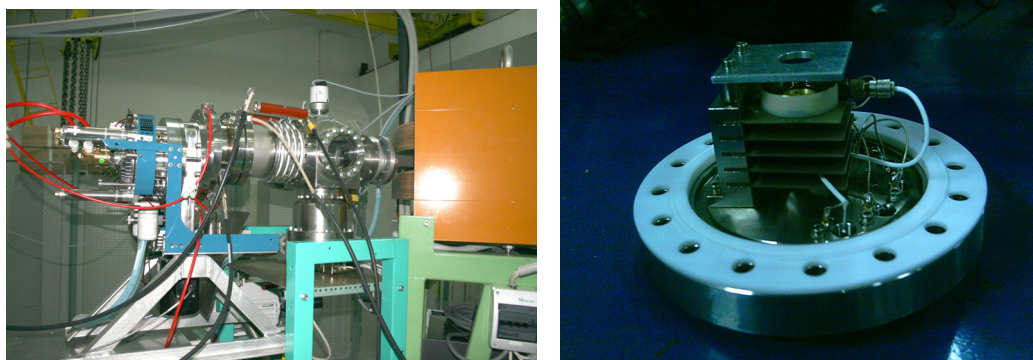


Fig.1 Image of the new sputter ion source used for dept profiling of elemental concentrations and the multi array of 3 Si-pin detectors, used for light particle detection and discrimination.

AMS performs a depth profiling (DP) of the measured concentration by sputtering with an accelerated (6keV) ^{133}Cs ion beam. The depth scanning is done by sputtering with accelerated ^{133}Cs on the

sample surface, at its location in the ion source. By measuring continuously the produced rare ions (Tritium) one will register in the detector different beam currents according to the concentration at depth of scattering. Experimentally, the DP requires the sputter erosion rate to be uniform on the analyzed target area. Ions sputtered from the crater sides should not be included in the analyses because they do not reveal the true concentration. In order to correct the rim effects we developed a mathematical unfolding procedure [4].

For an efficient and confident depth profiling of concentrations by AMS the parameters of the devices of the facility have to be optimized experimentally. Optimal values have to be carefully chosen for the beam currents and for the acceleration conditions.

The new prepared standard samples were mounted on the target wheel and were introduced into the vacuum chamber of the ion source (Supplementary, two blank samples of pure Carbon were introduced to determine the background level and the cross talk effect in the ion source. Moreover, 2 samples of low T/C concentration, with T implanted in pyrolytic carbon, were also introduced in the sputter ion source to allow a complete simulation of a depth profiling.

The ^{12}C ions were chosen to form the pilot beam. However, the stripping probability of negative ions in the terminal is not the same for all possible charge stages to be attained at a certain terminal potential. The main constraint is to be able to obtain the magnetic rigidity value for ^{12}C ($M(1+q)/q^2 = \text{const}$) very close to the magnetic rigidity value of Tritium. The differences between the two values should not exceed 0.5 MeV for the Terminal voltages of the tandem accelerator. For a larger value of the difference the tuning with the pilot beam is not anymore precise. The state charge 3^+ of the ^{12}C ions satisfies well this constraint. Thus, the pilot beam was chosen to be formed by $^{12}\text{C}^{3+}$ ions. The experimental testes to optimize the working conditions of the AMS facility were done by means of: i) Variation of the electric parameters of the ion source (sputtering potential, ionizer temperature, extraction potential and einzel lens voltage), ii) Variation of the acceleration energy of the pilot beam, iii) Optimization of particle detection and data acquisition (entrance aperture to the detector array, data registration electronics, data storage and data on line processing). The final optimized conditions for an AMS depth profiling experiment at the FN-8MV tandem at NIPNE Bucharest are as follows: 1) For the Ion sputter source: $U_{\text{sputter}} = 6.0 \text{ kV}$, $U_{\text{extr}} = 11.0 \text{ kV}$, $U_{\text{einzel}} = 1,1 \text{ kV}$, $U_{\text{pacc}} = 55.8 \text{ kV}$, 2) for Pilot beam: $^{12}\text{C}^{3+}$, acceleration energy 32 MeV, $U = 8 \text{ MV}$, Offset = 0.43 MeV, 3) For the Microscopic Tritium beam: $^3\text{H}^+$, acceleration energy: 14,2 MeV, $U = 7,105 \text{ MV}$.

The events in the detector are registered continuously. Assuming a continuous sputtering rate the elapsed time is converted to depth. The calibration of the scanned depth is done off line, by optic profilometry. Spectra of the Tritium particles were recorded and depth profile spectra were also performed, using the standard samples.

3. AMS analysis of tritium depth profiles in selected JET divertor tiles.

For the AMS analysis samples with lower T activity concentration from divertor tiles and JET campaigns 1998-2004 have been selected : 3 samples from G1B and 1 sample form tiles G7A and G8B. All samples were cut were like a disk, having 10mm diameter and 3mm thickness. Fig.2 shows the locations of the cuts in tile G1B.

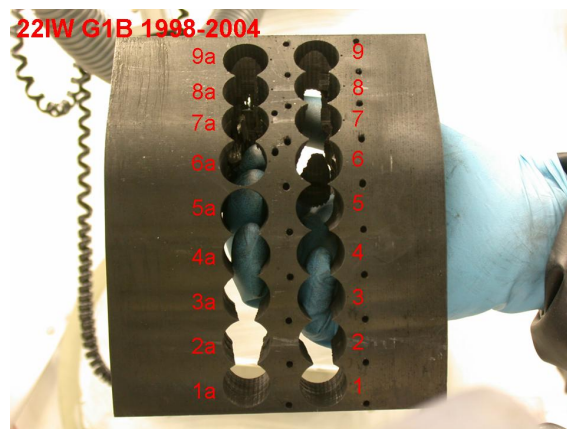


Fig. 2 : Locations of samples from tile G1B . In the AMS DP experiment samples form locations 2, 5 and 8 were used.

Each sample was measured by AMS in order to determine the T concentration depth profile. With this aim, the carbon sample containing T, is installed in the ion source and is sputtered by 6 keV accelerated ^{133}Cs ions. The sputtered negative T ions are extracted and then analysed by the AMS system. Only T ions will be accepted and will be registered in the detector. During the time of an AMS DP experiment, the sputtering beam produces a crater in the sample material. The counting rate of T atoms will depend each time on the concentration at the reached depth in the crater. The data is recorded corresponding to the elapsed time in the experiment. At the end of the experiment the excavated sample will be measured by optic profilometry. The crater dimensions will be used to convert and the time scale to depth and to correct for the rim effect. The measured concentrations DP are shown in Fig 3. All data were corrected for the background value of T during the measurements. For the entire experiment the background level was 10^3 lower than the smallest measured concentration. The averaged concentration of T does not exceed 10^{17} atoms/cm³. Taking into account the possible wide incidence angles of the colliding particles and the fast diffusion T in CFC, wide peaks are expected for the maximum values of the power ranges. The decisive contribution to the widening of the peak distribution is due to the CFC structure of the divertor tiles at JET. In a similar study we performed at ASDEX, using Long Time Samples of pyrolytic carbon placed in-between the protection tiles of the divertor, the energetic spectra of the retained Tritium shows a well defined, nearly sharp peak at the depth of 0,25 μm .

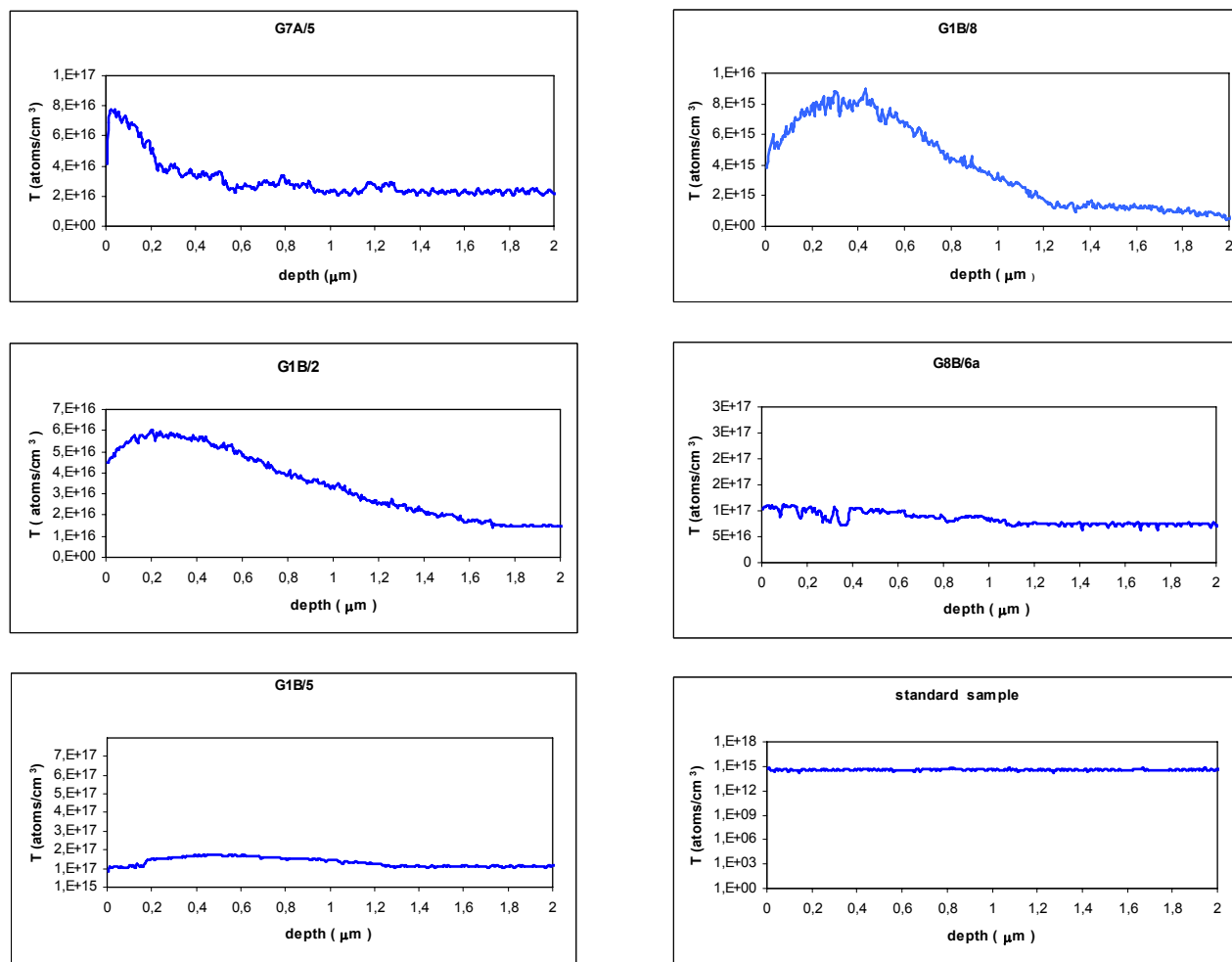


Fig.3 : Tritium depth profiles measured by AMS.

Therefore, the peaking of the DP at a depth of about 0.25 μm corresponds to the implant of Tritium removed at temperatures close to the plasma temperature. The divertor samples are cut from a toroidal distribution. Integrating the DP down to the measured depth one obtains the amount of T trapped per unit area (atoms/cm²). In fig.4 the integrated values of T deposition up to about 3 μm depth are indicated, according to their locations on the divertor from JET.

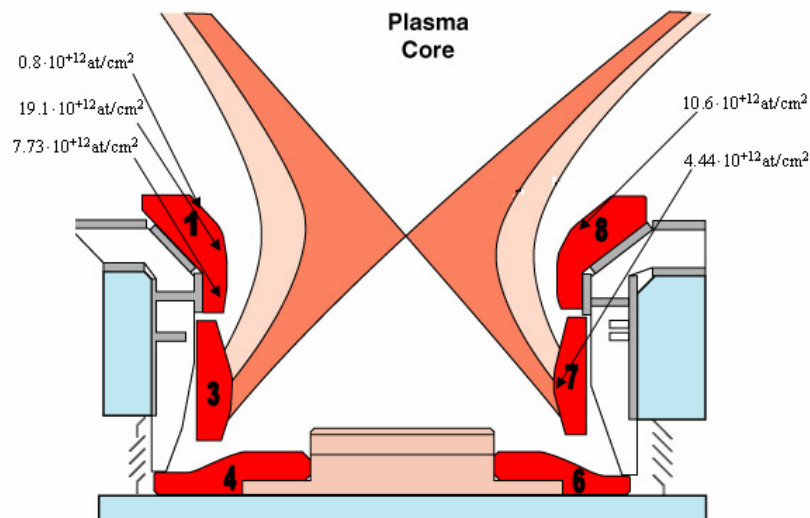


Fig.4. AMS integrated concentration values of T in CFC tiles at different locations on the JET divertor.

As can be seen from fig.4, nearly symmetric values were found for the T concentration on the tiles no.1 and no.8. Tile no. 7 has lower T concentration.

4. Conclusions :

In the first year of scientific research a modern analysing facility was upgraded and optimized for the extremely high sensitive measurements of the concentration and depth profiling of hydrogen isotopes in different substrates. First measurements have already been done on some protection tiles from the divertor of JET. Since at this moment the old protection tiles from the divertor were removed a complete analyses of hydrogen isotope retention is highly requested in order to obtain the information useful for the ITER project. AMS is also involved in measurements of inter-comparison of detritiation techniques and in measuring the retention of deuterium under the new deposition layers of Be (simulation of the first wall interaction at ITER). However, since the national financial support was rejected for the next two years, all these projects are jeopardized.

References

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