POSTER

CHANGE OF THE FRACTAL DIMENSIONS DUE TO PLASMA-WALL INTERACTION

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Introduction

It is very important to understand the recycling of the divertor tile in a fusion reactor because of the density control and plasma confinement. Many works on the relationship of the materials and hydrogen/deuterium are reported in recent 20 years[1]. However, it is not successful to foresee the recycling rate from these fundamental data. Because first the fluxes of the ions and/or electrons in divertor region are higher than that of the experiment in a laboratory, second, it is well known that the materials are damaged by plasma exposure e.g. the sputtering, arcing, etc., therefore, the characteristics of the materials will be changed during plasma exposure. In particular, the surface structure of the materials will be changed drastically. The study on this change of the materials due to plasma exposure is not sufficient today.

For simplicity, the sputtering due to plasma is thought of the following discreet model. At first step, the ions in a plasma sputtered the materials with average sputtering rate η. Second step, the plasma ions and the sputtered atoms and/or ions sputtered with average sputtering rate η, ζ respectively. ζ is meant self sputtering rate. Next step, and next step, and so on. On the k'th step, the average sputtering rate is approximately $\eta(1+\zeta+\zeta^2+ +\zeta^{k-1})$. In this expression, if η and ζ are regard as the transformation, this expression represent the self similarity. If k is infinite, this expression is regard as the fractal. The re-deposition process is also able to think about similar model. Therefore, it is expected that the change of the materials surface becomes to be fractal due to the plasma exposure.

On the other hand Avnir and their colleague[2] reported that the surfaces are fractal over many kinds of materials. The fractal dimension is thought to be related to the adsorption, diffusion, retention of hydrogen/deuterium and tritium. It is useful therefore to investigate the fractal dimensions of the surfaces and it's change due to plasma-wall interaction.

Experimental Method

The ETP-10 and B_4C conversion ETP-10 (graphite, IBIDEN) are selected as the sample materials, because these are used as the first and/or divertor tile of the large tokamak JT-60U. The size of each sample is ϕ10 diameter and thickness is 3 mm.

The hydrogen plasma is generated by DC arc and/or glow discharge (as shown in Fig.1). The electrode used is SUS304, and its size is ϕ60. The base pressure of the vacuum vessel is below 1×10^{-5} Pa, and the discharge pressure is 10^{-3}-2000 Pa. At 500 Pa discharge, the electron and ion densities are about 10^{10} cm^{-3} and the electron temperature is about 2-3 eV by electrical probe measurement. The neutral hydrogen temperature measured by the Doppler shift (Hα, Hβ, Hγ) is about 2-3eV. Therefore, the ion and electron temperature is the same under the high pressure discharge.

The surface area of the sample is measured by several adsorbates. The methanol, ethanol, isopropanol, and n-heptane are used. In our apparatus, the adsorption quantity is measured by TCD (the gas chromatography). He is used as the carrier gas of the adsorbates. This apparatus is shown in Fig.2. Typical He flow is 10-30ml/min.

Preliminary Results and Discussion

The fractal dimension of the surface is calculated by the adsorption quantity of the several adsorbates.

$$n = \sigma^{-D/2}$$

where n is the monolayer value and σ is the cross-sectional area[3] of the adsorbed molecule forming that monolayer and D is the surface fractal dimension. Therefore, it is needed that the adsorption quantities for several adsorbates which have the similar characteristics of the surface adsorption are to be measured.

Before plasma exposure, the typical adsorption quantities of the B_4C sample are below 0.1ml(stp) and 0.04ml/cm^2(stp), respectively. The temperature of the sample for adsorption equilibrium is 303K. The range of the relative pressure of adsorbates is about 0.15-0.35. The observed data are both meet BET plot and Langmuir plot. The monolayer adsorption capacity of Bet plot is smaller than that of Langmuir plot, and the fractal dimension of the B_4C sample is about 1.7±0.3 from BET plot and 2.0±0.3 from Langmuir plot. In general, the fractal dimension of 2 is thought to be flat surface, and if the dimension is increase by below 3, the surface roughness is thought to be increased. However, the adsorption quantities are small, the error of the fractal dimension is large.

On the other hand the adsorption of B_4C non-conversion sample (ETP-10) have not been observed because of the lower limit of our apparatus.

Therefore, the improvement of the measurement apparatus should be needed, and the modification is developing now. It is further problem for our device to generate the high temperature plasma like that of the divertor region in a fusion machine.

References

1) for example, D.E.Post and R.Behrisch, Physics of Plasma-Wall Interactions in Controlled Fusion, 1st ed. (Plenum, New York, 1984)
2) D. Avnir, The Fractal Approach to Heterogeneous Chemistry, 1st ed.(Wiley, New York, 1989) p271
3) A.L.Mcclellan and H.F.Harnsberger, J.Colloid and Interface Science 23 (1967) 577

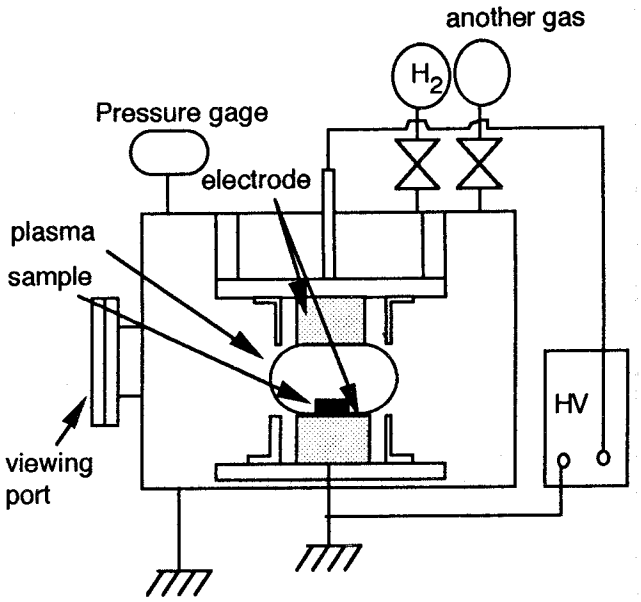

Fig.1 Experimental device by DC discharge

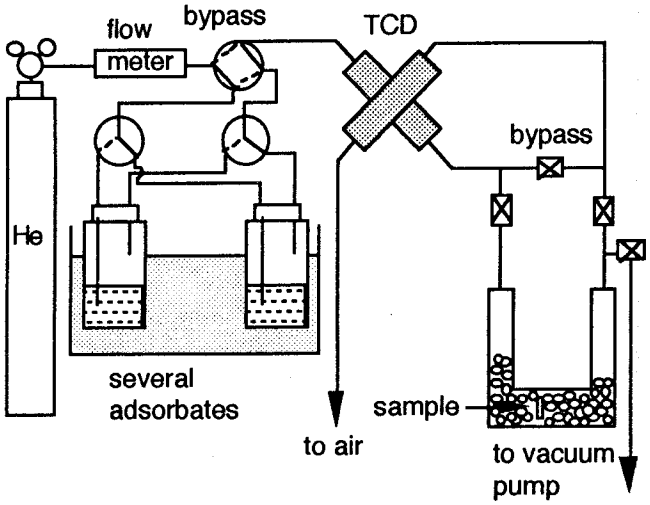

Fig.2 Adsorption measurement apparatus