



Contribution ID : 173

Type : Poster

Physics-informed neural networks for drift–diffusion simulation of silicon solar cells: a current-based formulation and a comparison with finite volumes

Physics-informed neural networks (PINNs) are increasingly proposed for semiconductor device simulation, but none has yet computed the current–voltage characteristic of an illuminated solar cell or been compared on equal terms with a classical solver. We solve the full drift–diffusion system for a one-dimensional $n^+ - p$ crystalline-silicon cell (180 μm thick, with SRH, Auger and radiative recombination, AM1.5G generation and finite surface recombination) and compare the PINN with a verified DEVSIM finite-volume reference.

The conventional formulation, in which the network outputs the quasi-Fermi levels, overestimates the current by about eight orders of magnitude, because majority carriers in the emitter conduct under gradients that the network cannot resolve. We instead let the network output the current and recover the quasi-Fermi levels from a Slotboom-type integral with exponential fitting, so that current conservation and the contact conditions hold by construction. The efficiency error is 0.19% with ohmic contacts and 1.2% with finite surface recombination. When the full computational cost is counted, however, DEVSIM and data-driven surrogates outperform the PINN: with five parameters, a network fitted to 64 DEVSIM runs (2 min) predicts the efficiency within 0.17%, against 4.1% for the PINN after 103 min of training.

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Session Classification : Poster Miscellaneous