Modeling Thermal Ionization in Hypersonic Shock Tubes

G. Colonna[1], A. Laricchiuta[1], L.D. Pietanza[1], R. Celiberto[1,2], D. Ninni[3], F. Bonelli[3], G. Pascazio[3]

[1] *CNR-ISTP, Bari, Italy*

[2] *DICATECH Politecnico di Bari, Bari, Italy,*

[3] *DMMM Politecnico di Bari, Bari, Italy*

In the next future, NASA is planning an exploration mission to ice giants (Uranus, Neptune) [1]. A critical aspect of the mission is the atmospheric entry. Large part of the kinetic energy of the space vehicle approaching a planet is dissipated in the upper atmosphere by the formation of a shock wave and temperature in the gas surrounding the vehicle jumps to tens of thousands Kelvins, slowly converted in internal and chemical energy, with a relevant contribution of the radiation [2]. The chemical processes inside the shock wave affect the temperature at the vehicle surface (of the order of 1000 K) as well as the heat flux. The knowledge of these quantities is a critical aspect for determining the size of the thermal protection system (TPS), with consequences on the mission costs. During Earth entry from low orbits, in the shock wave only dissociation is activated, but for ice giant entry the speed of the vehicle is very high, due to the large mass of these planets, so that also ionization becomes important [3]. While the dissociation regime has been widely investigated, atmospheric entries with ionizing shock wave are poorly known. Hypersonic ground test facilities (wind tunnels, shock tubes) are used to characterize the plasma during entry conditions and to validate theoretical models.

In this work we want to present a chemical model for shock tube in H_2/He, in conditions of ice giant entry. The model, including the level kinetics of relevant species, has been tested in 1D shock wave, coupling self-consistently the master equations with the Boltzmann equation for free electrons, and in 2D Navier-Stokes solver, accelerated by GPU's, assuming thermal electrons [4].

References

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