Thermal-electric modeling of graphite: Analysis of charge carrier densities and Joule heating of intrinsic graphite rods

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Abstract

Graphite is a versatile material with many applications. Its intrinsic density has been extensively studied and quantified experimentally and theoretically. Experimental data suggest that the electron and hole densities are roughly equal, but the degree of inequality or the magnitude of the difference has not been quantified before for intrinsic graphite under biased (applied voltage) conditions. In this paper, a steady-state one-dimensional drift-diffusion thermal-electric model is developed to explore and analyze the nature of the electron, hole and intrinsic carrier densities of graphite rods under an externally applied voltage. The maximum difference between hole and electron densities as a function of length and applied voltage are numerically determined, showing that the maximum absolute difference between hole and electron densities decreases as the ratio of length over electric field increases. Moreover, it is observed that the difference between hole and electron densities varies with position. The model is further utilized for the analysis of the dependency of charge carrier transport, heat transport and temperature under a variety of operating conditions. The results show that higher applied voltages lead to higher current densities and higher current densities result in higher power generation by Joule heating, leading to higher lattice temperatures and voltage gradients along the length of the graphite rod. Dimensionless and scaling analysis showed that in the range of operating conditions, convective and radiation losses were negligible, with the lattice temperature increasing significantly when Joule heating was high. Published by AIP Publishing.

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