“Snowflake” divertor configuration in NSTX*

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Spherical tokamaks (STs), a magnetic fusion confinement concept with low aspect ratio ($A < 2$), are viewed as potentially attractive devices for fusion development applications complementary to large aspect ratio tokamaks. The compact geometry of the ST divertor and the requirement of low normalized density (~ 0.2-0.3 n_e / n_G) operation for increased neutral beam current drive efficiency define a unique edge transport regime with much greater demands on divertor and first-wall particle and heat flux handling. At present, candidate strategies for steady-state mitigation of divertor heat and particle loads in tokamaks include both the passive techniques, such as divertor geometry and magnetic balance, and active techniques, such as radiative divertors, field ergodization and strike point sweeping.

A novel divertor configurtion, called the “snowflake“ divertor (SFD), has been recently proposed and shown theoretically to offer significant benefits for the plasma material interface [1-4]. The SFD uses a second-order X-point created by merging, or bringing close to each other, two first-order X-points of a standard divertor (SD) configuration. The possibility of SFD has been demonstrated through modeling for DIII-D and NSTX [4] and in experiments on TCV [5]. We report on the first experiments in NSTX that obtained the SFD for periods of hundreds of milliseconds and confirmed many of the predicted SFD benefits. When compared to the high-triangularity (δ=0.7-0.8) SD configuration in NSTX [6], the obtained SFD configuration with medium triangularity (δ=0.5-0.65) had a connection length longer by factors of 1.5-2, and a poloidal magnetic flux expansion at the outer strike point higher by factors of 2-3. The 4-6 MW NBI-heated discharges with SFD maintained H-mode properties with minimal degradation of stored energy and confinement. Divertor heat flux profiles showed a large reduction in peak heat flux during the SFD periods. Divertor radiation due to carbon impurity was significantly increased in the SFD. A large volume recombination region with $T_e \sim 1.5$ eV, $n_e > 3 \times 10^{20}$ m^{-3} developed, while ion flux to the divertor plate reduced, suggesting an extended divertor scrape-off layer region detachment. As in previous divertor detachment experiments in NSTX [6], the core carbon density was reduced by up to 50 %. A critical SFD issue is magnetic control of the positions of the two X-points [1-4]. The experiments on NSTX provided insights on further SFD magnetic control optimization.

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