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Characterization Process of MOSFET with Virtual Instrumentation for DP4T RF Switch—A Review

Viranjay M. Srivastava[1], K. S. Yadav[2], G. Singh[1]
[1]*Department of Electronics and Communication Engineering, Jaypee University of Information Technology, Solan, India*
[2]*VLSI Design Group, Central Electronics Engineering Research Institute (CEERI), Pilani, India*
E-mail: viranjay@ieee.org
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Abstract

With the increasing interest in radio frequency switch by using the CMOS circuit technology for the wireless communication systems is in demand. A traditional n-MOS Single-Pole Double-Throw (SPDT) switch has good performances but only for a single operating frequency. For multiple operating frequencies, to transmitting or receiving information through the multiple antennas systems, known as MIMO system, a new RF switch is required which should be capable of operating with multiple antennas and frequencies as well as minimizing signal distortions and power consumption. We already have proposed a Double-Pole Four-Throw (DP4T) RF switch and in this research article we are discussing a process for the characterization of the MOSFET with Virtual Instrumentation. The procedure to characterize oxide and conductor layers that are grown or deposited on semiconductors is by studying the characteristics of a MOS capacitor that is formed of the conductor (Metal)-insulator-semiconductor layers for the purpose of RF CMOS as a switch is presented. For a capacitor formed of Metal-silicon dioxide-silicon layers with a thick oxide measured optically. Some of the calculated material parameters are away from the expected values. These errors might be due to several factors such as a possible offset capacitance of the probes due to improper contact with the wafer which is measured by using the LCR (Inductance-Capacitance-Resistance) meter with the help of Visual Engineering Environment Programming (VEE Pro, a Agilent product).

Keywords: RF CMOS, LCR Meter, VEE Pro, Resistance of MOSFET, DP4T Switch, RF Switch, VLSI

1. Introduction

Currently, instruments as well as instrumentation technique have been replaced at an increasing pace by hardware/ software mixed measurement oriented systems. The software component provides the hardware extended measuring capabilities and the instruments are thus named virtual instruments [1]. With its growth and wide applications, virtualization has come through a revival in computer system community. Virtualization offers a lot of benefits including flexibility, security, ease to configuration and management, reduction of cost and so forth, but at the same time it also brings a certain degree of performance overhead. Furthermore, Virtual Machine Monitor (VMM) is the core component of virtual machine (VM) system and its effectiveness greatly impacts the performance of complete system [2]. Designed for measurement precision, we use LCR meters which is suitable for production applications as well as research and development purpose. As shown in **Figure 1**, this offers excellent performance at an affordable cost [3-5]. It has the properties of wide selection of frequency range from few Hz to 3 GHz, frequency list sweep for continuous testing at multiple frequency points used for general purpose testing of surface-mount components, leaded components, materials, general purpose interface bus (GPIB) and handler interface for easy test automation in production environment with 0.05% basic accuracy. By this device we can measure the parameters as impedance (Z), admittance (Y), θ, resistance (R), Inductance (L), capacitance (C), transconductance (X), magnetc field (B), quality factor (Q), DC resistance (R_{dc}), DC currnt (I_{dc}), DC voltage (V_{dc}) [6,7].

This LCR meter supports the VEE programming environment, which provides simulated signal sources and displays. We can experiment with program flow and data

Figure 1. LCR meter.

processing with only LCR meter and VEE programming. VEE provides an Instrument Manager and a Dynamic input/output (I/O) server to simplify the tasks of discovering, configuring, and managing external instruments [8-10]. The VEE supports several types of instrument drivers. Earlier, when the instruments were not available, just press one button in the Instrument Manager to take a driver "off line" and continue developing the program.

2. Earlier Works

Previous approaches to RF-MOSFET modeling involve adding lump elements to a compact model for digital and analog circuit designs, such as BSIM3, BSIM4, and MM9, and they focus on how to build a reasonable sub-circuit and how to extract their values according to equivalent circuits [11-13]. These methods consist of analysis and optimization. Few attempts have been made to build a scalable RF-MOSFET model, including the layout-based extrinsic elements. For RF MOSFET modeling, lots of issues need to be considered [14-16] especially the three most important parasitic components: gate resistance R_g, which influences the input impedance and noise performance of RF-MOSFETs [17,18].

Henry and Coumou [19] have presented a model for thermal conductivity, specific heat and thermal diffusivity which are the essential properties of engineered plastics, ceramics, composites and other materials, whether for end-use products or processing applications. They also presents fully automated instrumentation for direct measurement of these properties on a wide variety of materials. *Gaioni et al.* [20] has discussed a measuring system that was developed to characterize the gate current noise performances of CMOS devices with minimum feature size in the 100 nm span. These devices play an essential role in the design of present day mixed signal integrated circuits, because of the advantages associated with the scaling process. The reduction in the gate oxide thickness brought about by CMOS technology down-scaling leads to a nonnegligible gate current due to direct tunneling phenomena; this current represents a noise source which requires an accurate characterization for optimum analog design. *Cvjetkovic et al.* [21] proposed a laboratory helicopter model with two degrees of freedom was developed to teach mechanical engineering students static and dynamic characteristics and controls. They performed different measurements and experiments with the laboratory helicopter model both locally and remotely. Also, remote experiments are performed by using a web-based user interface for controlling the laboratory equipment and an IP (Internet Protocol) camera for observing the movements of the helicopter model.

Grout and Dasilva [22] have presented a language used to describe the structure and capabilities (attributes) of remote, or online, laboratories. The structure of the presented language is provided with reference to the specific case study remote laboratory. This language can be readily extended to describe current laboratory attributes in more detail and to extend the language in order to identify and present new laboratory attributes. *Pradarelli et al.* [23] have addressed the local and remote use of an Integrated Circuits (IC) Automated Test Equipment (ATE) for both educational and engineering purposes. Here, practical information regarding IC testing and network setup for remote access are detailed, together with the associated training program.

Lowe et al. [24] have discusses a novel approach to the integration of support for multi-user distributed access to a single remote laboratory instance. The approach retains the benefits of the lightweight client inherent in the underlying architecture. *Pandey et al.* [25] have presented an automated evaluation procedure to characterize MOS capacitors involving high-k gate dielectrics. Suitability of LabView environment for online web-based semiconductor device characterization is demonstrated. Implementation of the algorithm for use as a remote internet-based characterization tool, where the client and server communicate with each other via web services, was also presented.

3. Recent Overviews

Dasa and Biswas [26] have presented the impacts of an ultrathin Si interfacial layer on the electrical properties of GaAs MOS capacitors fabricated using RF-sputtered $HfAlO_x$ as the dielectric. It is found that the Si passivated GaAs MOS capacitor exhibits excellent electrical properties compared with the non-passivated ones. *Orgiu et al.* [27] has found that the charge transport across the bulk of a polymeric dielectric layer exerts a strong influence on the performances of the organic field-effect transistors. In particular it gives place to a large hysteresis on the transfer curves which impacts the extraction and the straight interpretation of major device parameters such as the field-effect mobility and the threshold voltage. This charge contribution was highlighted through space-charge limited current measurements carried out on MIM capacitors having a polymeric dielectric as the insulating layer.

Recently, the CMOS switch uses the technique of silicon-on-insulator (SOI), which is attractive because of the high speed performance, low power consumption, its scalability and effective potential. As compared to bulk silicon substrate, the architecture of SOI MOSFETs is more flexible due to several parameters such as thicknesses of film and buried oxide, substrate doping, and back gate bias which can be used for optimization and scaling. The short-channel effects are mitigated in ultrathin SOI films. The continuous downscaling of CMOS technology has greatly improved the RF performance of transistors. These improvements to the CMOS manufacturing process have made it an excellent choice for RF integrated circuit (RFIC) design. The success of RFIC design strongly relies on accurate device models. However, general device models provided by semiconductor foundries are not guaranteed within a certain bias and frequency range, and they also offer poor correlation between the device layouts and the RF characteristics. Transistor layout and its wiring effect are considered as one of the crucial issues for gigahertz circuit design, since they directly affect the RF transceiver performance [28-31].

Due to the single operating frequency, simple switch has a limited data transfer rate. Therefore, a Double-Pole Double-Throw (DPDT) switch is designed to solve the problem. The DPDT switch has dual antenna and dual ports, one port for transmitting and the other for receiving, which is not sufficient for MIMO systems. Hence, DP4T switch is designed to enhance the switch performance for MIMO applications [32]. This DP4T switch can send or receive two parallel data streams simultaneously.

4. Process for Characterization

In this article, we discussed the application of LCR meter as virtual instruments for the purpose of RF CMOS characterization with measurement of some parameters with VEE programming as shown in **Figure 2** [33-35].

Firstly, we put the designed die on the platform of LCR meter, and switch ON the LCR meter then setup the meter according to measurement condition. Perform the measurements by varying the voltage from +5V to –5V and then back to +5V again or from +7V to –7V depending upon applications and also varying frequency from low to high depending upon the MOS structure from 1MHz to some RF frequency as GHz [36,37]. The required parameter will display on the screen of LCR meter as well as on computer monitor where VEE programming is stored. By this process we can perform the measurement and take the reading of required parameters.

Some of the calculated material parameters were far from the expected values might be due several factors like a possible offset capacitance of the probes due to improper contact with the wafer which is measured using LCR meter with help of Visual Engineering Environment. To solve those problems, we suggest a process to recalibration of the probes, vary the voltage with smaller increments and another possibility is that the heating temperature for MOS device should approximately 200°C, because at lower temperature effect on the oxide charges will be negligible whereas at high temperature arrangement of oxide charges will perturb. To solve this problem, take the two readings of C-V curve one before heating

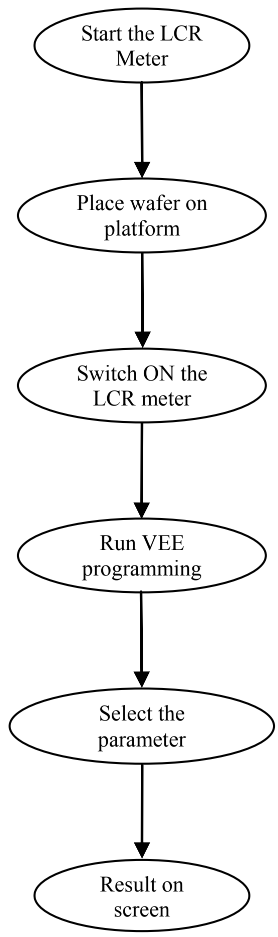

Figure 2. Program flow chart for RF CMOS characterization.

the device and other reading after heating, so that we can avoid the dislocation of charges. Also probes could have internal capacitances of their own that has not been accounted in the software of the machine, so the machine would actually be reading the series equivalent capacitance of its probes and the wafer capacitors. To solve that problem, the machine should be calibrated using reference wafers whose properties are well known.

5. Conclusions

Based on virtual instrumentation characterization of a RF CMOS, a capacitor which resulted in erroneous values of material parameters, mainly the substrate dopant concentration, on which most of the other parameters are based, we recognized those errors and correct that with a test wafer measurement for the different parameters.

A RF CMOS has the properties as fixed tuned matching networks, low Q matching networks, ruggedness, high power output, mounting flange packages, and Silicon grease. Power gain (a measure of power amplification, is the ratio of output power to input power, dB), Noise figure (a measure of the amount of noise added during normal operation, is the ratio of the signal-to-noise ratio at the input and the signal-to-noise ratio at the output, dB), High power dissipation (a measure of total power consumption, W or mW). Most of these parameters can be measured using the processes as in **Figure 2**. Some bipolar RF CMOS transistors are suitable for automotive, commercial or general industrial applications.

We can calculate the drain current, resistance, potential barrier, gate voltage and control voltage. After the characterization, we apply the device for the application of DP4T switches [32]. We can also apply this characterization process for the double-gate MOSFET and Surrounding-gate MOSFET [23,38].

Radiation characteristics and clinical implementation of an implantable MOSFET radiation detector (dosimeter) can be discussed with the proposed process. The dosimeter is powered by radio frequency telemetry eliminating the need for a power source inside the dosimeter. The data can be accessed telemetrically for each treatment day during the course of therapy. The detector has been validated in vitro to confirm its accuracy. Variance between predicted and measured dose in patients is discussed. Factors such as patient setup, treatment plan error, and physiologic motion can affect the accuracy of dose delivery in moving from in vitro to in vivo dose measurements [39]. A method for the extraction of damage metrics based upon the transient response of the drain-to-source current Ids to a step input to the gate of the device can also be performed [40]. Systematic mismatch at the drain capacitance of the IA with the current mirror load is the major contribution to a low CMRR at high frequencies. To mitigate this effect, one can use the capacitive neutralization and demonstrated its effectiveness from the fabricated CMOS instrumentation amplifier chip samples, achieving an average CMRR [41].

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