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DESIGN OF MILLIMETER WAVE TFMS BANDPASS FILTER

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Abstract: In this paper, a Ka-band thin film microstrip line(TFMS) filter with multi-layer structure on silicon substrate is introduced. The simulated results show that it is possible to design compact millimeter-wave filter on silicon substrate with process compatible to current VLSI technology.

Key words: TFMS; Bandpass Filter; Silicon substrate

I Introduction

The development of system-on-chip MMICs that include antenna, RF circuits and IF circuits is essential to realize low-cost wireless modules. Significant process in sub-micrometer silicon devices, such as 0.18μm-class CMOS, has made it possible to realize silicon-based mixed-signal MMICs even at high frequencies up to millimeter-wave region. However, for silicon VLSI technology, the performance of integrated circuits on wafers is very poor at microwave and millimeter wave frequencies due to the high loss coming from the low resistivity substrate. To overcome this problem, the thin film microstrip line(TFMS)can be used for circuit design.

TFMS are essentially highly miniaturized microstrip lines, fabricated on thin dielectric film. TFMS can be realized with silicon VLSI multi-layer technology , the ground metal planes of TFMS can be on the top-side of the wafer ,then the parasitic components from substrate properties are isolated effectively. This is why the performance of a TFMS line on a low-resistivity substrate equals that of a GaAs substrate.

In[1],the advantages of the TFMS line are clarifies. The loss value of

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the 50Ω TFMS line which is higher relative to that of the conventional microstrip line is less than 2dB per wavelength in the millimeter wave region. However, TFMS can give a dramatic reduction in circuit size. TFMS have been successfully applied to a range of novel circuits. An X-band multi-layer on-chip passive transmitter module was proposed in [2], including a filter and a patch antenna which are all planar and processed at two different layers.

In this paper, an vertically coupling multiplayer Ka-band bandpass TFMS filter approach is presented. Simulated results show that high performance millimeter filter can be achieved on silicon substrate with process compatible to current VLSI technology.

II Design considerations

RF and microwave circuits are usually fabricated in single-layer configurations. Fig.1(a) is the layout of a typical edge-coupled line filter using three coupled line resonators($\lambda/4$ each at the center frequency). Filter bandwidth is decided by the coupling for a given space between resonators. This filter structure is more convenient for constructing filter with a wide bandwidth as compared to the structure for the end-coupled filter. However, very tightly coupled lines are difficult to be fabricated in this configuration also.

As it is known, the use of multi-layer circuit configurations makes RF and microwave circuits more compact and the design more flexible. A 0.18μm CMOS process technology provides six metal layers(Alumina) on silicon wafer. The thickness of the 1^{st} to 5^{th} layer are about 0.53μm and the 6^{th} metal thickness is about 0.99μm. Dielectric films(SiO_2) are sandwiched between metal layers, which can be used as the building blocks for TFMS.

Fig1(b) is the filter structure proposed in this paper. It can be thought as the variation of Fig1(a).Met-2 layer is the ground. The tight coupling can be achieved by overlapping the Met-6 and Met-5 layers. In this design, the overlapping area is should to be optimized for getting the best filter band performance. In[3],equivalent circuit formulas for the multi-layer coupling structure are presented. The initial design values for the filter structure can be gotten by these formulas. In the design of this paper, the filter is analyzed and optimized by full wave electromagnetic simulator HFSS.

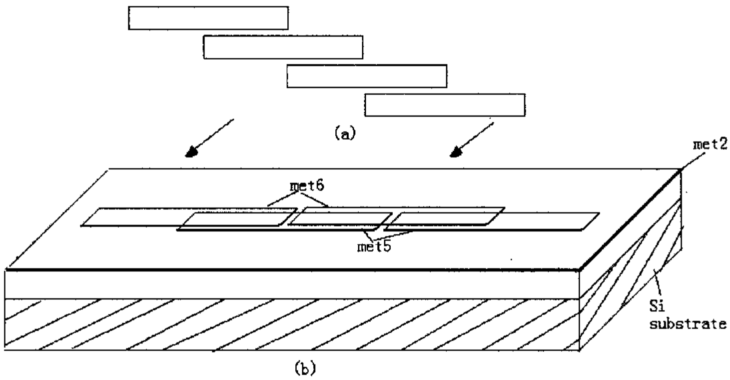

Fig.1 (a) layout of typical edge-coupled line filter
(b) layout of proposed multi-layer coupled line filter

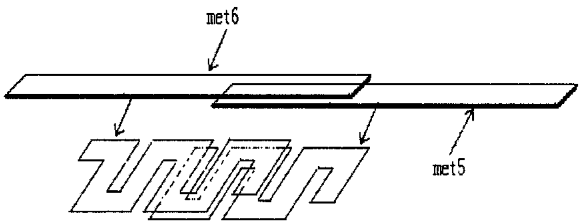

Fig.2 meander line vertically coupling

Ⅲ Simulated Results and Discussions

A disadvantage of TFMS is that the ε_r of common dielectric films is considerably lower than that of silicon, and so the physical line lengths are longer. The filter can have a meander-shaped formation to achieve the most compact area, as shown in Fig.2. The filter area is just 0.44mm × 0.33mm.By EM simulation, the cross-coupling effect due to the meander lines and metal thickness effect are considered completely. Fig.3 presents the RF performances The filter has only –2.54dB loss at peak transmission of 28GHz with a broad 5-GHz bandwidth.

It is expected to improve the filter performance by replacing Al metal layer with other low resistivity metal or alloy. There are process technologies that provided this options[1][4].

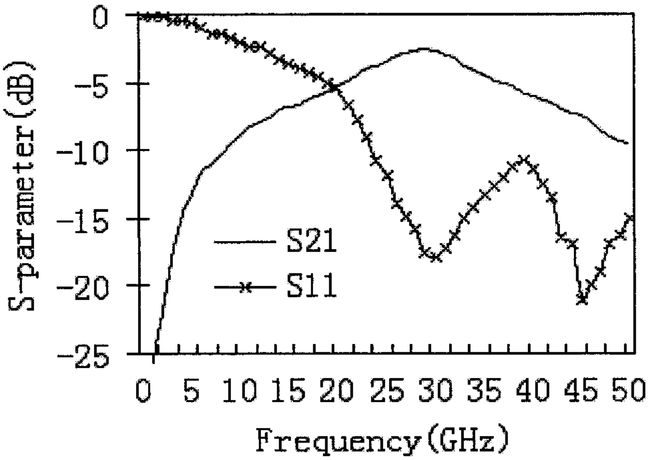

Fig.3 Simulated filter performances

IV Conclusions

In this paper, a Ka-band thin film microstrip line (TFMS) bandpass filter is proposed. TFMS are achieved on silicon substrate and the filter has a multi-layer structure. Simulation results for the filter performance show the potential for compact passive circuits at millimeter wave frequency band on silicon substrate with current VLSI process technology. Further work should concentrate on testing the proposed design idea by experiments.

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