MICROMACHINED DETECTOR MOUNTS FOR MILLIMETER WAVE APPLICATIONS

R. F. Drayton, C. Kidner, J. East and L. P. B. Katehi
NASA Center for Space Terahertz Technology
University of Michigan
Ann Arbor, MI 48109-2122

Abstract

High frequency circuit development requires that circuits are miniature in size with good electrical performance. These types of circuits can be achieved by utilizing micromachining techniques that allow individual planar geometries and shielding environment to be fabricated monolithically. This paper will present the development of such circuits including a detector mount where the advantage of this configuration is a lowcost circuit system with small weight and volume. Since the shield is integrated with the planar geometries, characterization is simplified and the resulting circuit performance is comparable to conventional planar lines. At the higher frequencies this is particularly useful since various geometries can be easily fabricated using silicon micromachining techniques.

1.0 Introduction

Micromachined circuits have been studied at the University of Michigan for development of passive circuit components [1] where the individual planar geometries and shielding environment are fabricated monolithically resulting in miniaturization of conventional circuit components. The advantage of this configuration is a lightweight circuit system with small weight and volume. In addition, characterization of such systems is simplified since the shield is integrated with the planar components resulting in circuit performance that is comparable to conventional planar lines. For higher frequency applications, this is particularly useful since various geometries can be easily fabricated to desired dimensional requirements using silicon micromachining techniques.

This paper presents the development of a variety of micromachined circuits including a detector mount that utilizes the advantages of micromachining to create the circuit components and a

mounting structure for planar diodes. A description of the development of the system and the sub-components required along with a discussion of circuit performance is presented.

2.0 Fabrication Issues

The mounting structure is a two silicon <100> wafer system which relies primarily on standard fabrication processes and etching techniques. The semiconductor processing steps include standard photolithography techniques for wafer patterning along with lift-off and evaporation techniques for metallization of the patterned areas. Ethylene diamine pyrocatechol (EDP), an anisotropic etchant, is used to etch silicon where it selectively stops on the <111> crystal plane resulting in sidewall angles of 54.7° as shown in Figure 1.

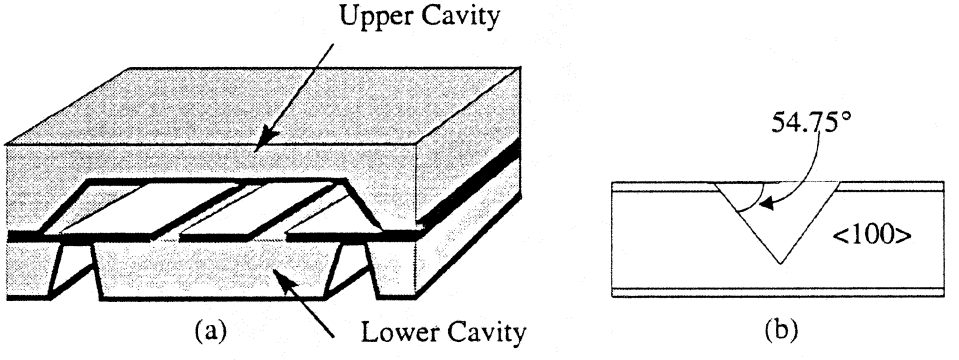

FIGURE 1. Two wafer silicon system of the transmission line with integrated shielding environment.

In Figure 1, the top wafer shows the air-filled upper cavity, having a width of 1200 μm and height of 280 μm, that is metallized after etching low resistivity silicon. On the bottom wafer coplanar waveguide transmission lines are printed on the polished side of high resistivity silicon using photolithography with lift-off and evaporation techniques for metallization. Since the etched grooves on the bottotm side of this wafer define the lower substrate-filled cavity, they are metallized last to provide the lower shielded region having a height of 350 μm and width of 950 μm. Once the indi-

vidual wafers are fabricated, they are secured using adhesion techniques while alignment is done via alignment windows.

3.0 Circuit Design and Results

Since micromachining techniques allow the integration of the shield with the transmission line components, circuit parameters are needed to establish a feedline that matches to 50 ohm systems. For the configuration shown in Figure 1, the transmission lines are coplanar waveguides having a conductor width of 180 μm and a slot width of 130 μm with above shielding dimensions.

For very high frequency circuits, initial circuit performance can be determined using on-wafer measurement techniques in the Ka-band. The results provide good indicators of the expected circuit response when scaled to terahertz frequencies excluding loss performance. In order to accurately measure the circuits, however, the measurement test wafer contains various circuit components having identical upper and lower shielded regions in addition to individual calibration lines, needed for the performance of a Thru-Reflect-Line (TRL) de-embedding [2,3]. Resulting experimental measurements of the micromachined circuits are thus obtained using on-wafer probing techniques [4] via a measurement system which consists of an HP 8510B Network Analyzer, Alessi Probe Station, and Cascade Microtech ground-signal-ground (GSG) probes with 150μm pitch.

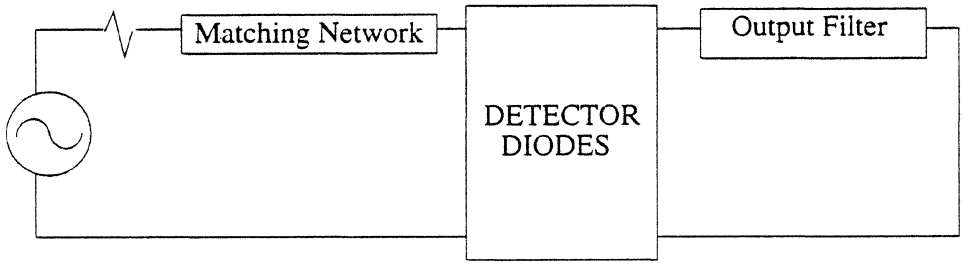

FIGURE 2. Detector Mounting Structure Design Scheme

Specific design issues are addressed in order to develop a micromachined detector which requires the use of the circuit shown in Figure 1 [5]. The design procedure begins by determining [6] and evaluating the range of realizable impedances available to implement a lowpass filter with a requirement of -20 dB insertion loss and the open circuit input impedance at the design frequency. Using the cross-sectional dimensions of the shielded regions given above, the high and low impedances are determined where the low impedance sections have a conductor width of 380 μm and slot width of 30 μm and high impedance section has conductor width of 20 μm and slot width of 210 μm. The filter response shown below in Figure 2 for a 5 section stepped impedance filter is compared to results obtained from a finite difference time-domain model [7].

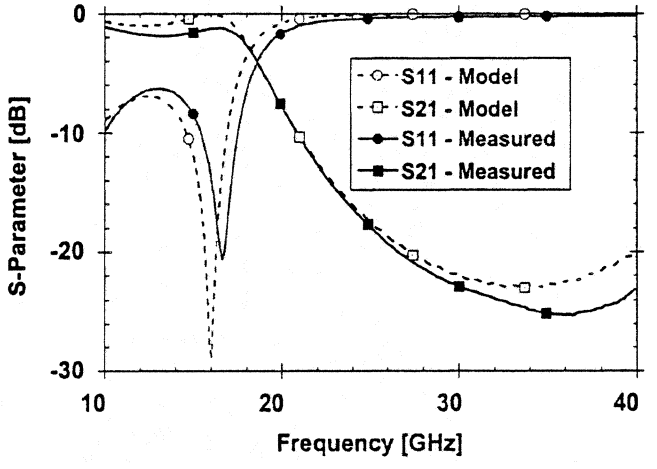

FIGURE 3. 5-section Stepped Impedance Lowpass Filter

The above response is needed in order to match the output of the filter design. Since the transmission lines are coplanar waveguides, this detector scheme uses the diodes in an anti-parallel configuration across the slots. In order to determine an appropriate input matching network the dc parameters of the diodes must be determined to minimize the power reflected from the diode input.

4.0 Conclusion

Subsystem components have been developed for a detector mounting scheme. In order to complete the detector system, in-house or commercially available diodes may be used which determine the type of appropriate input matching network. From a circuit perspective, micromachining can be used to develop detector mounting structures quite easily, where the problem is addressed from a component level prior to cascading these elements into the overall system.

5.0 Acknowledgments

This work has been supported by the Office of Naval Research under contract No.N00014-92-J-1070 and the NASA Center for Space Terahertz Technology. The authors would like to thank Dr. Nihad Dib for his contribution of theoretical models and Mr. Chen-Yu Chi and Mr. Steve Mollenkopf for technical discussions.

6.0 References

[1] R. F. Drayton and L. P. B. Katehi, "Micromachined Circuits for Mm-Wave Application", *23rd European Microwave Conference*, Madrid, Spain, pp. 587-588, September 1993.

[2] G. Engen and C. Hoer, "Thru-Reflect-Line: An improved Technique for Calibrating the Six-Port Automatic Network Analyzer", *IEEE Trans. Microwave Theory Tech.*, Vol. MTT-27, No 12, Dec. 1979, pp. 987-993.

[3] M. Maury, S.March, and G. Simpson, "LRL Calibration of Vector Automatic Network Analyzers", *Microwave Journal*, May 1987, pp.387-391.

[4] E.W. Strid and K.R. Gleason, "Calibration Methods for Microwave Wafer Testing", *1984 IEEE MTT-S Digest*, pp. 93-97.

[5] Bhartia-Bahl, *Microwave Solid State Circuit Design*, John Wiley & Sons, Inc., New York, 1988, Chap. 11.

[6] N.I. Dib and L.P.B. Katehi, "Impedance Calculation for the Microshield Line", *IEEE Microwave and Guided Wave Letters*, Vol.2, No. 10, pp. 406-408, October 1992.

[7] N.I. Dib, personal communication.