Measurement and Modeling of Surface Temperature Dynamics of the NSTX Liquid Lithium Divertor *

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Dual-band infrared (IR) measurements of the National Spherical Torus Experiment (NSTX) Liquid Lithium Divertor (LLD) are reported that demonstrate liquid Li is more effective at removing plasma heat flux than Li-conditioned graphite. The LLD was installed for exploration of density and impurity control, and edge plasma modification [1]. The LLD surface was heated up to and beyond the melting point of Lithium, 180.54 °C, both prior to a plasma discharge by electrical or hot air heating of its copper substrate, and by exposure to successive plasma discharges in which the LLD bulk temperature rose by ~5-10 °C per discharge. Discharges were operated with the outer strike point (OSP) on the LLD plates with up to P_{NBI}=4 MW, I_p=1.2 MA, B_T=0.5 T, and $T_{surface,LLD}$=320 °C. During the highest energy discharges, the LLD survived peak perpendicular heat flux of up to $q_{\perp,peak}$=5 MW/m^2 inter-ELM and up to 10 MW/m^2 during ELMs without damage to the porous Mo surface.

2-D temperature dynamics of the NSTX lower divertor surface (~0.27 m < R < ~0.85 m, ~210° < φ < ~228°) were measured by a fast IR imaging system [2] retrofitted with dual-band capability [3]. Extended dwell of the OSP on the LLD caused an incrementally larger area of the LLD to be hotter than the Li melting point through the discharge. Measurement of $T_{surface}$ averaged over the near-OSP LLD surface demonstrates a significant reduction of the LLD surface temperature compared to that over a Li-coated graphite tile at the same major radius. During post-discharge cooling of the LLD surface, the latent heat of fusion is indicated by a thermal decay transition to the Li melting temperature on the LLD surface, compared with simultaneous decay in Li-coated graphite temperature below the Li melting point. Initial modeling and interpretation of these data has been carried out using a 2-D numerical simulation of the LLD structure with a new code, DFLUX [4] using a realistic geometry and temperature-dependent thermal parameters. Results from the comparison between measurements and modeling suggest that the structure of the LLD was successful at efficiently removing heat from its plasma-facing surface as intended, and by determining the time for the Li layer to solidify after removal of direct heat flux, reveal an innovative method for inferring the Li layer thickness.

[1] H.W. Kugel, *et al*., J. Nucl. Mater. 415 (2011) S400.
[2] J-W. Ahn, *et al*., Rev. Sci. Instrum. 81 (2011) 023501.
[3] A.G. McLean, *et al*., Rev. Sci. Instrum. (2011), submitted.
[4] K. Gan, *et al*., Rev. Sci. Instrum. (2011), to be submitted.

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