Abstract

Nuclear fusion research aims to the production of electrical power by utilizing the D-T fusion reaction. In fusion devices the fusion ash He and impurities from the plasma vessel are magnetically directed to armoured targets of C or W. Typical interactions are reflection, physical sputtering, and chemical erosion. The material is eroded, transported along magnetic field lines, and redeposited at other components. Deposited C binds radioactive H isotopes and leads to the growth of C-H layers as a function of exposure condition and duration. In order to minimize the crack formation and the evolution of eddy currents, wall components are segmented into single tiles. Therefore the total surface area is increased by hidden gap areas. Consequently, more deposition on surfaces areas is possible, so that a substantial additional amount of hydrogen isotopes is retained. The tile geometry is optimized to withstand extreme heat loads and simultaneously influences the deflecting space charge between tiles. Until now, typically investigations are performed with smooth surfaces, although technically rough surfaces are installed in future devices. Hence, the influence of the surface morphology on particle-surface interaction processes and the influence of the tile geometry on the particle transport into gaps is investigated in this thesis. Performed experiments are analyzed with different simulations.

The effects of surface roughness on angular distributions of reflected and sputtered particles is investigated by ion-surface interaction experiments. The UHV experiment ALI was enhanced in order to bombard differently rough W samples with C under incidence angles of 30° and 80°. Reflected and sputtered particles are collected on foils which are measured with secondary ion mass spectrometry. For the analysis, the SIMS evaluation procedure is enhanced to enable a quantitative determination of the C isotope ratio. The absolute C-deposition is determined with a nuclear reaction analysis. To account for surface roughness, additions are made to the code SDTrimSP. Experimental as well as calculated results prove a significant influence of the roughness on the angular distribution of reflected and sputtered particles. It is demonstrated that the effective sticking of C on W is a function of the angle of incidence and surface morphology. The dominance of various ion-surface interaction processes is fluence depend.

The particle transport into gaps of adjacent tiles is investigated in plasma experiments TEXTOR and DIII-D. Two tile geometries are exposed to the scrape-off layer plasma under various inclination to the toroidal magnetic field. The deposited amount of C and D in gaps is quantified by electron probe microanalysis and nuclear reaction analysis. An upgrade of the FZJ NRA facility and an enhancement of the analysis procedure of μ-NRA measurements is conducted. Deposition profiles inside gaps are simulated with the Monte Carlo code 3D-GAPS in combination with ion flux distributions resulting from the particle-in-cell code SPICE2. Experimentally as well as theoretically it is shown, that the deposited amount of C is halved due to an optimized gap geometry. The discrepancy between simulated and experimental deposition profiles is attributed to the effects of the surface roughness. It is demonstrated, that the surface roughness has a significant influence on ion-surface interaction processes on large scales.