Extraction of Parasitics in Sub-millimeter Wave Devices via Full-Wave Electromagnetic Modeling

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Over the past several decades, Schottky barrier diodes (SBDs) have become the most successful room-temperature nonlinear device for the THz band, and exclusively used in mixers, detectors, and frequency multipliers. The performance of sub-mmW devices gradually degrades as the frequency range of operation is extended into THz band. Loss of performance can originate both from intrinsic device behavior (related to carrier lifetime and charge transport inside the device junction), and extrinsic factors including parasitic capacitance and inductance of device connectors. Operation frequency may be increased if utmost care is exercised to optimize the device geometry in a way to combat device parasitics. Therefore, accurate estimation of device parasitic elements are indispensable for high performance sub-mmW range circuit design. In this paper, we present a systematic method to examine geometry-dependent parasitic couplings of zero-bias sub-millimeter-wave diodes in the context of THz integrated circuits. The limiting factors for THz detection performance of diodes are identified by making use of 3D electromagnetic (EM) simulations. An empirical lumped equivalent circuit model is developed to better describe EM field interactions of the diode with the surrounding environment. Based on this "parasitic-aware" equivalent circuit model, a parameter extraction algorithm is proposed and tested. The algorithm produces the frequency-dependent parasitic elements of the diode by breaking the whole equivalent circuit down into multiple sub-circuits. In each step, diode geometry in the EM simulator is manipulated in a way to isolate several parasitic elements from the rest of the circuit. Focusing on one sub-circuit at a time, substantially reduces the complexity of least squares error fitting procedure being used to match frequency response of the equivalent circuit with that of 3D EM simulation of the diode. Numerical results, involving a zero-bias surface channel planar Schottky diode with multi-THz cutoff frequency, is presented to exemplify the operation mechanism of the proposed characterization technique.