Micromachined Cavity Resonator Sensor for on Chip Material Characterisation at 260 GHz

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I. INTRODUCTION

The characterization of dielectric properties in the J-band (220–330 GHz) is necessary for different applications such as dielectric heating, remote sensing, molecular detection and could also be used for measurements of the sheet resistance and conductivity of thin films [1]. Typically, cavity resonators are used for dielectric characterization, as their high Q factor allows achieving a high sensitivity to the permittivity of the material under test (MUT) [2]. In this paper, we present a two-port cavity resonator filter at 260 GHz used for dielectric characterization and show the response of the sensor on different probed materials.

II. DESIGN

The silicon waveguide height is 285 µm and its width is 864 µm. The cavity is 750 µm long and a square aperture of 250 µm by 250 µm protrudes the top wall. A two-port cavity resonator filter is designed for 260 GHz. The coupling coefficient is adjusted for critical coupling using HFSS simulations. Changing the opening width, here 560µm, see Fig.1, a critical coupling of the cavity resonator is achieved when the cavity is evanescently coupled to the MUT.

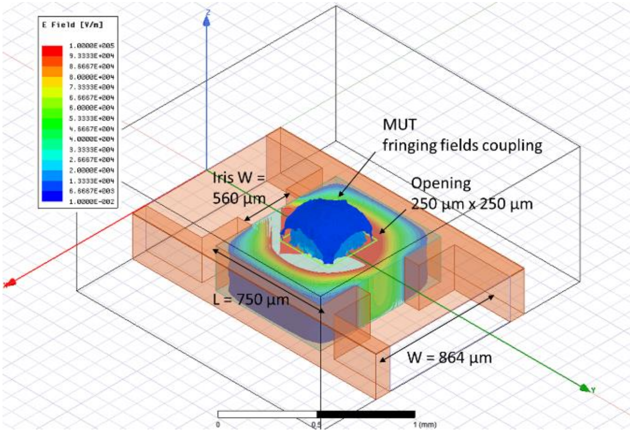

Fig.1: Two-port waveguide sensor with E field and fringing fields coupling to the material under test (MUT).

III. FABRICATION AND ASSEMBLY

The cavity sensor was fabricated in a low-loss micromachined waveguide technology developed at KTH, consisting of a 285 µm thick silicon-wafer etched by deep-reactive ion etching, using a silicon dioxide mask. The wafers are metallized by gold sputtering of 1 µm and the assembly is realized using thermocompression bonding. More details on the fabrication process could be found in [3].

IV. RESULTS

Measurements were conducted using a Rohde&Schwarz ZVA24 Vector Network Analyzer with two ZC330 TxRx millimetre-wave extenders in the band 220-330 GHz. A TRL calibration was carried out, using a micromachined calibration kit implemented on the same chip containing the sensor. The micromachined TRL calibration kit allows for de-embedding the reference planes located inside the micromachined rectangular waveguides, i.e., directly adjacent to the two-port waveguide sensor, shown in Fig. 1.

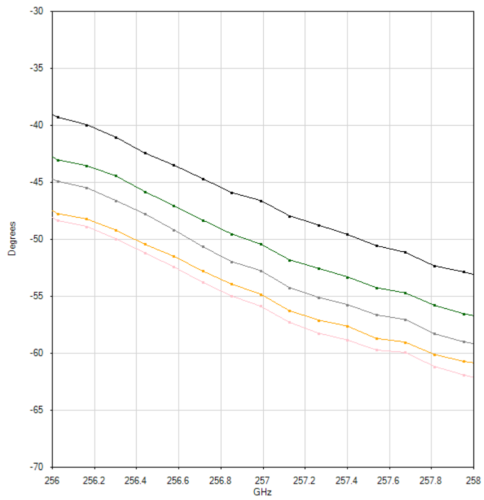

Fig.2: Phase extracted from S_{21} measurements, as follows: black line – air; green line – RO3003; grey line – Al_2O_3; orange line – SiHR and pink line – dielectric permittivity 30.

Measurements are performed on different dielectric materials, MUT is placed on top of the sensing area and S parameters are measured. The phase of S_{21} is present in Fig. 2 for different materials. For increasingly higher permittivities, we observe an increase in the phase shift of S_{21}. The materials probed, as follows (in bracket known permittivity at lower frequencies e.g. 10 GHz): black – air (epsr = 1); green – RO3003 (epsr = 3); grey – Al_2O_3 (epsr = 9); orange – SiHR (epsr = 11.9) and pink – dielectric material (epsr = 30).

V. CONCLUSIONS

A silicon micromachined waveguide sensor at 260 GHz is used to measure dielectric materials. A good correlation between permittivity at lower frequencies and phase shift at 260 GHz is observed. The sensor is well suited to implement on chip material dielectric characterisation at J-band.

VI. ACKNOWLEDGEMENT

Work is supported by the Swedish Foundation for Strategic Research (SSF) with Synergy Grant Electronics SE13-007.

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