Fundamentals of Space-Charge-Limited Current Measurements

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The success of semiconductor-based optoelectronic diode technologies, such as solar cells and light-emitting diodes, is partly due to improved understanding of the charge transport of semiconductors. A number of charge-transport characterization methods exist which have been used towards this development. The space-charge-limited current (SCLC) measurement is one of these methods, and is convenient for estimating charge-transport characteristics of relatively intrinsic semiconducting thin films. This is partly due to the devices used for SCLC are relatively simple to fabricate, and partly due to the measurement being simple to perform. SCLC measurements have for that reason been widely used to probe charge transport in a variety of semiconducting thin films used for optoelectronics, such as metal chalcogenides, amorphous silicon, semiconducting polymers and small organic molecules, fullerenes, and lead halide perovskites. Analytical models are, however, commonly used to analyze the data which can lead to a wrongful description of the charge-transport characteristics. We here discuss the fundamentals of SCLC measurements, how devices should be fabricated and measured, and what can be learned from them. We also discuss which analytical models are typically used and how to avoid pitfalls during analysis. We finally show how to perform detailed SCLC analysis using drift-diffusion simulations and discuss how such analysis gives improved understanding of the probed materials compared to when analytical models are used.