Glow-Discharge Optical Emission Spectroscopy for Plasma-Surface Interaction Studies

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Introduction

Reliable analysis of plasma-facing materials (PFMs) is indispensable to understand plasma-surface interactions (PSIs). Glow-discharge optical emission spectroscopy (GDOES) is a technique to measure depth profiles of constituent elements in a solid sample by detecting emissions from atoms accommodated in plasma by sputtering. The benefits of this technique are:

(1) PFMs used in fusion devices can be analyzed without modification (no ultra-high vacuum, large sample is acceptable),

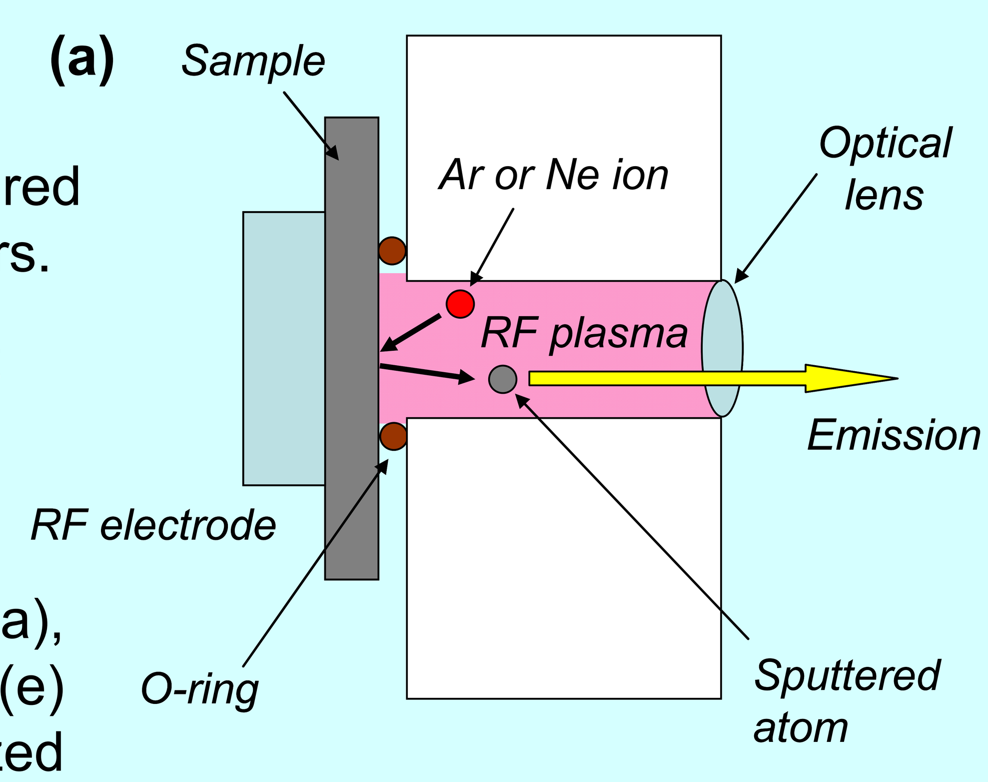
(2) high depth resolution (a few nanometers), and (3) very quick measurements (several minutes)

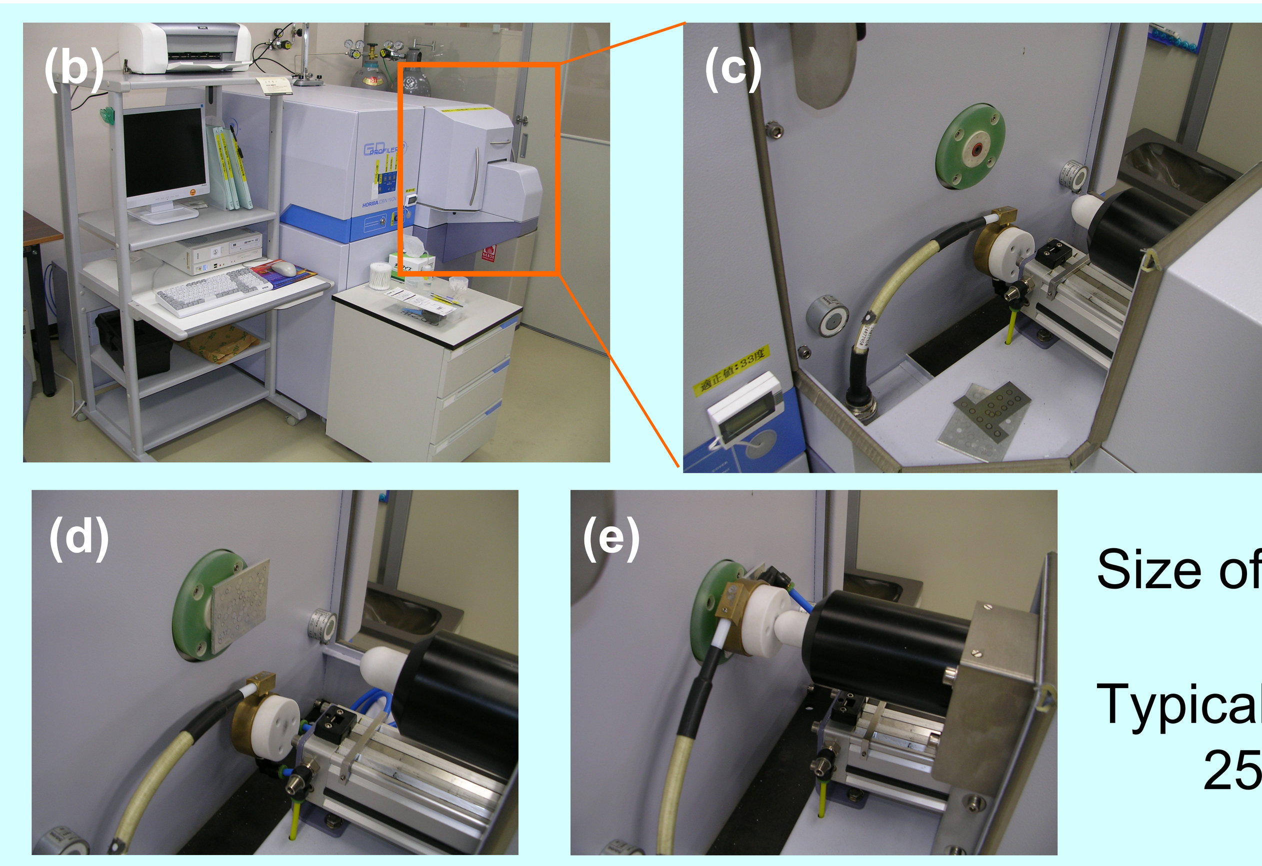
In PSI studies, we need to measure depth profiles of H, D, T and He. *In the present study, the abilities of GEOES for (1) isotopic measurements of hydrogen and (2) detection of He have been examined.*

What is GDOES?

Emission spectrum is measured by grating and photon detectors.

Low energy, high flux incident ions give minimum damage to sample.





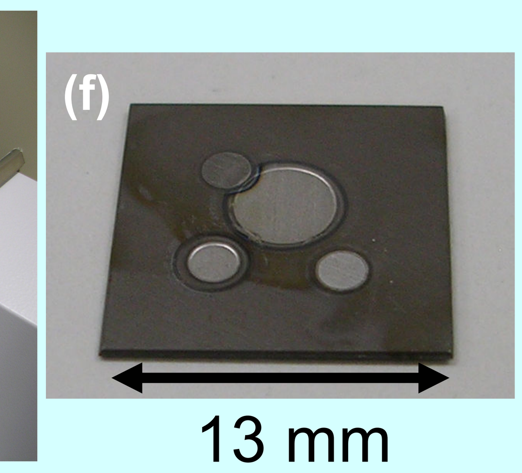


Fig. 1 Principle of GDOES (a), analysis procedure (b)-(e) and example of analyzed sample (f).

Size of sputtering crater
1 – 10 mm

Typical sputtering rate
25 nm/s for tungsten

HORIBA Jobin Yvon GD-Profiler2 in Instrumental Analysis Lab., U. Toyama

Isotopic Measurement of Hydrogen

Various kinds of alloys (F82H reduced activation ferritic steel, stainless steels, Zircaloy-2, etc.) were oxidized in H_2O and/or D_2O at around 300 ºC for various period of time.

Depth profiles of H and D were analyzed by adjusting optics arrangements under conventional plasma conditions (600 Pa Ar, 35 W, anode diameter 4 mm).

H and D were detected distinctly, and profiles at oxide-metal interface were successfully measured. GDOES allows profile measurements of hydrogen isotopes at interface between dissimilar materials such as deposited layer and PFMs. This type of measurement is difficult with SIMS due to difference in secondary ion yields.

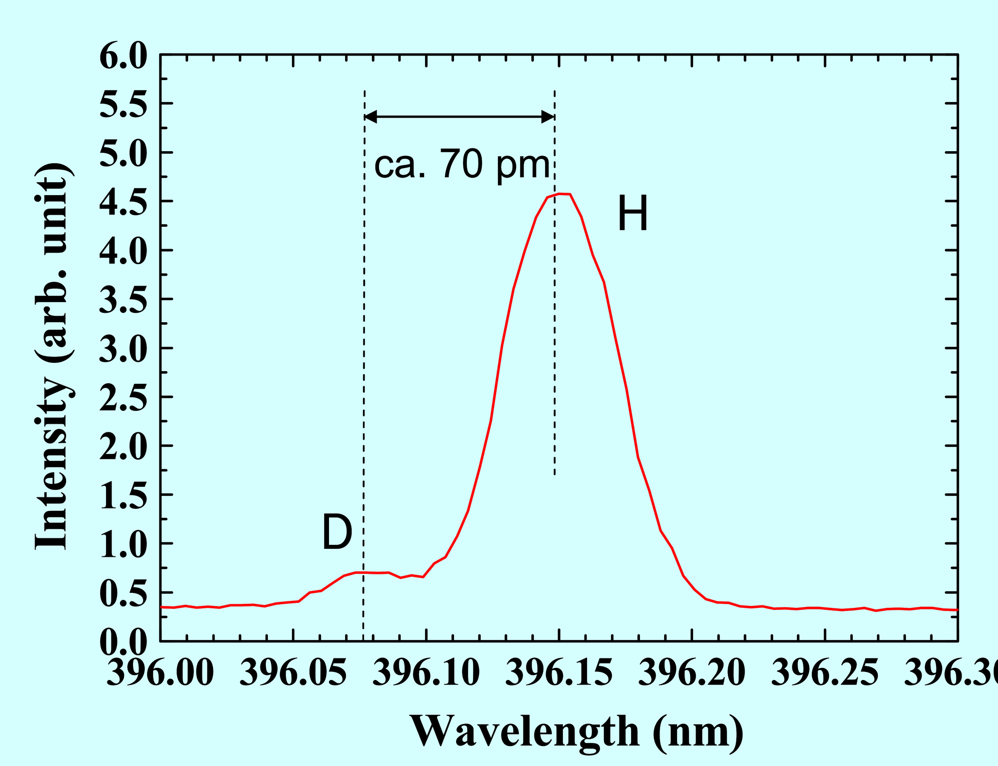


Fig. 2 Emission spectrum from Zircaloy-2 oxidized first in H_2O and then in D_2O.

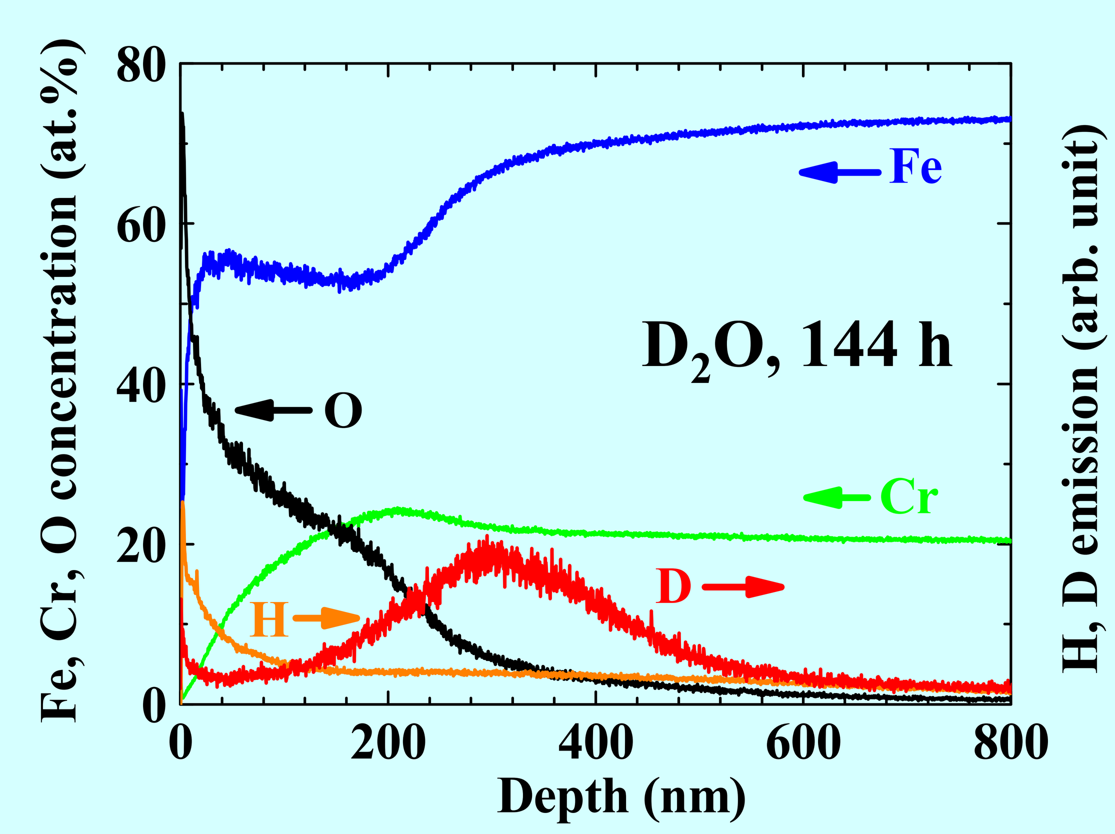


Fig. 3 Depth profiles of H and D in type 304 stainless steel oxidized in D_2O for 144 h.

Summary 1: Profiles of H and D could be measured distinctly !

He Measurement

Measurement of He with GDOES is relatively difficult because energy for He excitation (> 20 eV) is high compared with the first ionization potential of Ar (15.8 eV). Hence, we employed high power, high pressure Ne plasma to detect He because of higher ionization potential of Ne (21.6 eV).

The depth profile of He implanted into tungsten up to fluence of 3×10^{21} m^{-2} at 8 keV and room temperature was measured under the following conditions:

He I (587.562 nm), Anode diameter: 10 mm
Ne plasma (1200 Pa, 80 W).

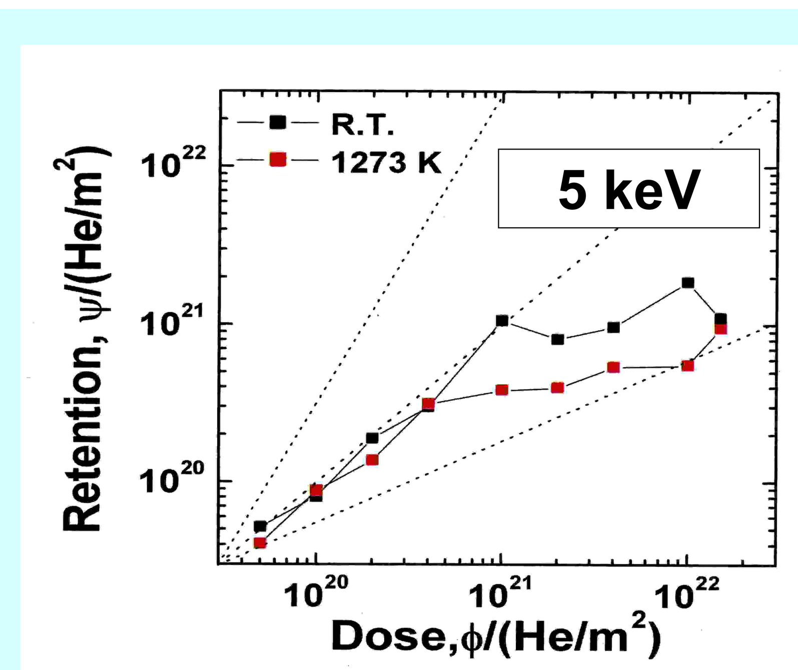


Fig. 4 Retention curves of He by W.

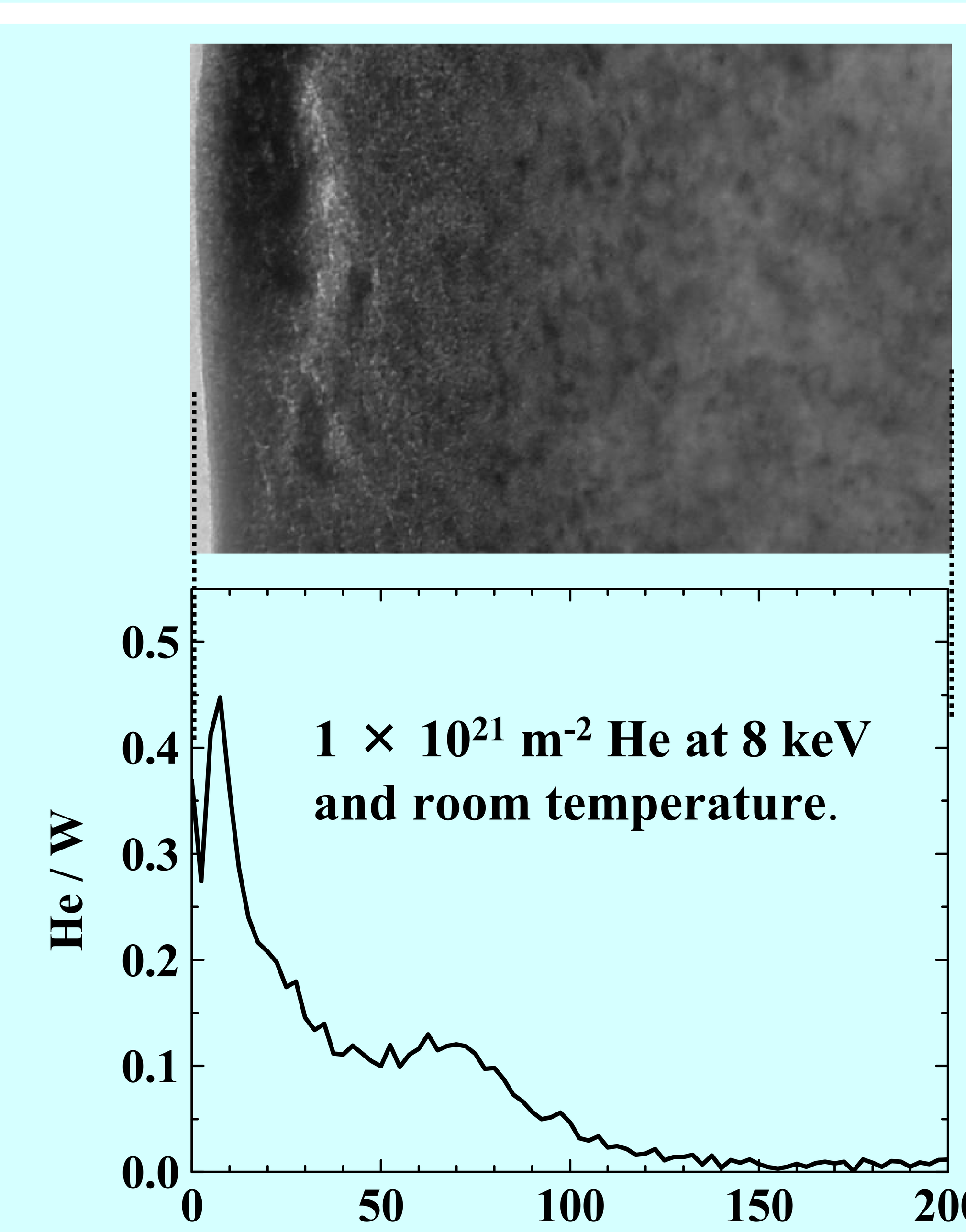


Fig. 5 Depth profile of He in W and TEM image with the same depth scale.

Summary 2:Profiles of He was successfully measured with Ne plasma !

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