A NOVEL KA-BAND BANDPASS FILTER USING LIGA MICROMACHININED PROCESS

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A novel class of three dimensional (3-D) micromachined microwave planar filter at Ka-band is presented using LIGA process. The filter shows wide bandpass characteristic of 39 % with the insertion loss of 1.7 dB at 33.2 GHz, and can be applicable in high power MMIC or MIMIC.

1 Introduction

The progress of semiconductor process technology has driven the development of planar monolithic microwave integrated circuits (MMIC's), in which the design for the small RF circuit that integrate many functions on a chip while providing high performance is possible. However, conventional circuit technology has reached its technical limitation as the frequency range used in communication system increases up to Ka-band (25 ~ 40 GHz), and wide-bandwidth characteristic is needed. Unfortunately, for the microstrip, broad-band characteristic is hard to be obtained due to the large loss for the high frequency range.

To overcome this disadvantage of the conventional transmission line, a new transmission line topology of RF MEMS (micro-electro-mechanical system) has been suggested as an alternative for the high frequency application. As one of the low cost and most efficient micromachining processes, LIGA, a German acronym consisting of the letters LI (RöntgenLIthographie meaning X-ray lithography), G (Galvanik meaning electro-deposition), and A (Abformung meaning molding), has been attracted much attention for the microwave and millimeter-wave devices [1].

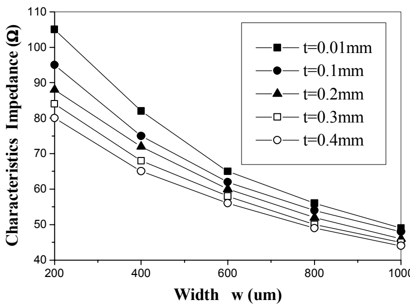
In the LIGA process, PMMA (polymethyl methacrylate) resistor on the substrate is spin-coated, and the pattern for the circuit is generated through deep X-ray lithography and plated metal for the conductor. The structural characteristics for LIGA are the thick conductor (10 μm ~ 1 mm) and the high aspect ratio of conductor side-wall (steep side-wall > 89.9°), which give the effect of increased conduction interface to the circuit and the high coupling compared with the conventional integrated transmission line [2,3]. These advantages make the LIGA structure applicable for high-power monolithic circuits for the transmitter and the wide-band filter, which are hard to be realized in the case of conventional thin-film process.

In this paper, a bandpass filter with very wide bandwidth at Ka-band using the LIGA-like process is designed, fabricated, and characterized .

2 Design and Fabrication

In this paper, a 3-D microstrip bandpass filter with wide bandwidth is presented. Since the impedance in LIGA structure is quite different from that in 2-D microstrip transmission line, the analysis for the characteristic impedance in LIGA microstrip structure is needed for the circuit design. Fig. 1 shows the relationship between the characteristic impedance and microstrip width for the LIGA structure, which are obtained from FD (Finite Difference) analysis. From the figure, the characteristic impedance is decreased with increasing the width of the 3-D transmission line and with increasing the thickness of the conductor metal [4].

The design rule of 0.5 dB Chebyshev prototype using high coupling characteristic in LIGA structure is adopted for the wide bandpass filter. The design parameters are given as follows; the substrate is a fused quartz with the dielectric constant of 3.82 at 30 GHz and the thickness of 625 μm. The thickness of the conductor metal (Cu) is 100 μm. The center frequency (f_0) of the filter is 30 GHz and the bandwith in passband is about 40 %. Fig. 2 shows the wide-band parallel-coupled bandpass filter with 5-stage coupling section [5,6]. This filter is designed with the characteristic impedance of 75 Ω. For the measurement with GSG (Ground-Signal-Ground) CPW (CoPlanar Waveguide) probe, the impedance transformer (Z_t = 61.2 Ω) is inserted between the first stage of 50 Ω part and the third stage of 75 Ω part. Similar one is used for the last part of the filter because it has symmetric structure. Here, the widths and lengths for the parts of 50 Ω, 61.2 Ω, and 75 Ω for this design are L_{50} = 0.3 mm, W_{50} = 1 mm, $L_{61.2}$ = 1.3 mm, $W_{61.2}$ = 600 μm, L_{75} = 1.35 mm, and W_{75} = 400 μm, respectively. Also, the widths and lengths for the coupling parts are given as follows; L_1 = 1.26 mm, W_1 = 100 μm, S_1 = 150 μm; L_2 = 1.235 mm, W_2 = 200 μm, S_2 = 300 μm; L_3 = 1.26 mm, W_3 = 200 μm, S_3 = 300 μm.



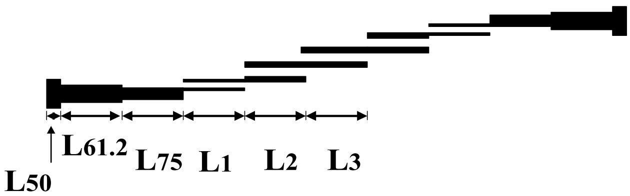


Fig.1. Impedance characteristics for the LIGA micorstrip. Fig.2. Layout of a 30 GHz LIGA bandpass Filter

The LIGA bandpass filter has been designed by HP HFSS ver. 5.4, which is a 3-D microwave simulation tool. Fig. 3 shows the 3-D field simulation results for the wide bandpass filter at Ka-band. The 3-dB corner frequencies are 23.5~36 GHz, the minimum insertion and return losses are about 1.0 dB and –12.3 dB at the center frequency of 30 GHz, respectively.

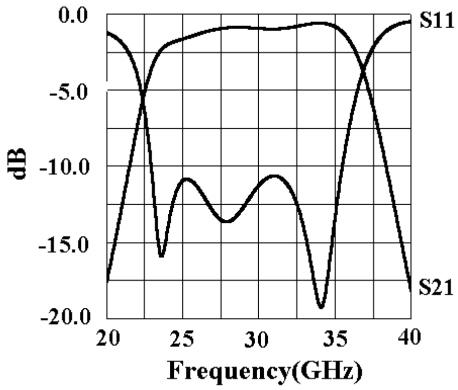
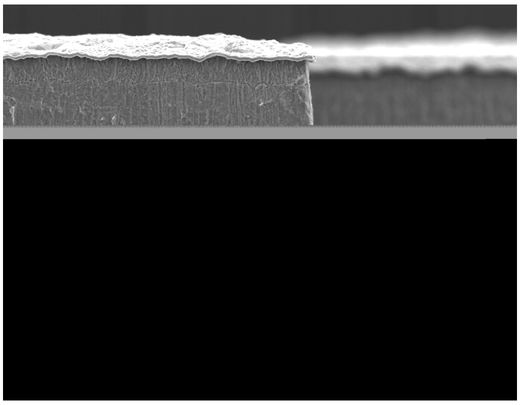


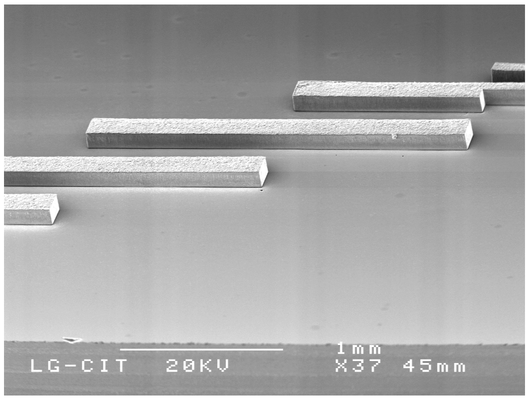
Fig. 3. Simulation results for the bandpass filter

This bandpass filter is fabricated on the fused Quartz using LIGA-like process. First, the seed metals of Ti (300 Å) / Cu (1500 Å) / Ti (300 Å) are deposited on the Quartz substrate. Then, SU-8 epoxy is spin-coated and patterned (120 μm) for electroplating of copper. After removing top Ti layer by wet etching, the formed molds are filled with plated copper. Finally, the LIGA filter is obtained by removing SU-8 epoxy resin and the seed metal layer (Ti/Cu).

Fig.4 shows the SEM photographs for the bandpass filter. From the figures, the conductor metal is observed to be very steep and clear, and the thickness is measured as 104 μm close to the design value of 100 μm.



(a)



(b)

Fig. 4. SEM photographs for the LIGA bandpass filter

3 Experiments and Discussion

For the characterization of the filter with GSG probe which is matched to the characteristic impedance of 50 Ω, the microstrip-to-CPW transition is needed. In this paper, the Probepoint™ 0503 test interface circuit from the Jmicro Technology Co.[7] is used between the microstrip filter and the GSG CPW probe. This circuit works as a CPW-to-microstrip transition adapter without loss up to 40 GHz. The connection between the adapter and the filter has been done by gold wire bonding.

The bandpass filter has been characterized by HP 8510C Network Analyzer. Fig. 5 shows the measurement results for the filter. The 3-dB corner frequencies are observed to be 27.0 ~ 39.8 GHz, which are shifted toward upper-band about 3.0 GHz and correspond to the bandwidth of ~39 %. The minimum insertion loss is 1.7 dB at the center frequency of 33.2 GHz, which is quite close to the simulation value of 1.0 dB. Taking into account the fact that the part of adapter has not been considered for the simulation, the measurement result can be said to be very accurate compared with the design value. The return loss is varied from 8 ~ 18 dB within the passband.

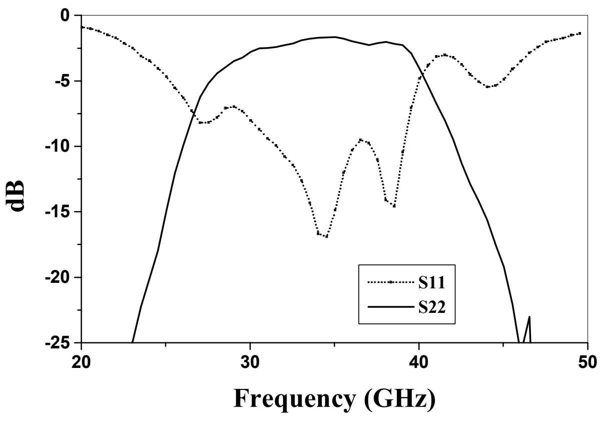


Fig. 5. Measurement results for the LIGA filter

The frequency shift in measurement results compared with the simulated ones is believed due to the fact of fabrication margin and high-frequency property. The difference in return loss between the simulation and the measurement comes mainly from the impedance mismatch, lack of considerations for transition, and wire-bonding effect between the adapter and the filter.

4 Conclusion

We have demonstrated the novel 3-D microstrip bandpass filter on quartz substrate (ε_r= 3.82). This LIGA-like filter has been designed by 3-D microwave simulation tool, HP HFSS and fabricated with thick metal conductor (copper) of 100 µm. It shows very wide bandwidth of 39 % with the low insertion loss of 1.7 dB at Ka-band. Further improvement in microwave performance for the filter is expected if the circuit design and test environment with perfect impedance matching can be provided. This filter can be used in the high-power MMIC or MIMIC.

Acknowledgement

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