Sub-terahertz testing of millimeter wave monolithic and VLSI circuits

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As was shown in [1], silicon MOS transistors with identical above-threshold characteristics but a different subthreshold leakage have a dramatically different response to sub-THz radiation. The response mechanism is the rectification of the overdamped plasma waves, which is quenched by the leakage current [2]. Our recent experimental data [3] showed that a sub-THz beam (of under 1 mW power) impinging on a microwave monolithic integrated circuit (MMIC) induces easily detectable DC voltages at the MMIC pins, which are very different for the working and defective MMICs and could identify a faulty transistor. Our simulations (using THz SPICE [4]) confirm that tracing these voltages identifies specific defects. The spatial resolution of this technique is better than a micron and could reach the nanometer scale because it is determined by the transistor gate size.

We now propose augmenting this testing technique by using polarization dependencies of the response at the MMIC or VLSI pins. The goal is to generate unique signatures for good and genuine parts and for parts with specific VLSI defects. We will also discuss the application of this technique for testing BJT and HFET ICs. This new technique, which enables a fast and robust testing process, will become increasingly useful and important with increasing VLSI complexity and diminishing reliability, as minimum device feature sizes scale to 10 nm or even smaller and the number of transistors on chip increases to reach 1 trillion.

1. W. Stillman, D. Veksler, T. A. Elkhatib, K. Salama, F. Guarin, and M. S. Shur, "Sub-terahertz testing of silicon MOSFET", *Electronics Lett.* **44**, 1325 (2008).
2. M. I. Dyakonov and M. S. Shur, "Detection, mixing, and frequency multiplication of THz radiation by two-dimensional electronic fluid", *IEEE Trans. Electron Dev*. **43**, 380 (1996).
3. S. Rumyantsev, A. Muraviev, S. Rudin, G. Rupper, M. Reed, J. Suarez, and M. S. Shur, "Terahertz beam testing of millimeter wave monolithic integrated circuits", *IEEE Sensors J.* **17**, 5487 (2017).
4. M. S. Shur, "Terahertz compact SPICE model", invited presentation at *23rd Intern. Conf. Mixed Design Integr. Circ. Syst. (MIXDES-23)*, Lodz, Poland, 2016, pp. 27–31.