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Correlations of Dust Particles at DIII-D With Plasma Parameters* EX-D

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The first quantitative measurements of submicron dust size distribution and spatially localized number densities during normal plasma operation have been made using Rayleigh/ Mie scattering from a pulsed Nd:YAG laser in DIII-D. Dust represents potential safety issues as it can contribute to tritium inventory at ITER as well as the possibility of spontaneous ignition upon exposure to oxygen or steam [1]. The creation and transport of submicron-sized dust represents a source of plasma contamination that has not previously been included in tokamak impurity modeling. Modeling of the observed pulse height distribution indicates an average particle size of ~80 nm during normal plasma operation with particles of 1 micron or greater radius being rare. The average number density is small, ~4x10^3 m^{-3} indicating that dust is unlikely to be a major contributor to plasma contamination.

DIII-D carbon tile walls and divertors are a good test bed for dust generation during plasma operation for carbon components on ITER. The DIII-D vessel is covered with carbon tiles on all plasma facing components, Hence, dust collected from the vessel is comprised primarily of carbon from the plasma facing components, allowing the study of density and transport from a single, significant plasma facing material. Existing dust size analysis of dust collected during entry vents of major tokamaks show the final dust distribution of normal plasma operation, off-normal events, and non-plasma related dust sources.

Dust particles are observed by Rayleigh/Mie scattering from the pulsed Nd:YAG lasers used for Thomson scattering. Rayleigh scattering from a pulsed, high-powered laser is sensitive to much smaller particles than observvation of glowing particles using video cameras. Large signals are observed in the 13 detection channels which have a narrow band interference filter centered at the laser wavelength and view the scrape-off layer (SOL) region outside of the separatrix and the eight channels which view the lower divertor region. The sensitivity of these channels is calibrated using Rayleigh scattering from argon gas that is admitted into the vacuum vessel at a pressure of about 2 torr. Fusion neutrons provide the primary background signal for dust detection, but are very rare and monitored with a separate background channel.

The measured dust particles are significantly smaller than those injected into tokamaks for trajectory studies. The average dust particle radius is 80 nm. Micron sized dust particles which are observed by cameras and typical of the dust collected with wipes of the tiles after run campaigns are rarely seen by laser scattering. These previously unobserved dust particles are much more prevalent in the SOL than the larger particles and may significantly contribute to carbon migration during plasma operations.

Measurements indicate that the observed dust particles do not penetrate into the plasma core, with the event rate inside the plasma edge (Fig. 1) being consistent with the neutron background rate. The number density of the particles drops in the SOL to zero near the last closed flux surface. Observations in the SOL correspond to a dust particle density of 4000 m^{-3}. Additional measurement points in the lower divertor produce size and number densities similar to the SOL.

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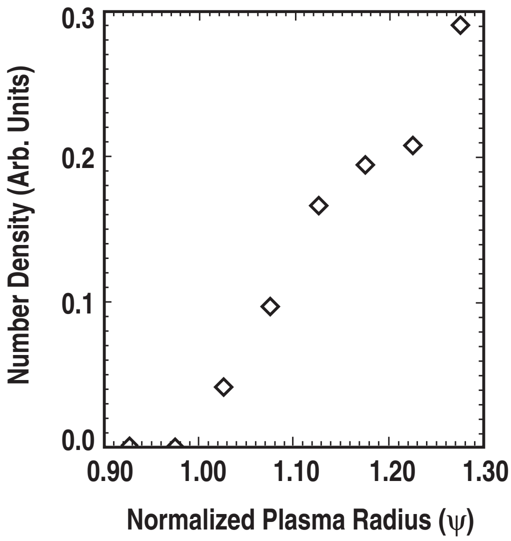

Fig. 1. Location of Observed Dust Particles

This diagnostic technique is allowing the development of a large database of observed dust events. A typical shot contains 300 core laser pulses with average rate of 0.7 observed particles per discharge in the SOL producing a sample set of 2500 dust particles from the 3630 discharges in the DIII-D 2004/2005 run campaign. Studies of the database show significant asymmetries in the dust production rates for different plasma configurations. For example, there is a significant increase in dust production with H-mode discharges relative to L-mode discharges. Plasma configuration is also very important for dust production. Upper single-null plasmas have double the dust density in the SOL of lower single-null with similar confinement. In addition, dust observation rates, increase during the first several seconds of high power discharges and reach a constant level for long pulse (8 s) discharges. These studies provide information about poorly understood production mechanisms and their parametric dependence in tokamaks.

The production of dust, dust transport, dust-plasma interactions, and dust destruction can have a significant impact on plasma performance and safety of fusion devices. Dust production from plasma-surface interactions can depend on many factors such as edge parameters, confinement, stored energy, heating, and wall heat loads.

A better understanding of dust is of great interest for ITER. Current tokamak experiments exhibit dust accumulation behind plasma facing components with significant deuterium and tritium retention. The increases in power and particle flux to the first wall and pulse duration for burning plasma experiments will likely lead to increases in dust production and accumulation.

In summary, quantitative measurements of number densities and size distributions of dust particles can be made by combining the data gathered from the Thomson scattering system on many shots. The observed pulse height distribution indicates an average size significantly smaller (80 nm median radius) than the size of glowing particles observed with cameras and collected from wipes after plasma operations. The number density drops in the SOL to zero near the last closed flux surface. The number density is correlated with global plasma parameters including shape and confinement. Continued studies of the core and divertor data will provide a better understanding of the significant plasma parameters for dust production from the carbon tiles at DIII-D. Continuing work on the dust database will include adding plasma operational data and searching for correlations with production rate. These correlations may provide insight into the production mechanisms.

[1] G. Federici, et al., Nucl. Fusion **41**, 1967 (2001).