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First tests of the ion irradiation and implantation beamline at the CMAM

D. Jiménez-Rey [a,c], M. Benedicto [a], A. Muñoz-Martín [a], D. Bachiller-Perea [a,b], J. Olivares [a,b,c,d], A. Climent-Font [a,b], B. Gómez-Ferrer [a,b,c], A. Rodríguez [a], J. Narros [a], A. Maira [a], J. Álvarez [a], A. Nakbi [a], A. Zucchiatti [a,*], F. de Aragón [c], J.M. García [c], R. Vila [c]

[a] Centro de Micro-Análisis de Materiales, Universidad Autónoma de Madrid, C/Faraday 3, Madrid 28049, Spain
[b] Dpto. de Física Aplicada, Universidad Autónoma de Madrid, Ciudad Universitaria de Cantoblanco, Madrid 28049, Spain
[c] Laboratorio Nacional de Fusión, EURATOM/CIEMAT, CIEMAT, Avda. Complutense 40, Madrid 28040, Spain
[d] Instituto de Óptica, CSIC, Calle Serrano 121, Madrid 28006, Spain

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ABSTRACT

The implantation and irradiation beamline of the Tandem ion accelerator of the Centro de Micro Análisis de Materiales (CMAM), in Madrid, has been recently completed with a beam sweep and monitoring system, and a cryostat/furnace. These new implementations convert the beamline into a versatile tool to implant ions, between H and Au_2, in different materials with precise control of the sample temperature, which may be varied between −180 °C and 600 °C. The size of the swept area on target may be as large as $10 \times 10\ cm^2$. The implantation chamber also allows carrying out *in situ* or/and on line analyses during the irradiations by means of advanced optical measurements, as well as ion beam analyses (IBA). These advancements can be employed in novel applications such as the fabrication of optical waveguides and irradiation tests of structural and functional materials for future fusion reactors. The results of beam tests and first experiments are shown.

1. Introduction

Techniques on ion beam modification of materials (IBMM) are the basis of a well established research field. The implantation of ions in a wide variety of materials has found a range of applications, such as semiconductor devices fabrication, nanofabrication, metal finishing and study of the radiation effect in inorganic, organic, or even biological materials [1,2], in view of e.g. industrial and space applications. If we work with ion beams in the range 10–500 keV, we can carry out implantations in materials with depths of several hundreds of atomic layers and thus modify their surface properties. On the other hand, if we use ion energies lower than 10 keV, we can perform ion beam sputtering and plating, as well as ion plasma deposition, and thin layers coating. In higher energy accelerators, such as the one at Centro de Micro-Análisis de Materiales (CMAM) which covers, depending on the ion type, a range from 500 keV to 50 MeV, we can work with high electronic stopping power and modify materials using low fluences, with penetrations up to several microns. Furthermore, an implantation beamline allows obtaining high displacements per atom (d.p.a.), and high implantation depths, making it an ideal instrument to carry out radiation damage studies. Apart from the IBMM techniques, an implantation beamline may allow carrying out *in situ* and on line analysis in the irradiated samples by any of the so-called ion beam analysis (IBA) techniques, optical methods and others.

One of the key research lines at CMAM, a relevant one also in other accelerators around the world, deals with materials involved in the development of new energy sources, such as nuclear fusion [3]. A hypothetical future commercial fusion reactor must be manufactured with materials capable of tolerating harsh conditions such as strong irradiation damage with high displacements per atom (d.p.a. close to 50–100), high operating temperatures (above 600 °C), and large productions of He and H (from 1 to several hundreds of appm/dpa), as well as production of other ions that affect the radiation damage [4–6]. Testing these materials under conditions similar to those that they will stand in the installation, or not too far, within the performances available from actual accelerators, is fundamental to understand their alteration mechanisms and guarantee proper operation as a reactor component. Conducting experiments on the evolution of the irradiated materials requires keeping precise control of the sample temperature within a wide range and defining precisely the size of the irradiation area and thus the fluence, which is a key parameter in the modification of the material properties. Many ion accelerators have installations

* Corresponding author. Tel.: +34 914972791; fax: +34 914973623.
E-mail address: alessandro.zucchiatti@uam.es (A. Zucchiatti).

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capable of carrying out homogeneous implantations on samples with relatively reduced areas [7,8], but it is not common for these installations to have the ability to control the sample temperature within a wide range and on large areas [9]. To extend the potential of the implantation beamline of the CMAM we have installed and tested a new cryostat furnace and modified the beam sweep and monitoring system to allow implantation of ions within a wide range of masses and charge states, in areas up to $10 \times 10\,cm^2$ on target, with precise control of the sample temperature and the swept area and fluence. In this paper we describe these new

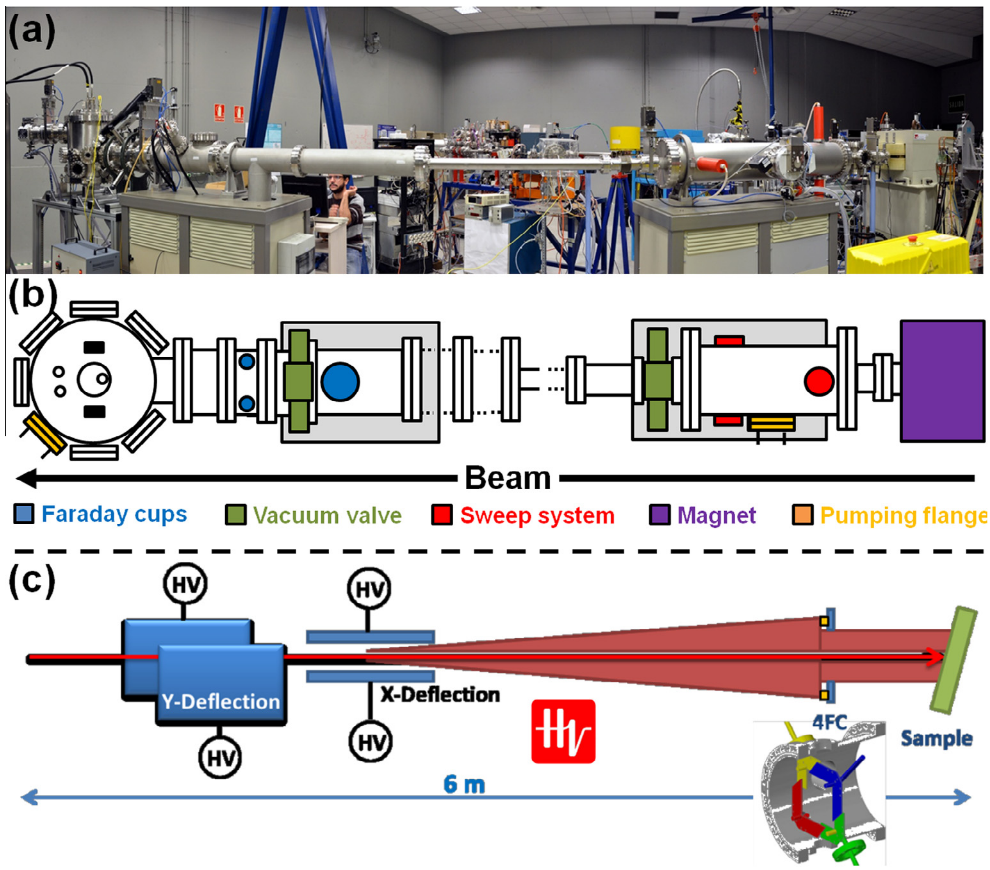

Fig. 1. (a) Panoramic view of the CMAM implantation and irradiation beamline and (b) a schematic diagram with its main elements. (c) Schematic drawing of the HVE beam sweep, collimation and monitoring system.

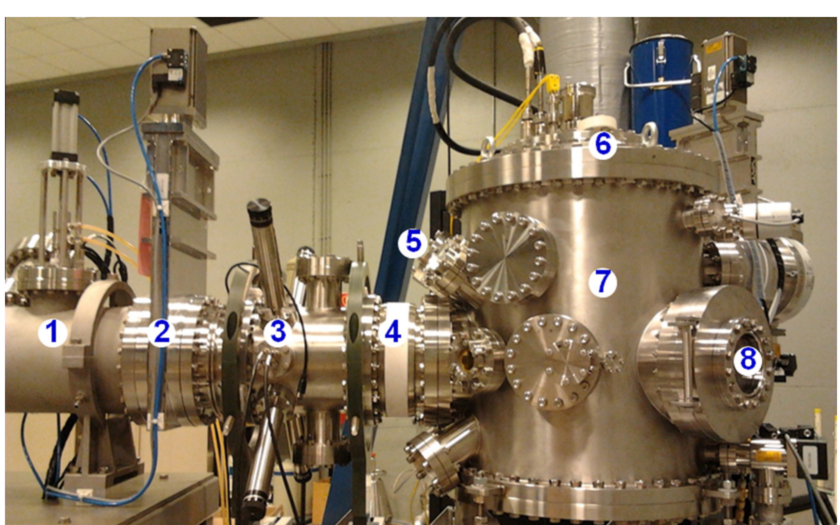

Fig. 2. Irradiation chamber of the CMAM implantation beamline. (1) Location of the single Faraday cup (FC), (2) vacuum valve, (3) location of the beam collimation and monitoring four-Faraday cups system (4FC), (4) ceramic insulator, (5) ZnSe optical window, (6) irradiation chamber, (7) location of cryostat furnace, (8) access port.