Measurements and Simulations of Carbon Flow in the Main Scrape-off Layer of the DIII-D Tokamak*

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Carbon ion velocities of the order 5-15 km/s parallel to **B** and flowing in the direction of the high-field divertor were measured in the main scrape-off layer (SOL) of DIII-D low-density, low and high-confinement plasmas with the ion **B**x∇B drift toward the divertor. Understanding the physics of these carbon flows in the main SOL is critical to predicting carbon migration and hydrogen retention in tokamaks with carbon plasma-facing components. Flow velocities of singly and doubly ionized carbon along **B** were obtained from Doppler spectroscopy viewing the crown of the plasma in a tangential geometry. The measured carbon velocities are consistent with entrainment of the carbon ions in the deuteron flow of Mach ~0.5 measured at the plasma crown using a reciprocating Mach probe. Images of emission from successive carbon charge states C^0 to C^{3+} during methane injection with tangentially viewing cameras demonstrated that injected carbon ions are fully entrained in the background plasma flow toward the high-field divertor.

Simulations of the low-confinement plasma with the UEDGE code predict that the poloidal flow of low-charge state carbon ions in the far SOL at the crown is in the direction of the outer divertor, opposite to the observations, and determined by the drag exerted by the deuterons and the ion temperature gradient force. In this application, radial transport was modeled with UEDGE using diffusive trial solutions with ad-hoc, radially varying diffusivities and drifts due to **E**x**B** and **B**x∇B, while in the parallel direction the Braginskii equations were solved. The calculated deuteron flow in parallel-**B** direction at the crown is nearly stagnant, Mach ~ 0.1. Poloidally, deuteron flow toward the crown is driven by pressure imbalance between the inner and outer X-point regions and the crown produced by radial ion **B**x∇B drifts and diffusion. Near the separatrix, the poloidal flow of higher-charge state carbon ions, carrying the bulk of the total carbon flow, is dominated by $\mathbf{E}_r$x**B** cross-field drifts toward the inner target. Assuming ballooning-like radial transport at the outer midplane and pumping at the inner target plate can drive deuteron and carbon flow at the crown toward the inner divertor, their radial profiles fail to match the measurements. The dependence of the simulated flows on the assumed radial transport model, wall pumping, and the momentum transfer conditions at the core boundary will be discussed.

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