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Effects of Ion Diffusion on Fusion Burn at the Shock Flash in Inertial-Confinement Fusion Implosions

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Understanding the physics responsible to the disagreement between experimental results and numerical simulations are of fundamental importance to inertial-confinement fusion (ICF) implosions, and particularly to the ignition-scale layered implosions currently taking place at the National Ignition Facility (NIF). The plasma kinetic effects, which have been overlooked in the conventional single-spices-averaged hydrodynamic codes, are attracting increasing attentions. It has been realized that such effects, including the ion diffusions, play important roles particularly in the early implosion phase and can potentially affect the dynamics in the later implosion phases. To quantitatively study the effects of ion diffusions at the early implosions, we have imploded a series of thin-glass shells filled with tritium-helium-3 (T^3He) gas or deuterium-trium-helium-3 (DT^3He) gas. For the first time, spectra of multiple charged-fusion products from these implosions are obtained at the time of shock flash and used to infer stratification of ions with different electric charge states (Z), ion masses (m) and charge-to-mass ratios (Z/m). These experiments provide useful information to verify the recent theoretical work by Amendt et al [1] on plasma diffusion crossing the shock front due to the thermodynamic gradients. While there are a number of diffusion sources, including the conventional concentration diffusion (due to concentration gradient), barodiffusion (due to pressure gradient), electrodiffusion (due to electric field), and thermodiffusion (due to temperature gradient), the preliminary analysis suggest that barodiffusion and electrodiffusion are the dominant sources in these implosions. These experiments provide new physical insight into the effects of the ion diffusion on species stratification in shocked/reshocked hot plasmas and have important implication to the ongoing experiments at the NIF.

[1] P. A. Amendt et al., Phys. Rev. Lett. 109, 075002 (2013).

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