Plasma kinetic effects on interfacial mix in one and two spatial dimensions*

Lin YIN, Brian ALBRIGHT, Erik VOLD, William TAITANO, Luis CHACON, and Andrei SIMAKOV

Los Alamos National Laboratory, USA

E-mail: lyin@lano.gov

Mixing at interfaces in dense plasma media is a problem central to inertial confinement fusion (ICF) and high energy density laboratory experiments. In this work, particle-in-cell VPIC [1] simulations in one- and two-spatial dimensions (1D and 2D) with a binary collision model are used to explore kinetic effects arising during the mixing of unmagnetized plasma media. In 1D, comparisons [2] are made to the results of recent analytic theory in the small Knudsen number limit [3]. While the bulk mixing properties of interfaces are in general agreement, some differences arise, primarily near the low-concentration fronts of the diffusing ions during the early evolution of a sharp interface (within a few hundred cross-species ion collision times). The theory is strictly valid only in the limit of small Knudsen numbers and it predicts small diffusion velocities compared with the ion thermal speeds. In kinetic simulations, however, we found that the diffusion velocities can be larger or comparable to the ion thermal speeds, and the Knudsen number can be large; this occurs when the species' perpendicular scattering rate dominates over the slowing down rate. As a consequence, super-diffusive growth in mix widths ($\Delta x \sim t^a$ where a $\geq 1/2$) is seen before transition to the slow diffusive process ($\Delta x \sim t^{1/2}$) in the small Knudsen number limit predicted from fluid theory. For both short and long timescales, mixing at interfaces leads to persistent, bulk, hydrodynamic features in the center of mass flow profiles. This behavior arises as a result of the diffusion process and conservation of momentum. In other words, interfacial mixing inevitably generates modifications to the bulk hydrodynamics, a result that has not been examined extensively in prior studies. These conclusions are drawn from VPIC results together with simulations from the RAGE code [4] with a new implementation of diffusion and viscosity from theory [3] and a novel implicit Vlasov-Fokker-Planck (iFP) code [5]. The applicability of the 1D ambipolarity criterion (from which theoretical plasma transport models have been derived) was evaluated in 2D VPIC simulations of a plasma interface with a sinusoidal perturbation. Kinetic effects on interfacial mix were also examined in 2D. Results of these studies, including comparisons with 1D kinetic models and with 2D RAGE calculations, will be presented and discussed.

*Work performed under the auspices of the U.S. DOE by the Los Alamos National Security, LLC Los Alamos National Laboratory and supported by the LDRD and ASC programs.

References

[1] K. J. Bowers et al., Phys. Plasmas **15**, 055703 (2008)

[2] L. Yin et al., Phys. Plasmas **23**, 112302 (2016)

[3] K. Molvig et al., Phys. Rev. Lett. **113**, 145001 (2014); K. Molvig, A. N. Simakov, and E. L. Vold, Phys. Plasmas **21**, 092709 (2014)

[4] E. L. Vold et al., Phys. Plasmas **24,** 042702 (2017)

[5] W. T. Taitano et al., J. Comput. Phys. **318**, 391 (2016).