Modeling of dust in tokamak plasmas*

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Dust has been identified as having a potentially large impact on ITER-scale plasma experiments. Understanding and predicting the role of dust require models of dust production mechanisms, dust interactions with plasma and surfaces, and dust transport within and outside the plasma. Here, recent theoretical studies and experimental observations of dust in fusion plasmas are reviewed and a physical model used to describe dust transport in fusion devices is described. The model includes the dynamics of dust due to dust-plasma, dust-turbulence, and dust-surface interactions. These processes have been incorporated into the DUST Transport (DUSTT) code that includes the following capabilities: a 2D curvilinear non-uniform mesh based on MHD equilibrium; plasma and neutral-gas parameters calculated by the edge plasma/neutrals transport code UEDGE; and tracking of test dust particles in 3D using the resulting force, particle and energy fluxes, and other parameters based on UEDGE data. Results of dust particle dynamics and transport simulation are shown for current tokamaks (NSTX, DIII-D, C-Mod) as well as for the ITER. These simulations demonstrate that dust particles are very mobile and accelerate to large velocities due to the ion drag force (cruise speed >100 m/s). Deep penetration of dust particles toward the plasma core is predicted. It is shown that DUSTT is capable of reproducing many features of recent dust-related experiments. The simulation of dust particle penetration into the ITER burning plasma shows that dust particles launched either from the main chamber walls or from the dome can penetrate all the way to the separatrix. Penetration of dust toward the core plasma can represent a significantly enhanced impurity source there. As follows from our UEDGE simulations, a feedback can occur where radiation from ionized dust-impurities can reduce the divertor temperature, which in turn allows further penetration of the dust and associated impurities. Such a feedback can result in strongly detached plasma conditions.

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