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Erosion and transport of Sn and In in the SOL of MAST plasmas

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Abstract

A satisfactory method for monitoring the erosion of vessel wall tiles in a fusion power plant remains an important missing diagnostic in the fusion program. Spectroscopic observation of embedded impurity layers may provide such a capability. In a preliminary experiment, Sn and In have been introduced to the scrape off layer of MAST plasmas by erosion from a target mounted on the reciprocating probe system, and have been successfully observed spectroscopically in the core and at the edge. The atomic transitions corresponding to each observed spectral line and feature have been predicted and then identified, with those in the visible region being used to estimate the erosion/influx rate. The confined plasma emission has been measured and modelled using the impurity transport code UTC-SANCO. The results show that eroded Sn and In emission is observable and distinguishable in MAST, and shows that the technique has promise for use in future devices.

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Keywords: MAST; Erosion and deposition; Impurity transport; Probes; Spectroscopy

1. Introduction/motivation

In a future fusion power plant erosion of the vessel walls will be a serious concern. Estimates of the erosion rates of the graphite divertor tiles in ITER range from 1 to 16 nm/s depending on the plasma regime [1,2], equivalent to up to 50 cm/burn year of erosion in ITER. This will only become worse in continuously burning power plants. One proposed method of monitoring this without resorting to frequent in-vessel inspections is to embed marker layers of non-intrinsic elements in the wall tiles. As the tiles erode these layers will be exposed to the plasma. If the marker elements enter the core and emit an observable characterising spectral signature then the location of the damage can be localised. A more detailed discussion of this technique is given in [3]. As a preliminary study of this technique, heavy elements (In and Sn, $Z = 49$ and 50, respectively) have been eroded from a probe into the SOL of MAST plasmas to observe the release and transport of these impurities in the SOL and core, and the distinguishability of their emission.

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2. The materials probe

A new materials probe head, shown in Fig. 1, has been designed for use on the MAST reciprocating probe system. The probe is constructed with removable boron nitride mushroom shaped tips which are coated with the material to be studied. The radius of the probe is 5 cm, with the mushroom being 5 cm in radius and 1 cm in height (0.5 cm for the upper surface, 0.5 cm for the stalk). In these experiments, a coating thickness of 0.7–1.0 μm was used (the layer is not completely uniform due to uneven deposition on the curved surface). The mushroom shape maximises the area of material exposed to the plasma, and also reduces the C redeposition onto the upper surface.

Embedded in the tip are two Langmuir probes, one on the very front and one 2.5 mm further back and towards the edge. These have been used mainly in ion saturation current mode to give a measure of the local particle flux at the probe tip.

The reciprocating probe system on MAST is located on the outboard midplane, and can reciprocate inwards up to 10 cm in 100 ms. It has interchangeable heads, including the newly designed Gundestrup Probe [4]. This has been used in similar plasmas to provide a comparison with Sn/In free plasmas.

3. Experimental setup

Two impurity spectrometers were used to monitor the released elements in the plasma. SPEX, a visible spectrometer, was setup to observe the probe tip by mounting a lens almost directly opposite the probe tip, as shown in Fig. 2. The angle was such that it allowed use of a lens with a very narrow field of view. This ensured that all the emission at the tip was captured but relatively little of the background plasma light. SPEX was used to observe the neutral, singly and doubly ionised stages which ionise close to the probe tip and so can provide an influx estimate.

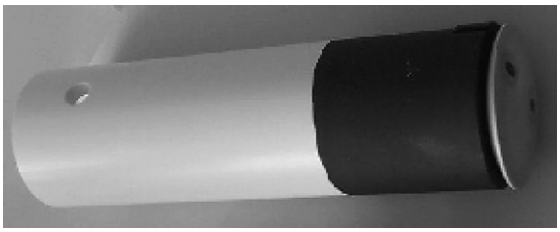

Fig. 1. The new materials probe head for the MAST reciprocating probe system.

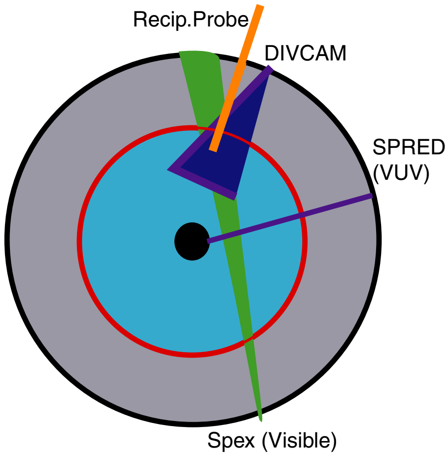

Fig. 2. The experimental setup showing the lines of sight of the spectrometers. All are mounted on the midplane except DIVCAM, which is below the midplane looking towards the upper divertor.

SPRED, a VUV grating spectrometer [5] mounted on the outboard midplane with a radial line of sight was used to monitor the higher ionisation stages of the impurity in the confined plasma.

A divertor imaging camera (DIVCAM) was fitted with a filter to show the Sn II line at 5333 Å. This camera has a wide field of view, which encompasses the probe tip, allowing a 2D picture of the Sn emission near the tip. The system has two CCDs recording the same view with different filters, allowing emission from two different lines to be observed simultaneously (D_α has been used as the additional line here).

Several different plasma types have been used for these studies to investigate heavy species SOL transport and core penetration in a variety of SOL conditions. Sn has been eroded into upper single null (USN, 13832-13835) and lower single null (LSN, 14479, 14480) ohmic plasmas. In has been introduced to identical lower single null, ohmic plasmas as for Sn. New scenarios have been devised to provide sawtooth free ohmic LSN and connected double null (CDN) plasmas, which are simpler for modelling. These have been used with In. Most of the work in this paper refers to the studies with Sn. Plasma parameters for these shots are shown in Fig. 3.

Simulations were made of the spectral line emission and envelope feature emission for Sn and In as a function of plasma conditions with code from the