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On-wafer RF high-power measurement with an LSMO load at 40 GHz

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Abstract— We present a novel technique to measure RF power directly in the plane of a DUT using a CPW (CoPlanar Waveguide) test-pattern as an on-wafer power meter. Preliminary results show that we have been able to measure 24 dBm at 40 GHz.

I. INTRODUCTION

The rigorous characterization of high-power RF device requires low-uncertainty measurements. On a high-power RF probe station, the applied power is commonly measured with a directional coupler based on diodes or thermistors [1]. However, the measured power can be relatively different from the one applied on the DUT: the coupling coefficient must be known with accuracy and sensors have to be calibrated as a set. Moreover, the need of a large heat sink and an external meter, make them non-portable. While a RF wattmeter or a directional power sensor can be connected in line with the DUT, they provide a larger reading error (about 5% or more) than other methods. As an alternative, with a properly CPW test-pattern designed on a sample, we have been able to measure 40-GHz RF power directly under the probe.

II. LOAD

A 20nm-thick SrTiO₃ (STO) layer was deposited by Molecular Beam Epitaxy (MBE) on 3-inch high-resistivity Si substrate to minimize electromagnetic losses [2]. The 55nm-thick La_{0.7}Sr_{0.3}MnO₃ (LSMO) layers were then deposited by Pulsed Laser Deposition (PLD). About 150nm-thick gold layers were deposited by lift-off and sputtering to form contact pads. An Ion Beam Etching (IBE) was used to pattern LSMO layers.

III. RESULTS

Fig 1 illustrates the principle of the proposed method. A 40-GHz frequency is generated by a Non-linear Vectorial Analyzer (Keysight N5245A-NVNA). A power amplifier from Bonn Elektronik enables to produce up to 5 W power in the 40-44 GHz band [3].

Different CPW test patterns have been designed, with variable lengths (L) and variable widths (W) to find one with a characteristic impedance close to 50 Ω at targeted frequency [4]. Once the variation of impedance with frequency for one of the pattern (L = 100 μm, W = 11 μm) characterized, DC bias point has been adjusted (I₁ = 66 mA, V₁ = 5 V, R = 76.6 Ohm) to minimize the reflection coefficient at 40 GHz: ρ = 0.001 + j0.078.

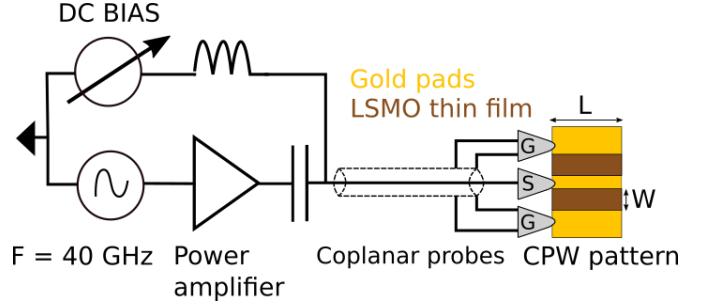


Fig. 1. Principle of RF power measurement using a CPW test pattern tuned to be 50-Ohm at targeted frequency. (G: Ground, S: Signal). L variable (80, 100, 120, 140, 160 μm) and W variable (10, 11, 12 μm). .

The power measurement is done by keeping at constant temperature the LSMO pattern and by modifying its DC bias point (and joule effect) to keep the same DC resistance when the RF power is varied. With this technique, RF power is measured simply by substitution with two DC measurements:

$$P_{RF,absorbed} = P_{DC,RF OFF} - P_{DC,RF ON} \quad (1)$$

Finally, to know incident RF power $P_{RF,inc}$, we take account of the reflection coefficient:

$$P_{RF,inc} = \frac{P_{RF,absorbed}}{1 - |\rho|^2} = \frac{P_{RF,absorbed}}{0.994}$$

Mismatch effect is less than 1%. Table 1 shows some first measurements obtained with this technique from 5 to 23 dBm. Even if the measured precision is not ideal for the moment due to non-ideal experimental conditions, it shows that the concept of a “probe station” power meter based on LSMO loads works in the mm-wave range. Further experiments with better conditions will be done at 94 GHz.

P_{inj} (dBm)	$P_{DC,RF OFF}$ (mW)	$P_{DC,RF ON}$ (mW)	$P_{RF,inc}$ (dBm)
5.0	335.41	330.76	6.7
10.0		323.98	10.6
20.0		217.34	20.7
23.0		76.05	24.2

Table. 1. Example of measurements obtained with the proposed technique.

IV. SUMMARY

This paper presents a novel technique to measure the RF power in the plane of a DUT with an LSMO load. In the future, they will be fabricated to operate at 94 GHz and an electronic circuit will be set to maintain automatically the thermal equilibrium of the sample. Further results will be shown at the conference.

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