Skyworks Capacitor Model for ESD Applications

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***Abstract* — The Skyworks Capacitor model for ESD applications is described and discussed. A Skyworks ESD Capacitor is modeled as an ideal capacitor in parallel with a leakage current source, along with a resistor to the ground modeling the substrate leakage at each terminal. The current-voltage and small-signal characteristics predicted by the model coincide with measurement results. Furthermore, by employing the human body model (HBM), an ESD simulation environment is set up in order to simulate ESD tests on Skyworks ESD Capacitors. The breakdown criteria of two kinds of Skyworks ESD Capacitors are investigated and the corresponding model is investigated and developed based on experimental data.**

***Index Terms* — ESD capacitors, breakdown, Human Body Model (HBM)**

I. INTRODUCTION

The handset industry has grown rapidly in recent years. The increase in demand for handsets, together with the factor that more GaAs-based MMIC components in the RF front-end modules are needed in each handset, raises the demand for GaAs-based MMIC chips. In the midst of this cellular tsunami, the market requires these MMIC chips to possess a certain level of ESD robustness because the unique material properties of GaAs, such as its lower thermal conductivity and melting temperature in comparison to those of Silicon devices, make GaAs components more vulnerable to ESD damages [1][2]. As a result, ESD tests are becoming standardized during the production of GaAs-based MMIC. A variety of standard models were developed by the semiconductor industry during the standardization of ESD tests. In the set of standards published by the ESD Association in Rome, New York, USA, three models are based on where the charge is stored, including human body model (HBM), machine model (MM), and charged device model (CDM) [3]. In the handset industry, HBM is considered the most important model and employed by most production ESD tests as well as in this paper.

The current models for MIM capacitors for ESD applications are physics-based models [4] [5]. Despite their advantage of close association with physical parameters, they are not suitable for industrial design as some physical parameters cannot be determined easily and promptly for rapid simulation during product design. Consequently, empirical models come handier to designers under such a special environment.

II. MODELING APPROACHES

The equivalent circuit schematic of Skyworks ESD capacitors is shown in Fig.1. This structure consists of an ideal capacitor in parallel with a current source modeling the leakage current flowing through the capacitor, and two resistors modeling the substrate leakage, one at each terminal.

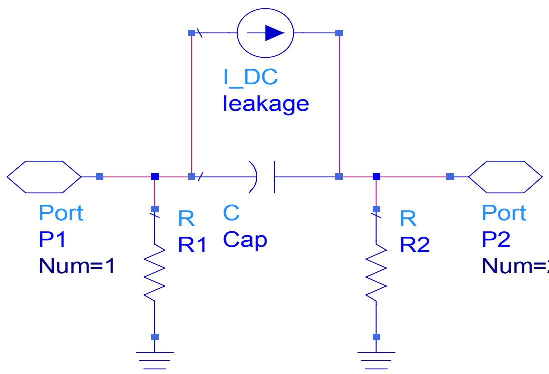

Fig.1. Equivalent circuit schematic of Skyworks ESD Capacitor Model.

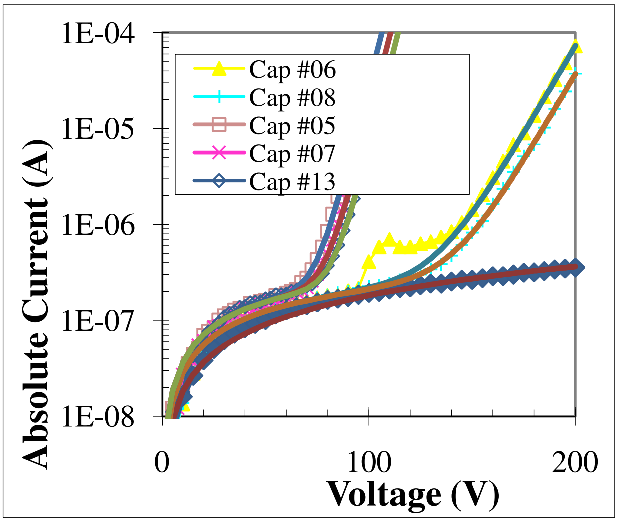

Fig.2. Log-scaled measured and modeled IV curves of five Skyworks ESD Capacitors with different areas. The substrate leakage current from metal pads to the back of the wafer is also listed for comparison

The corresponding model is developed in accordance with the schematic shown in Fig.1. The current source defines the leakage current while the capacitor decides the component's RF characteristics. The two resistors determine the substrate leakage current from metal pads to the back of the wafer. Further DC measurement with insulated stand proves the existence of substrate leakage current. Moreover, another measurement in which only a single probe is applied demonstrates stable current level of the substrate leakage current, which is shown along with modeled data in Fig.2. Log-scaled modeled and measurement IV curves of five Skyworks ESD capacitors, of two kinds and with different areas, are shown in Fig.2 as well. The model prediction and measurement data step on each other in all cases.

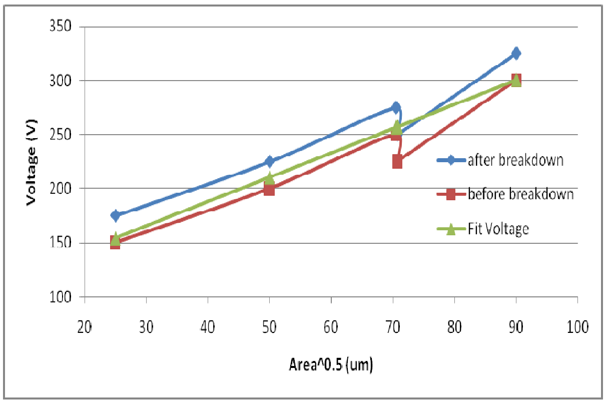

Fig.3. Measured and modeled ESD breakdown voltages of five Skyworks ED capacitors with different areas.

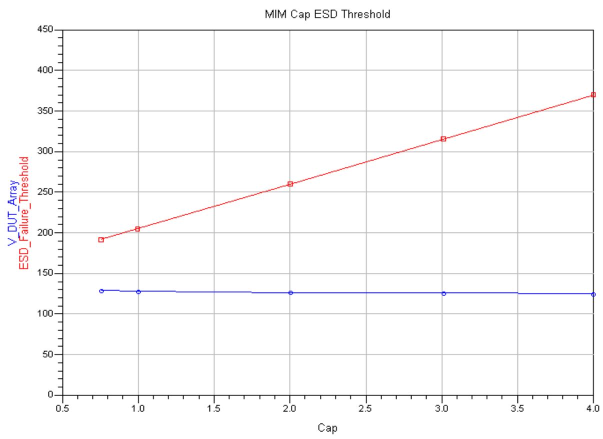

Fig.4. Simulated ESD breakdown voltages of a variety of capacitors and the voltage drop across these capacitors when they explode

As the next step, the ESD breakdown voltages of a variety of capacitors are investigated. The measured ESD breakdown voltages, demonstrated by the last ESD voltage which the devices survived and the voltage under which they fail, are shown in Fig.3. In the modeling approach, we noticed a linear relation between the ESD breakdown voltage and the square root of the area of the capacitor. The modeled relation is also shown in Fig.3. After integrating these models into ADS, we further noticed during ADS simulation that the voltage drop across capacitors of a certain kind when ESD breakdown happens almost keeps constant. The simulation result is shown in Fig.4. This simulation result actually stays in accordance with prediction of physics-based model since capacitors of the same kind share the same physical structure.

III. Conclusions

In this paper, the Skyworks Capacitor model for ESD applications is described and discussed. The model-predicted DC and RF characteristics coincide with measurement data. Furthermore, by employing the HBM for ESD tests, we modeled the ESD breakdown voltage. After we integrated these models into ADS, the IV curve proves to be crucial in the modeling of ESD capacitors because we found that breakdown of a capacitor during ESD tests is decided by the voltage drop across the device and this voltage drop is determined by the current source defining the leakage through the capacitor.

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