Recent Achievements in Silicon-Micromachined THz Filters at KTH

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Summary

This paper reports on the most recently developed filter designs implemented on new multilayer silicon-micromachined platforms for sub-THz and THz frequency ranges. These include inline H-plane filters with unprecedent accuracy and lowpass filters demonstrated in 220-325 GHz band.

1. Introduction

THz frequencies (100 GHz – 3 THz) have been drawing increasing attention with the development of science and technology in many applications. Filters are indispensable components of microwave systems where signal selectivity in frequency domain is required. At sub-THz and THz, it is still very difficult to achieve highly accurate filters with low losses and low fabrication cost. Moreover, integration of THz filters with CNC-milled metallic flanges has been a major issue in the last decade due to insufficiently accurate interfaces.

Silicon micromachined waveguide technology based on a double H-plane split, having only 0.02 dB/mm measured insertion loss in the 220-330 GHz band [1], has enabled a family of filter platforms allowing for fabrication of highly robust structures with µm-sized features and geometries with aspect ratio of over 110:1, combining it with a parallel batch fabrication technology where thousands of devices can be fabricated simultaneously on silicon wafers with high product uniformity and high yield [2, 3]. In this work, we show several examples of sub-THz and THz filters successfully designed and fabricated using the developed silicon-micromachined technology, including the first design of a silicon-micromachined lowpass filter with axial interfaces.

2. Silicon-Micromachined Filters for Sub-THz and THz Ranges

Figure 1 shows a typical configuration of the vertically stacked multilayer silicon micromachined platform including two chips with E-plane bends and one chip with waveguide circuits, here, filters. Each chip contains waveguide structures in the middle, pin alignment holes, and Vernier scales in the corners. This platform allows for axial feeding of filters located in the middle layer, and the filters can be fabricated with very high accuracy of geometrical dimensions using the fall-out technique, which enables very low non-verticality of sidewalls.

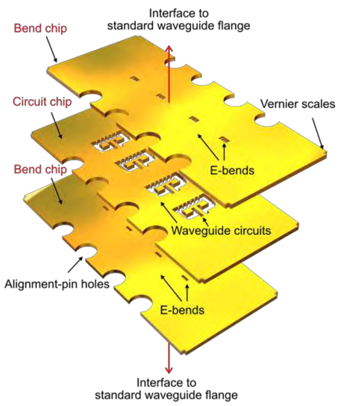
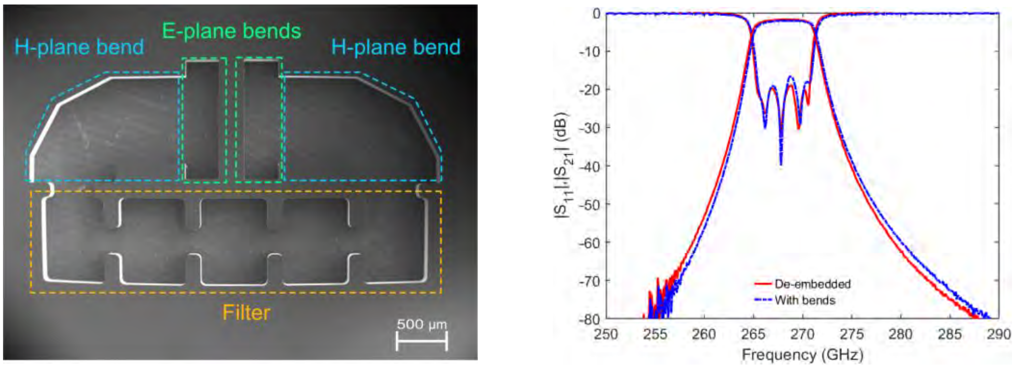


Figure 1. Configuration of a multilayer silicon-micromachined filter platform with axial interfaces.

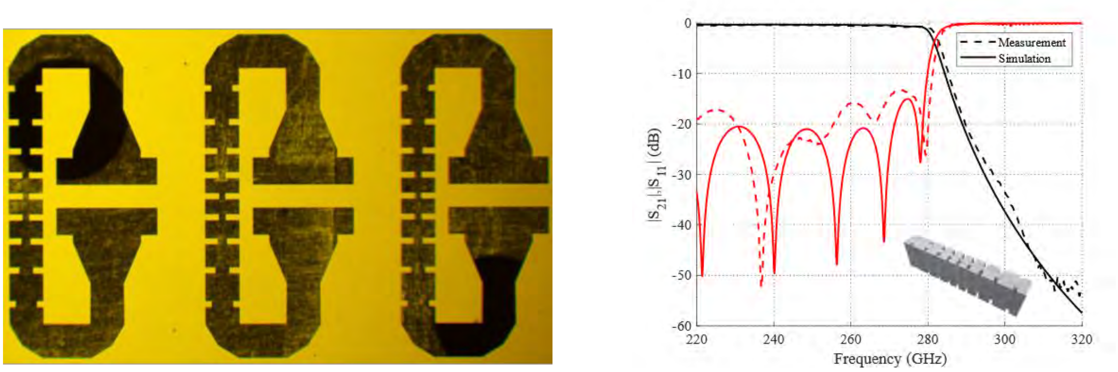
Using the multilayer silicon micromachined platform, filters with H-plane and E-plane configurations are designed. Figure 2a shows a microphotograph of the chip which contains a 5th-order all-pole bandpass filter designed at 270 GHz. In Fig. 2b, the measured results of the filter in two configurations (de-embedded and with bends) are shown. The filter has an excellent performance with an average insertion loss of 1.92 dB (best value 1.75 dB) and a return loss of better than 19 dB in the whole passband. The configuration with bends demonstrates extra 0.3 dB insertion loss in passband. The unloaded quality factor of the resonators, extracted from the measured response by vector fitting, reaches 750.

The E-plane waveguide configuration enables lowpass filters integrated on the silicon-micromachined platform. A lowpass filter with a cutoff frequency at 280 GHz is designed here. Figure 3a shows a microphotograph the middle layer of the lowpass filter before assembly. The de-embedded measured results are shown in Fig. 3b, along with the simulated, which are in good agreement. The average insertion loss in passband is 0.4 dB, and the return loss is better than 14 dB.



(a) (b)

Figure 2. H-plane bandpass filter: (a) micrograph of the fabricated filter on the chip; (b) measured responses in two configurations of reference planes.



(a) (b)

Figure 3. E-plane lowpass filter: (a) three filters arranged on a chip; (b) measured and simulated results.

3. Conclusion

A silicon micromachined multilayer platform has been presented. The platform allows for integrating H- and E-plane sub-THz and THz filters. An H-plane bandpass filter and an E-plane lowpass filter have been designed using the platform. Excellent performances in terms of losses have been demonstrated. Very good agreement with simulations has been obtained for the lowpass filter.

References

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