A Scalable RF Model of the Metal-Oxide-Metal (MOM) Capacitor

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ABSTRACT

An accurate, scalable RF subcircuit model is presented for Metal-Oxide-Metal (MOM) capacitor. Polynomial equations are used to describe the relation between the value of each subcircuit component and the area of MOM capacitor. The model fits very well the measured data in frequency range 50 MHz to 10 GHz. The scalable characteristic of model makes it very easy to be implemented in normal EDA software and provides great convenience for circuit designer.

Keywords: RF, MOM capacitor, S-parameter, Scalability, Polynomial equation, Subcircuit.

1 INTRODUCTION

RF CMOS integrated circuits have become increasingly important in modern mobile communications and accurate device models are required for designing high frequency circuits [1][2]. In the development of a model, the scalable characteristic will provide great convenience for the circuit designer and therefore greatly reduce the design cycle and time to market of product.

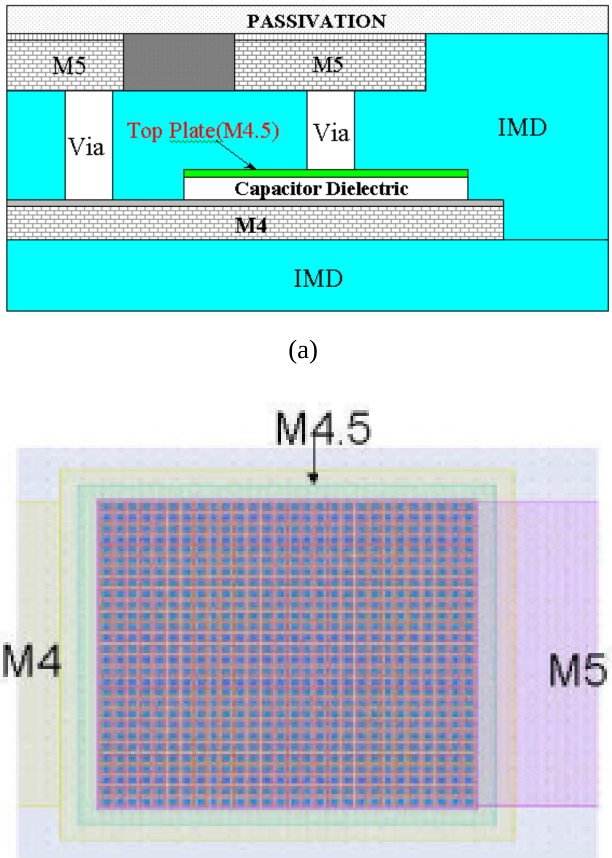
Capacitors are one of the most crucial elements in mixed-signal integrated circuits and are used extensively in many radio frequency integrated circuit (RFIC) applications such as data converters, sample and hold circuits, switched-capacitor circuits, RF oscillators and Mixers.

MOM capacitors, due to their linearity, high Q, and very small temperature variations, are very important passive components used in RF circuits [3].

In this paper, a scalable RF subcircuit model of Metal-Oxide-Metal capacitor is proposed. In this model, the value of each subcircuit component, which is scalable to the area of MOM capacitor, is modeled by a polynomial equation. The model is verified with the measured data in the frequency range from 50 MHz to 10 GHz.

2 DEVICE FABRICATION AND DESCRIPTION

The tested MOM capacitors are square structures and were fabricated by the Chartered Semiconductor Manufacturing 0.25µm RF CMOS technology. The MOM capacitor module requires an additional mask for fabrication. M4.5 and M4 served as the top and bottom electrodes of this capacitor. The cross-section and layout of the MOM capacitor are shown in Fig. 1.



(a)

(b)

Figure 1: (a) Cross-section and (b) Layout of MOM Capacitor

3 RF MODEL OF MOM CAPACITOR

The proposed model is presented in Fig. 2. It's a conventional model, and the physical meaning of each component is also shown in Fig. 2.

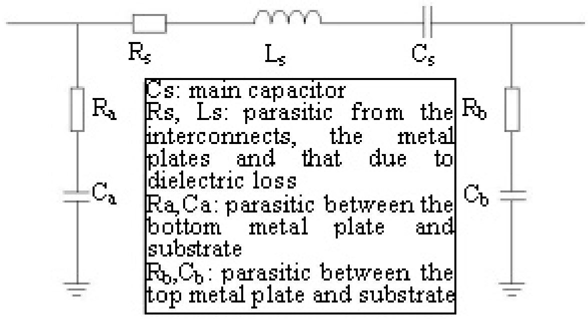
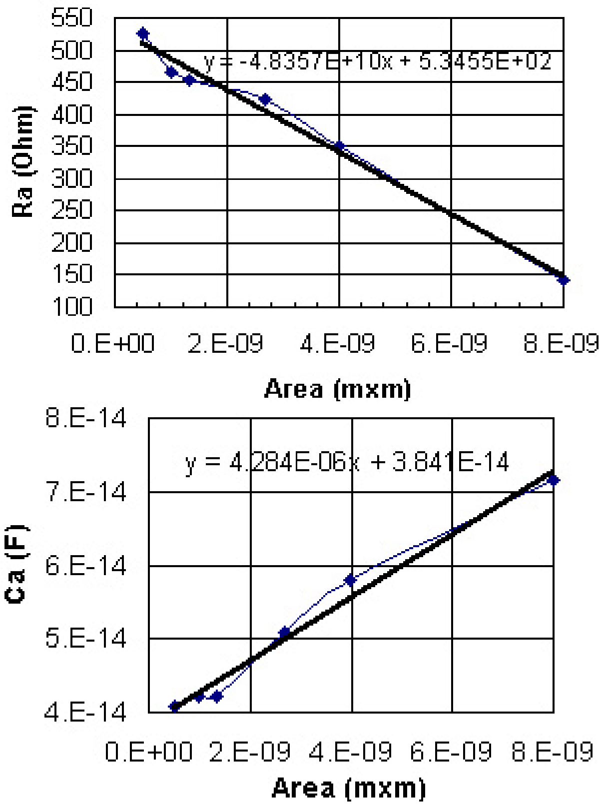


Figure 2: RF model of MOM capacitor

3 SIMULATION RESULTS AND DISCUSSION

Two-port *S*-parameter data of the capacitors and pad frame have been measured using the HP8510C Network Analyzer and Cascade Microtech coplanar ground-signal-ground probes. From the measured data, each value of the element in the model is extracted.

In the Fig. 3, the relationship between the capacitor's area and each component's value are shown, respectively. The polynomial equations, which are derived from curve fitting, are also shown in these figures. The dotted lines represent the measured data, and solid lines represent results given from those polynomial equations. The value of main capacitor (Cs) can be extracted directly from the DC measurement.



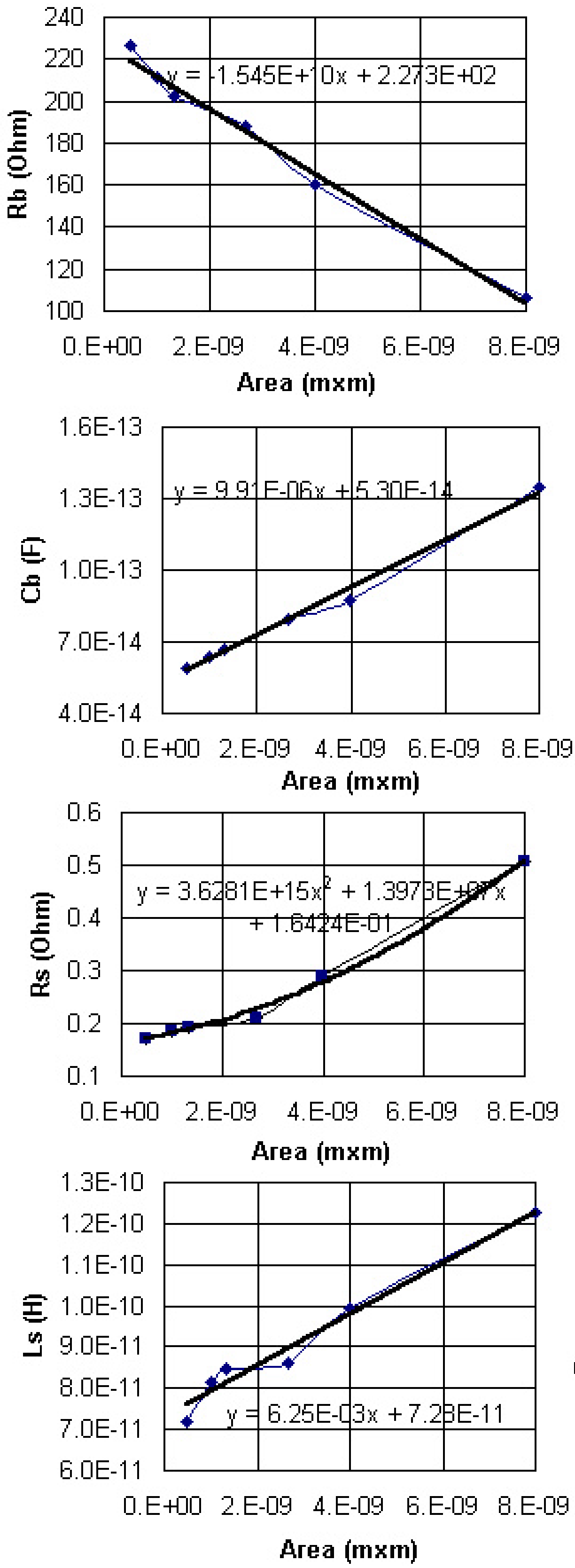


Figure. 3: The relationship between area of capacitor and the value of each component

The model can be easily implemented in normal EDA software. After the model was implemented, the simulation results achieved by the scalable model are compared with measured data as shown in Fig. 5 and Fig. 6 at frequencies of 450 MHz, 1.05 GHz, and 2.45 GHz, respectively. It's obvious that the scalable model can fit the measured data very well in a very wide frequency range. In the figures, Q is derived by:

$$Q=imag(Y.11)/real(Y.11)$$

And C is derived by:

$$C=imag(Y.11)/(2*\pi*freq)$$

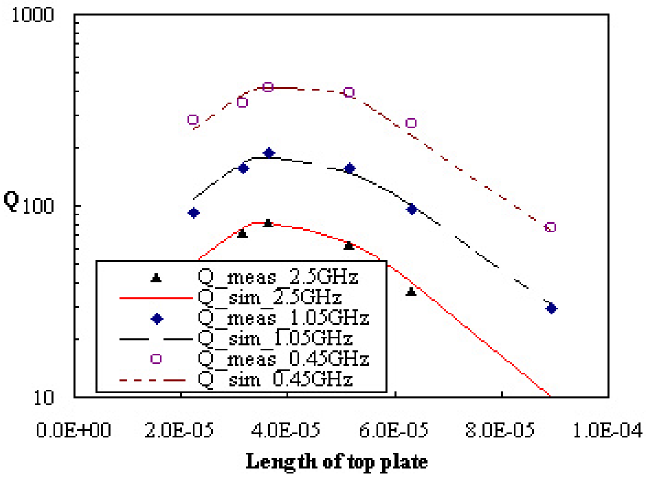


Figure 5: Measured and modeled quality factor for various dimensions MOM capacitor for frequencies of 450 MHz, 1.045 GHz and 2.45 GHz, respectively

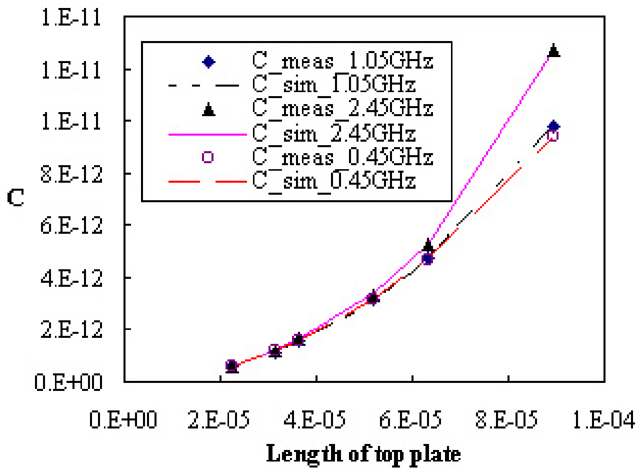


Figure 6: Measured and modeled capacitance for various dimensions MOM capacitor for frequencies of 450 MHz, 1.045 GHz and 2.45 GHz, respectively

In Fig. 7 and Fig. 8 the voltage dependency and temperature dependency of MOM capacitor (L=89.44 um) are presented. In the Fig. 8, the measured data and simulation results are gotten at temperature of -40^{o}C, 25^{o}C, 75^{o}C, and 125^{o}C, respectively. These two figures show that the proposed model is also suitable for DC condition.

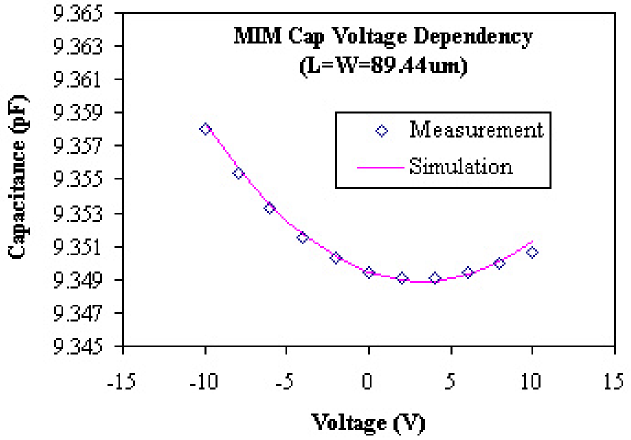


Figure 7: Voltage dependency of MOM capacitor (L=89.44um)

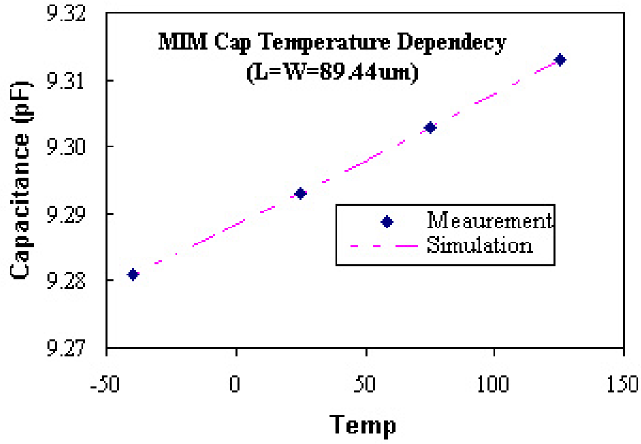


Figure 8: Temperature dependency of MOM capacitor (L=89.44um)

4 CONCLUSION

Polynomial equations are implemented in the conventional RF MOM capacitor model to describe area-dependent characteristic of each subcircuit element. An excellent agreement between measured data and simulation results is achieved by this scalable model. The model provides fast, accurate and very convenient way for circuit designer.

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