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Cross-Shaped Rounded Corner Terahertz Bandpass Filter on Silicon

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Abstract

Cross-shaped rounded corner terahertz bandpass filter is fabricated on aluminum coated silicon wafer. Finite difference time domain (FDTD) method is used to design this filter with rounded corners and a continuous wave frequency domain terahertz system is used for transmission spectrum measurement of fabricated filter in 0.05-0.6THz frequency range. The measured first central frequency of fabricated band pass filter is 191 GHz with 115 GHz 3dB bandwidth compared to designed central frequency of 196 GHz with 53 GHz bandwidth.

1. Introduction

Terahertz (THz) radiation, also known as the submillimeter radiation consists of electromagnetic waves of frequencies from 100 GHz to 10,000 GHz. It occupies the gap region between microwaves and infrared light of electromagnetic spectrum. THz radiation can pass through clothes, shoes, plastics, bags, paper envelops, allowing detection of hidden biological and chemical agents, which can be imaged or have unique spectral characteristics at THz frequency [1]. It has potential applications in spectroscopy, imaging and wireless communication systems [2]. Functional devices such as filters, compensators, polarizers, modulators and waveguides are required for system applications of THz technology. Studies on frequency selective surface based narrow band and wideband THz bandpass filters have been reported [3-6]. Direct structuring of cross shaped filters in thin metal films using laser has been described [7-8]. The three-layer all-silicon interference optical filter and fold-cross metal mesh filter further advances these developments [9-10]. We report the design and fabrication of Cross-shaped rounded corner THz bandpass filter on silicon, and compare the experimental observations with our simulation results.

2. Design and Fabrication

The cross-shaped rounded corner bandpass filter on silicon is designed using numerical FDTD simulation, as shown in fig.1. The resonant frequency dependence on dimensions of cross-shaped filter has been reported earlier [11]. A 350 µm x 350 µm single cell consisting of 306 µm long and 98 µm wide two cross arms with 49 µm radius curvature at corners is designed. A photomask consisting of repeated cross pattern cells along x and y direction is made. The thermal evaporation system is used to deposit 0.26 µm aluminium film on 260 µm thick 2 inch diameter silicon wafer. The wafer is then coated with positive photo resist and UV lithography is carried out to transfer the pattern from photomask to substrate. The patterned aluminium is etched in solution of DI water and H_3PO_4 (9:1) followed by removal of etchants in DI water. The fabricated bandpass filter is shown in fig.2.

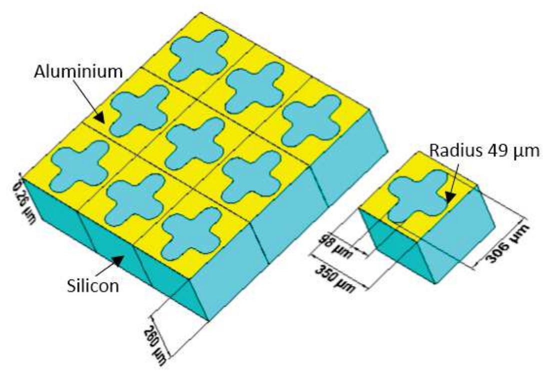

Figure 1: Layout of designed bandpass filter

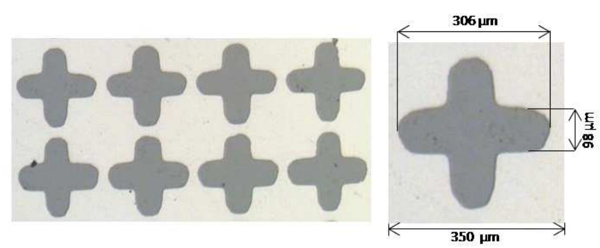

Figure 2: Cross-shaped rounded corner terahertz bandpass filter fabricated on silicon

The simulation studies on cross-shaped bandpass filter with sharp corners and rounded corners have been performed. Filter with sharp corners has maximum transmission at 190 GHz covering a span of 52 GHz, as shown in fig.3. The filter with identical dimensions but rounded corners is observed to have maximum transmission at slightly higher frequency of 196 GHz covering 53 GHz span.

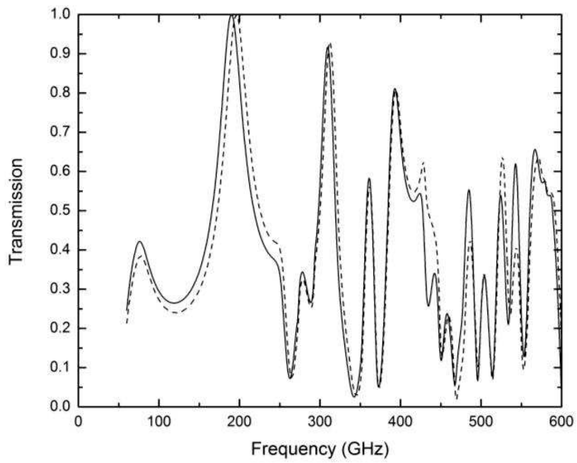

Figure 3: Transmission spectrum of cross-shaped terahertz bandpass filter with rounded and sharp corners. The spectra for rounded corner filter is in dash line and for sharp corner filter is in solid line.

The second transmission peak for filter with rounded and sharp corners are observed at 312 and 309 GHz respectively. The 3dB bandwidth for rounded corner filter is 22 GHz, 1 GHz higher than the bandwidth for sharp corner filter.

3. Test and Measurement

The continuous wave frequency domain terahertz system from Toptica is used to test the fabricated filter in transmission configuration, as shown in fig.4. The frequency scan in 50 to 600 GHz range with 4 MHz step size is performed.

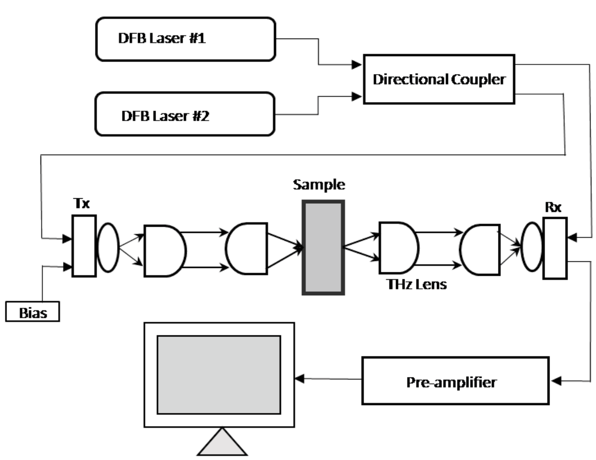

Figure 4: Continuous wave frequency domain terahertz setup for filter testing

The corresponding simulated spectrum is generated using numerical FDTD simulation for silicon based cross-shaped rounded edge filter as shown in fig.5. The peak transmission at 191 GHz (f_{1e}) spans from 127 GHz (f_a) to 242 GHz (f_b). This is 5 GHz less than the designed 196 GHz central frequency.

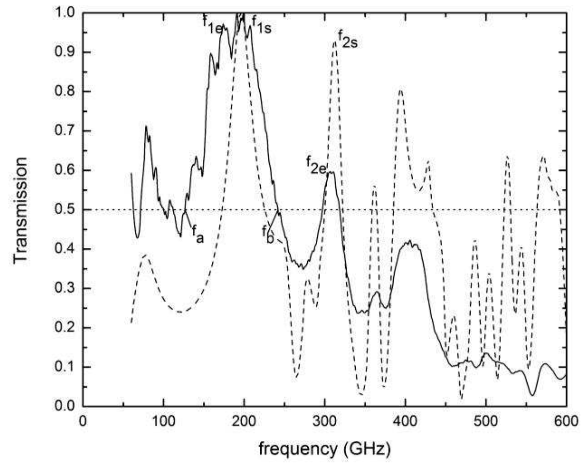

Figure 5: Transmission spectrum of designed and fabricated THz bandpass filter. The simulated spectra for rounded corner filter is in dash line and measured spectra is in solid line.

The difference in central frequencies is attributed to fabrication related variations. Periodically repeated cross shaped filter is expected to enhance the transmission characteristics in comparison to transmission through a single cell. However, variation in dimensions of cross shaped filter of individual cells is likely to broaden the transmission window, as EM contribution from each cell may differ in frequency as well as amplitude. The secondary transmission window observed at 306 GHz (f_{2e}) closely matched the 312 GHz (f_{2s}) of simulated spectrum.

5. Conclusion

Cross-shaped rounded corner THz bandpass filter on silicon has been designed and fabricated. The measured THz spectrum of fabricated filter closely matched our simulation results. The fabricated filter has transmission peak at 191 GHz. It is observed that rounded corners increase the central frequency from 190 GHz for sharp corner pattern to 196 GHz in our simulation. The corresponding increase in bandwidth from 52 GHz to 53 GHz is also observed.

6. Acknowledgements

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7. References

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