AN EXTENSIVE STUDY, DESIGN AND SIMULATION OF MEMS GUIDED MEDIA: MICROSTRIP LINE

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Abstract- In this paper, some design issues of one of the planar-guided media known as Microstrip line has been presented. The main purpose of this paper is to study the fundamental transmission properties of the microstrip line in view of varying the length, materials used for device formation/fabrication and highest frequency of operation. The paper is mainly divided in to two portions; first portion deals with theoretical portion because, it is necessary to know how the characteristic impedance, phase velocity, and attenuation constant of the dominant mode of microstrip depend on geometrical factors, on the electronic properties of substrate and conductors used, and on the frequency. Since this is a "mixed" dielectric system, the TEM mode can not be supported [2] and the second portion of the investigation was devoted to the effect of variation of length and frequency on the RF performance of the line. Although many papers are available on this topic, but the issues described in this paper have somewhat different point of view.

Index terms*:* RF MEMS, TEM mode, HRS, TFMLs.

I. INTRODUCTION

Recently, integrated circuit passive components have been recognized as high-performance and low cost elements of deep submicron BiCMOS circuits in Radio frequency integrated circuits (RFICs) technologies [1]. The integration of large no of passive components including the individual passive devices of transmission lines, inductors, capacitors or fundamental passive devices of filters and antennas with low loss and minimal cross-talk as important as the advancement of in active transistor technology [2,3]. However, the low resistivity substrate used in standard CMOS processing foe most RFICs has limited the integration of high quality passive components due to the high lossy performance of the silicon substrate [3].

Some solutions have been provided to improve the problem of lossy silicon substrates. First method is to integrate the passive components on top of the thick dielectric layer as far above the lossy Si substrate as possible [4]. Second method is to use high-resistivity silicon (HRS, $\rho > 5000\ \Omega$ cm) to lower the carrier transmission in the substrate [5]. Third method is to use high electron voltage (MeV) portion implantation to convert low-resistivity silicon (LRS) to HRS resulting in improved quality Q(f) of portion implanted passive devices [6]. Fourth method is to use micro-electromechanical technology to reduce the substrate loss [7-9]. However, a primary drawback of HRS technologies is their incompatibility to standard CMOS processes. In the past, polymides have been used as low loss, low K dielectrics allowing for a higher propagation velocity, which is necessary for high-speed circuits. They can form excellent dielectric insulators and provide excellent step coverage. Therefore, polymide is comprehensively used in fabricating various RF and microwave packages. Recently, in order to achieve low cost, high density and fully integrated interconnects for RF front end communication systems, low dielectric constant (K) thin film microstrip devices lines (TFMLs) have been presented as a good candidate for integrating the passives on RFICs up to 50 GHz [10]. But these have problem with standard MEMS fabrication technology, which uses gold as primary conductor. MEMS technology has developed enough to cope with problems of weak mechanical strength, complex fabrication and shorter lifetime.

II. THEORETICAL DESCRIPTION

The microstrip line is transmission line geometry with a single conductor trace on one side of a dielectric substrate and a single ground plane on the opposite side [Figure 2]. So the electromagnetic wave carried by a microstrip line exists partly in the dielectric substrate, and partly in the air above it. Interest of previous workers in the field of planer transmission lines [11-14] have been limited mostly to the properties of quasi-TEM mode through lossless inhomogeneous media as a matter of course, the microstrip structure can be regarded as loss-less, when the conductivity of the semiconductor decreased. However this condition is not necessarily realized in the IC design. Thus, in general, the effect of finite conductivity of the substrate cannot at all be expected to be small perturbation to lossless cases. There exist three fundamental modes i.e. dielectric quasi TEM mode, skin-effect mode and slow wave mode. When the product of frequency and the resistivity of the substrate is large enough to produce a small dielectric loss angle, the substrate acts like a dielectric. The fundamental mode would closely resemble to the TEM mode, so as long as the wavelength is much larger than the thickness of the wafer. With the further increase in the frequency, the conventional TEM approximation becomes invalid and mode would undergo dispersion. When the product of the frequency and the substrate conductivity is large enough to yield a small penetration into wafer, it will behave like a lossy conductor wall, and the line may be treated as microstrip line on imperfect 'ground plane' made of silicon. When the frequency is not so high and the resistivity is moderate, the substrate acts like neither of the above, and a slow surface wave propagate along the line.

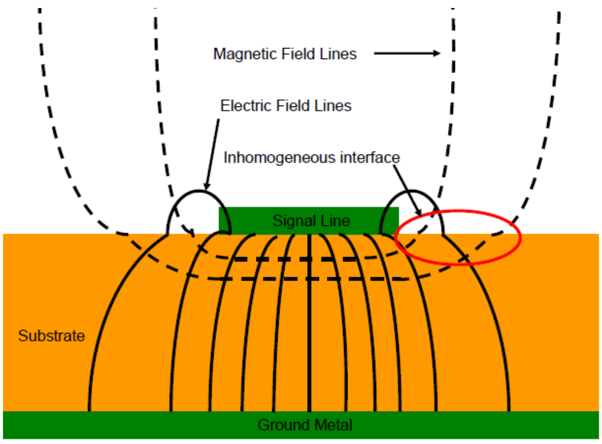

Figure 1. 2 D view of Microstip Line with its EM field Distribution

III. SIMULATION STUDY OF MICROSTRIP LINES

A. Variation of Insertion loss with length and frequency

As the length of microstrip line increases the propagation characteristic of the line also changes. It can be easily concluded that as the length of the line increases the insertion loss also increases linearly with it. In the present case it is lowest for 500µm and highest for 4000µm. It is also noticeable that an increase in insertion loss is more at higher frequencies compared to the lower frequencies. Figure 2 shows variation of insertion loss of microstrip lines having different lengths from 500 μm to 4000 μm with frequency. Insertion loss of designed microstrip line of length 500 μm is less then –0.02 dB for frequencies less than 10 GHz.

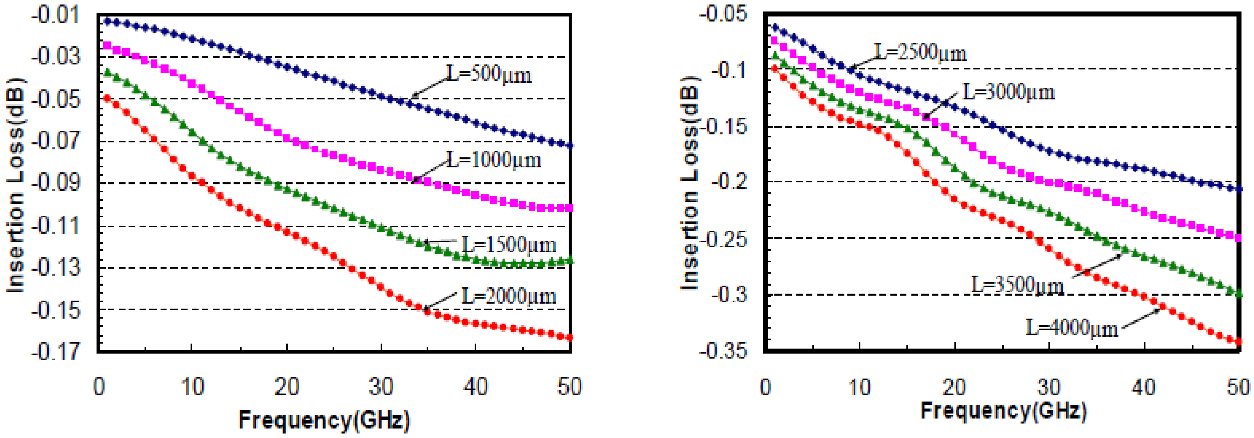

Figure 2. Comparison of insertion loss of microstrip lines with frequency having different lengths from 500μm to and 4000μm

B. Variation of Return loss with length and frequency

Variation of return loss with increasing frequency and length is shown in figure 3. One interesting fact about return loss curve is that there exist return loss dips, which are actually resonance dips. As the length of line increases the resonance dips appears more frequently. Resonance dip for 500μm appears at highest frequency of more than 50GHz whereas the resonance dip for 4000μm occurs only at 14GHz and again occurs at 28GHz. Other interesting fact about resonance dips is that secondary resonance peaks occurs at nearly integral multiple of frequency of first resonance peak.

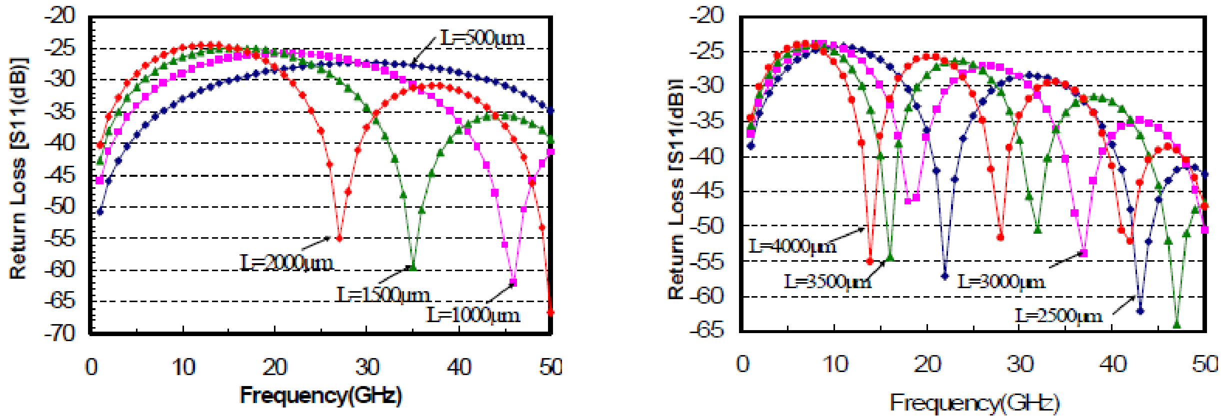

Figure 3. Comparison of Return loss of microstrip lines having different lengths from 500μm to and 4000μm

C. Variation of losses of line with highest frequency of operation

Next parameter for which microstrip line is studied is highest frequency of operation; both insertion loss and return loss variation are studied. The only important factor, which is noticeable, is that frequency of resonance dip increases with increase in the highest frequency of operation means possibility of reoccurrence of resonance dips decreases with increase in the highest frequency of operation whereas there is slight increase in the insertion loss with highest frequency of operation.

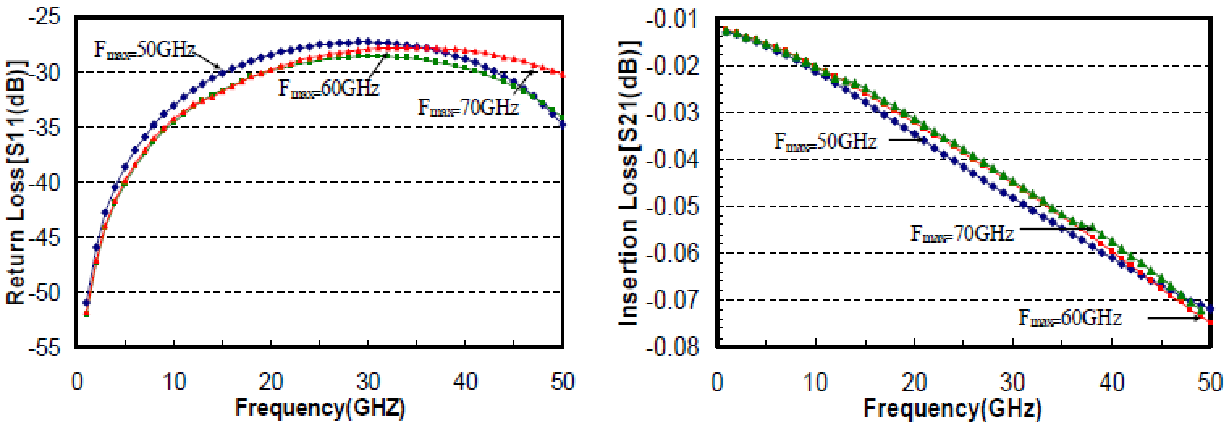

Figure 4. Return loss of microstrip lines simulated for different highest frequencies from 50GHz to 70GHz (length=500µm)

IV. CONCLUSION

In this paper, I have designed, studied and simulated the MEMS microstrip transmission line on the silicon wafer of resistivity 5000Ω. Various simulation studies have been carried out varying different parameters with the frequency. The low loss of designed microstrip line presented here is promising, having only –0.02dB insertion loss for frequencies less than 10GHz. The performance of proposed MEMS Transmission line suggest further advancement in performance of RF devices.

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