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Surface analysis techniques and in-situ measurements of dust particles in fusion devices

核融合プラズマ装置で発生したダストに対する表面分析評価および その場計測法について

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Investigation of dust particles in the fusion device is potential problems for impurity accumulations and tritium retentions. In this talk, two kinds of topics are presented. The first is the surface analysis method using collected dust particles after vacuum vent. The second is the in-situ measurement of dust counting and trapping. As one example of experimental data, a dust detection using silica aerogel in LHD is shown.

1. Introduction

Dust generation in the fusion device and its ejection to the confined plasma are potential problems for impurity accumulations and tritium retentions. Movements and characteristics of the dust particles have been measured by different diagnostics such as fast visible and IR TV cameras, laser scattering, and electrostatics detector (developed by C. Skinner in PPPL) in stellarator/heliotrons and tokamaks. Surface analysis on the first wall can provide properties and compositions of dust particles, but information of the dust dynamics at the implantation or deposition is lost.

In this talk, two kinds of topics are presented. The first is the surface analysis method using collected dust particles after vacuum vent in Fusion devices. An estimation of remained dust particles and locations in vessel in ITER are important, and then many groups in fusion devices have been done these researching works. In Japan, LHD in NIFS, JT-60U in JAEA and TRIAM-1M in Kyushu Univ. were collected. Major method of surface analysis is scanning microscope (SEM) with energy dispersive spectroscopy (EDX), an optical microscope and microbalance. In the limited case, transmission electron spectroscopy (TEM), X-ray photoelectron spectroscopy (XPS), thermal desorption spectroscopy (TDS), laser Raman spectrum are used. Diameters of dust particles are reported from the order of 1 nm to a few 100 microns and then an observation of those small particles is needed additional technical method. For example, if small particles have to install in vacuum area of analyzer, such as SEM, TEM and XPS, dust particles have to be connected or coated on the other base material.

The second is the in-situ measurements of dust counting and trapping. For example, a laser scattering method counts passing dusts on the optical axis and an electrostatics detector counts dust particles attached between vias grids applied voltage. These in-situ data are important to discuss a relation between operational parameter of plasmas and produced dust particles.

Some of analytical method is the same in the researching fields of space plasmas and industries. As one example, a dust detection using silica aerogel is shown in this abstract.

2. Experimental result

Silica (SiO_2) aerogel has been used as a dust collector in space plasma research: an aerogel (a silicon-based solid with porous) has sponge-like structure in which 99 % of the volume is empty space. In fusion devices, the same type of silica aerogel has been tested to detect accelerated dust particles and their trajectories, i.e. incident dust particles are trapped into the aerogel, and they are remained after vacuum vent. Information of the dust transport such as trapped angle and velocity as well as the particle properties such as size, shape and morphology can be evaluated by surface analysis. Four kinds of Silica aerogels with different densities, 0.020-0.061g/cc, were provided by KEK/JAXA. In this experiment, the highest surface density (0.0061g/cc) was chosen.

Two kinds of materials, i.e. Silica aerogel (15 mm x15 mm, t = 15 mm) and Si samples (10 mm x20 mm, t = 0.6 mm), are installed on the same holder. This holder is set on the movable probe system at the 4.5 lower port and the top of this holder was kept at the first wall level during LHD experiments. The total exposure time during hydrogen plasma discharges is about 300 seconds and a surface temperature is about room temperature. After this experiment, Silica aerogels were extracted from high vacuum level, 10^{-6} Pa to atmosphere of 10^{4} Pa. Surface morphologies on the surface of aerogel were measured by digital microscope (THX-1000, KEYENCE). One of these images are shown in Fig.1. The dust size of 10 x 20 micron is observed and the dust surface is the same level of the aerogel surface. Thus, it is considered the dust particle itself is trapped into the base aerogel.

Number density of dust particles trapped on the aerogel is two times larger than that on the Si target. This method is applicable for analysis of the dust deposition process without disturbance at changing pressure from a high vacuum area to atmosphere.

For comparison of the aerogel exposed to the plasma, image of as-reserved aerogel surface is shown in Fig.2. It is found that only the aerogel exposed to plasma have many small wrinkles on the surface and small dots are broken pieces of aerogel itself. At the last campaign in 2009FY, the same type aerogel was exposed to glow discharges in LHD. From the comparison of surface morphologies on the side and the top surfaces on the aerogel, only the top surface have wrinkles, while the side surface looks flat surface similar to the as-received aerogel. These results show that these wrinkles are produced by the plasma exposure. Following two reasons are considered. One is due to deposition of particle flux such as plasma ions, neutrals and impurities during plasma experiments or glow discharges. Second is due to the thermal effect, i.e. heat load caused by plasma and radiation. Since aerogel material is low thermal conductivity, even small heat load on the surface increases the surface temperature. At present, thermal effect is considered as the main reason.

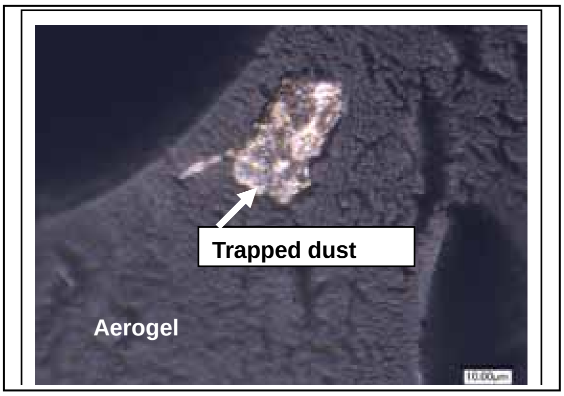

Fig.1 Surface morphology of trapped dust particle into silica aerogel. Magnification of the scope is 2000.

Fig.2 Surface morpholory of as-reserved silica aerogel. White background is aerogel surface.