Optimally Designed Membrane-Supported Grounded CPW Structure for Submillimeter-Wave Applications

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Introduction

Coplanar waveguides (CPW) have gained importance in monolithic microwave integrated circuits (MMIC) applications due to their low loss in microwave frequencies compared to microstrips. Loss in CPW lines originates from two sources: ohmic loss resulting from finite conductivity of the metal, and substrate loss due to finite resistivity of the dielectric. In addition, excitation of higher order modes through the substrate is another source of loss. Dispersion is also a major problem in many applications for CPW structures. Such applications include fabrication of high-Q filters, resonators, and corporate feed of antenna arrays. This issue is especially important at submillimeter wave region as the dimensions have to be physically small, skin depth is very small, and dielectric loss tangent of the substrate becomes high [1-7].

Different techniques have been used in the past to reduce the loss in the CPW lines. GaAs and quartz have usually been used as the substrate, instead of silicon, in order to decrease the dielectric loss to some extent [6]. Application of thin polyamide films on silicon has also been used to decrease the substrate loss [7]. Furthermore, micromachining techniques are adopted to eliminate parts of the substrate. V-grooved finite ground coplanar lines and microshield lines have shown much lower losses [5]. Other membrane-supported lines have been reported in which substrate under the line is removed, reducing the dielectric loss [1], [4].

In this paper, a very low loss CPW structure for application in submillimeter wave region is proposed and an optimized solution in terms of loss and dispersion is obtained. In this new structure (fig 1), substrate is removed totally, which allows a pure TEM wave propagation. Furthermore, using the side walls in the structure, there are no higher order substrate mode excitations. The only remaining source of loss is the conductor loss. Metallic loss has been reduced considerably by optimizing the structure so that a relatively uniform current distribution on the center conductor is established.

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Design and Simulation

In this new structure, the center conductor is holding on a metallic trench using a thin membrane. The membrane is made as thin as possible to minimize the dielectric loss. As mentioned before, the ohmic loss is the remaining source of loss in this structure. For that reason, dimensions of the line, which include the width of the center conductor (w_c), gap width (w_g), and the trench hight (h) are used to minimize the insertion loss:

$$\min \{ |S(1,2)| (w_c, w_g, h)\}$$

The structure dimensions have been optimized to give minimum insertion loss for 230 GHz, while not exciting higher order modes in the trench. Simulations are performed by the 3D structure simulator HFSS. As shown in figure 3, insertion loss is about 0.7dB/cm in the W-band and reaches 1.1dB/cm at 300 GHz, which is very low at this band. Loss results are compared with loss value reports from other CPW structures in the literature (fig3). To demonstrate the dispersion behavior of the proposed optimal line figure 4 shows the wave number of the line (β (ω)) which has a perfect linear behavior. This shows that the line does not have dispersion in the required band.

Microfabrication Process

The structure fabrication uses micromachining of silicon. The trench is etched on a 500-µm-thick silicon wafer. Then 0.5-µm gold is evaporated on the trench, covering all the surfaces.

In order to fabricate the membrane, a 1-µm stack of $SiO_2/Si_3N_4/$ SiO_2 is deposited on a second silicon wafer. The 3-layer oxide/nitride/oxide stack is used to give a low stress insulating membrane. After this step, gold is evaporated on the membrane. Gold layer is then patterned to shape the center conductor. Then the two wafers are bonded using gold-to-gold thermal compression bonding. After bonding, membrane is released by etching the second silicon wafer.

Measurement of the structure and comparison with the simulation will be presented at the symposium.

Conclusion

In this paper, a novel low loss CPW structure is presented. The line has less than 0.1 dB/mm insertion loss at 230 GHz, which is very small compared to previous CPW structures. The line can be used in millimeter- and submillimeter-wave MMIC applications as high-Q filters, resonators, corporate feed of antenna arrays, where high efficiency is a major issue.

References

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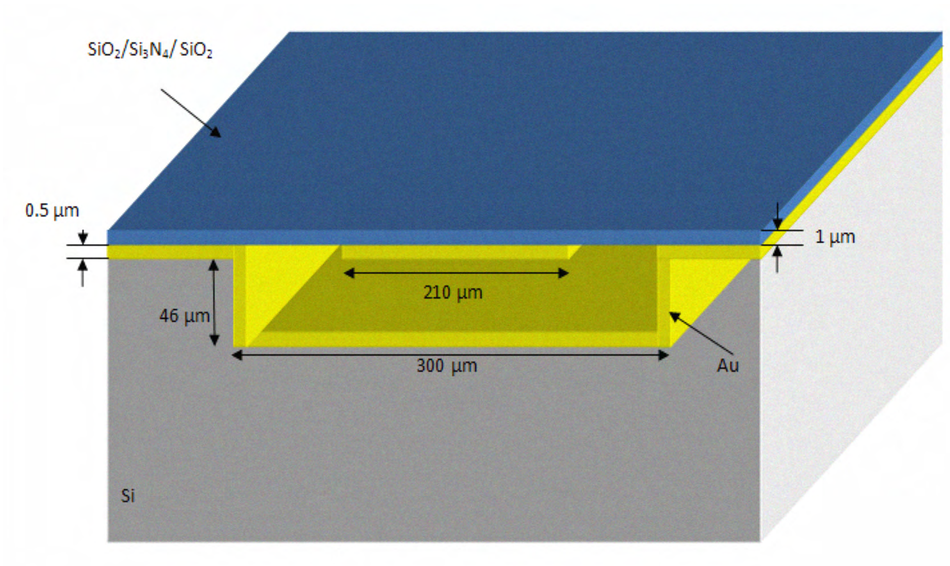

Figure 1 - Schematic and dimensions of the optimized CPW structure

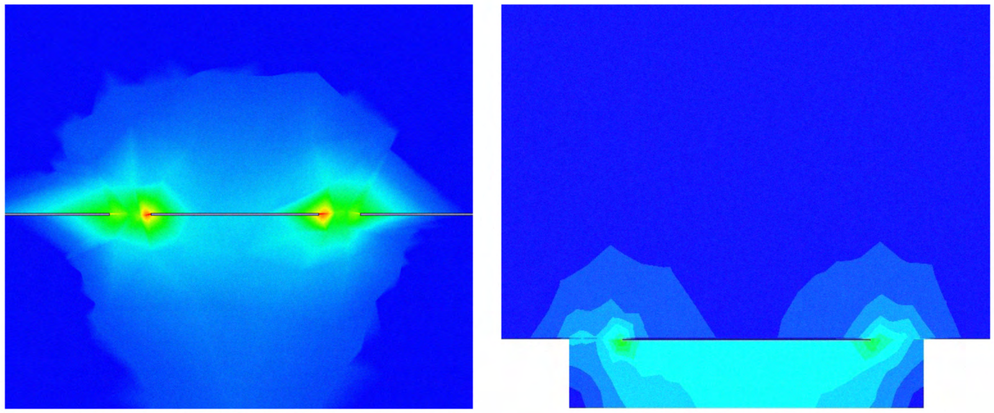

Figure 2 – Electric field distribution in (a) conventional CPW line
(b) membrane supported grounded CPW line

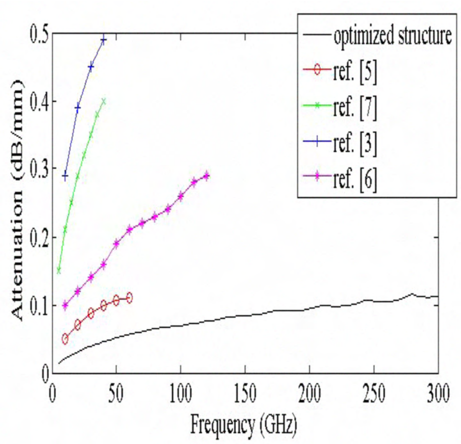

Figure 3 – Simulation results insertion loss of the membrane-supported grounded CPW line versus frequency

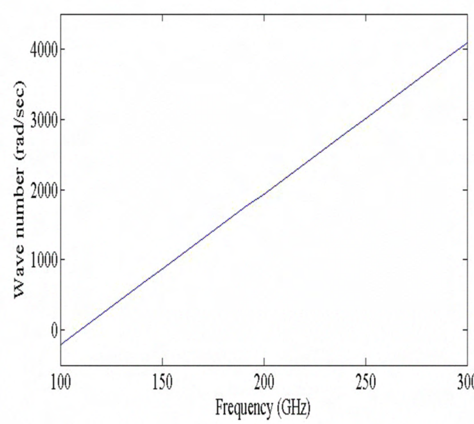

Figure 4 – wave number of the optimized vs. frequency