Modeling, linking process/device and circuit

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● Research Field

Investigation of carrier transport in ultra-small devices experimentally and theoretically for developing new type of devices as well as predicting circuit performances.

In ultra-scaled devices carrier behavior is governed not only by the macroscopic mechanism conventionally described as the current flow, but microscopic carrier fluctuation is becoming important. We focus our investigation under the high-frequency operation. Under the operation, nonequilibrium carrier dynamics of device is enhanced, thus the fluctuation of carrier dynamics becomes observable.

One important phenomenon for understanding carrier dynamics is the noise. The origin of the noise is known as the carrier fluctuation in the MOSFET channel. Thus the magnitude of the noise is increasing according to the reduction of device size, which induces severe problem for circuit performances with ultra-scaled MOSFETs. We have succeeded to measure the noise characteristics accurately and modeled based on the principle. It has been proved that the noise model reproduces measurements without any model parameter for the thermal noise, which dominates in the high-frequency regime. This enables to predict thermal noise even without measurement. This achievement concluded the fact that the nonequilibrium effect is still negligible for the channel length down to 100nm-MOSFET, and the noise feature is still governed by the equilibrium carrier dynamics.

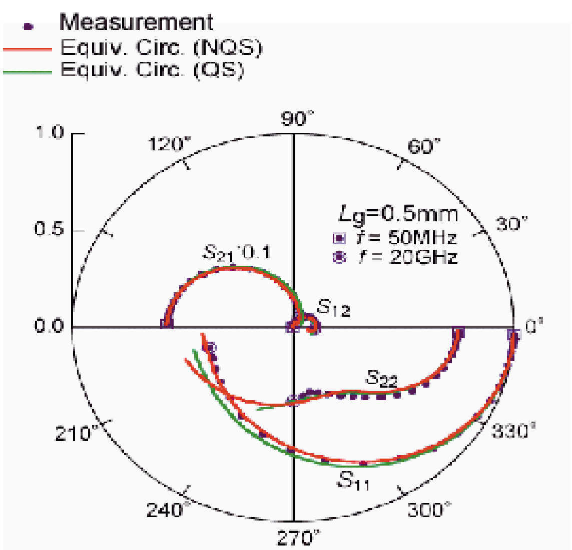
Higher-order device phenomena such as the noise and the harmonic distortion have to be considered in the RF-circuit design. All our achieved result is implemented in the circuit simulation model HiSIM, the first MOSFET model based on the complete surface-potential description developed together with the Semiconductor Technology Academic Research Center. The HiSIM source code has been released for public usage and the most of leading vendors have already implemented into their simulators.

● Objectives within the COE Project

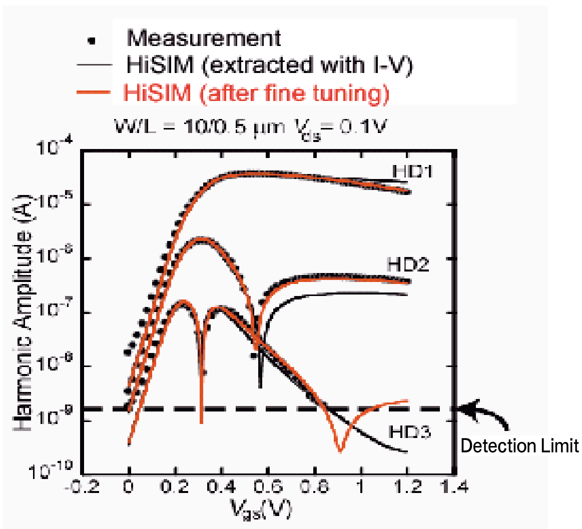
Within the COE project, our objective is to connect the process/device and the circuit fields in the development. HiSIM is used to realize the objective, providing device models used both process/device and circuit developers. The SOI-MOSFET is the first target to be modeled and is named HiSIM-SOI. HiSIM will also provide a framework merging different methods for exciting carriers, optically and electromagnetically. The final achievement will be merged as HiSIM-Microwave, enabling to simulate the 3D-custom stacked system.

● Investigations for the Project

Semiconductor development has been a leading force for new technology developments, and has been realized many unexpected progresses. Additionally many physical facts have been proved through the development. The mobility universality discovered in the MOSFET performances is one example. This discovery derived the idea of the strained silicon, challenging the device performance beyond the expected feature from the conventional silicon technology. The COE project aims to obtain a breakthrough for the technological limitation by merging all profits together. To our contribution the main breakthrough is to merge the optical response as well as the signal induced by the electromagnetic wave within the chip. Since 7 years, we have investigated measurement techniques for the optical response. With the measurements the modeling of the device response is now under development, including the nonequilibrium carrier dynamics. The signal induced through antenna is expected to induce a lot of noise. Measurement technique is investigated first to characterize the effect.



(1) S-parameters from measurements and the HiSIM model. The NQS results include 5 additional elements describing the high freguency response in the equivalent circuit.



(2) Harmonic Distortions (HD1: first, HD2: second, HD3: third) from measurements and the HiSIM model. The HiSIM parameter set extracted from measured I-V characteristics results in good reproducibility, which are improved by fine tuning of the parameter.