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100 Years of the Physics of Diodes[1]

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The Child-Langmuir Law (CL), discovered 100 years ago, gives the maximum current that can be transported across a planar diode in the steady state. As a quintessential example of the impact of space-charge shielding near a charged surface, it is central to the studies of high current diodes, such as high power microwave sources, vacuum microelectronics, electron and ion sources, and high current drivers used in high-energy density physics experiments. CL remains a touchstone of fundamental sheath physics, including contemporary studies of nano-scale quantum diodes and plasmonic devices. Its solid state analog is the Mott-Gurney law, governing the maximum charge injection in solids, such as organic materials and other dielectrics, which is important to energy devices, such as solar cells and light-emitting diodes. This paper reviews the important advances in the physics of diodes since the discovery of CL, including virtual cathode formation and extension of CL to multiple dimensions, to the quantum regime, and to ultrafast processes. We will review the influence of magnetic fields, multiple species in bipolar flow, electromagnetic and time dependent effects in both short pulse and high frequency THz limits, and single electron regimes. Transitions from various emission mechanisms (thermionic, field, and photo-emission) to the space charge limited state (CL) will be addressed, especially highlighting important simulation and experimental developments in selected contemporary areas of study. This talk will stress the fundamental physical links between the physics of beams to limiting currents in other areas, such as low temperature plasmas, laser plasmas, and space propulsion. Also emphasized is the role of non-equilibrium phenomena associated with materials and plasmas in close contact.

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