논문 2006-43SD-9-10

MCM-D 공정기술을 이용한 V-BAND FILTER 구현에 관한 연구

(V-Band filter using Multilayer MCM-D Technology)

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요 약

본 연구에서는 Si bump를 이용해 기판의 기계적, 열적 특성을 개선한 MCM-D 기판공정을 개발하였고, 이를 system-on-package(SOP)-D개념의 system 구현에 적용하고자 하였다. 이 과정에서 밀리미터파 대역에 적용될 수 있는 필터를 설계하고 구현하여 그 특성을 관찰하였다. 두 가지 형태의 필터를 구현하였는데 첫 번째는 공진기간의 커플링을 이용한 구조로서 2층의 금속층과 3층의 유전체(BCB)를 이용하였다. 구현된 필터 특성은 중심주파수 55 ㎓에서의 삽입손실이 2.6 dB이고 군지연이 0.06 ns정도로 우수한 특성을 나타내었다. 또한 일반적으로 알려진coupled line 형태의 필터를 구현하였는데 삽입손실이 3 dB, 군지연이 0.1 ns정도의 특성을 나타내었다. 이렇게 내장형 필터를 포함한 MCM-D 기판은 MMIC를 flip-chip 방법으로 실장 할 수 있어서 집적화된 밀리미터파 대역 초소형 system 구현에 적용되어 우수한 특성을 나타낼 것으로 기대된다.

Abstract

Novel system-on-package (SOP) - D technology to improve the mechanical and thermal properties of a MCM-D substrate was suggested. Based on this investigation, the two types of band pass filters for the V-band application with unique structure were designed and implemented using 2-metals, 3-BCB layers. The first type using distributed resonator had the insertion loss below 2.6 dB at 55 GHz and group delay was below 0.06 ns. For the second type with edge coupled structure, the insertion loss and group delay were 3 dB and 0.1 ns, respectively.

Suggested MCM-D substrate with band pass filter can be used to evaluate mm-Wave system including flip-chip bonded MMIC.

Keywords : SOP-D, V-band filter, resonator, edge coupled

Ⅰ. Introduction

The trend toward high-volume, low cost RF and microwave applications require suitable packaging techniques. They should offer a high degree of integration to reduce not only size and weight, but also cost and power consumption. Multilayer thin-film multi-chip module technology offers a very high reproducibility of small line dimensions and is therefore a promising technology for the low-cost integration of RF and microwave circuits[1].

Previously, a number of passive devices like coupler, balun and band pass filter have been demonstrated using MCM-D technology for mm-Wave applications [2-4].

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※ This work was financially supported by the Ministry of Commerce, Industry and Energy of Korea through mm-Wave SOP(System on Package) project.

접수일자: 2006년7월1일, 수정완료일: 2006년8월18일

Nowadays wireless PAN in V-band becomes an issue due to its capacity for high data rate communication and many kinds of passive devices for V-band application have been developed.

In this paper, a band pass filter for V-band with unique circuit was designed and demonstrated using multilayer MCM-D technology.

Ⅱ. MCM-D Technology Description

Fig. 1 shows the cross section of SNU's MCM-D substrate considering flip-chip interconnection. As shown in Fig. 1, Seoul National University's MCM-D substrate consists of a lossy silicon substrate, multi benzocyclobutene (BCB), metal layers, and Si-bumps under flip-chip bumps. Here the Si-bumps have the stability for the thermal expansion because they have a thermal expansion coefficient (3.5 ppm/C) similar to that of gallium arsenide (6.0 ppm/C), a typical substrate material for MMICs, and the heat generated during a chip operation can be dissipated effectively due to their high thermal conductivity (150 W/mK).

Due to the low-loss characteristics of thick BCB layers (25 μm), a high-quality filter could be evaluated on SNU's MCM-D substrate even if a lossy silicon substrate was used for a base substrate.For the evaluation of band pass filter, 2-Au metal layers and 3-BCB layers were used.

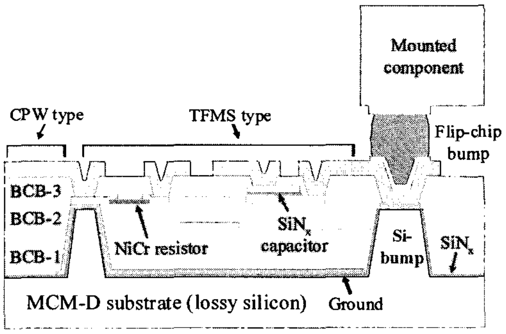

그림 1. MCM-D 기판의 단면 구조
Fig. 1. The Cross-section of SNU's MCM-D Substrate.

Ⅲ. BPF Using Distributed Resonator

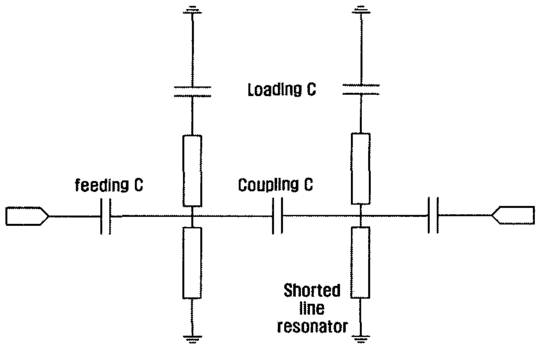

그림 2. 제안된 대역 통과 필터 회로도
Fig. 2. 2nd order band pass filter circuit suggested in this paper.

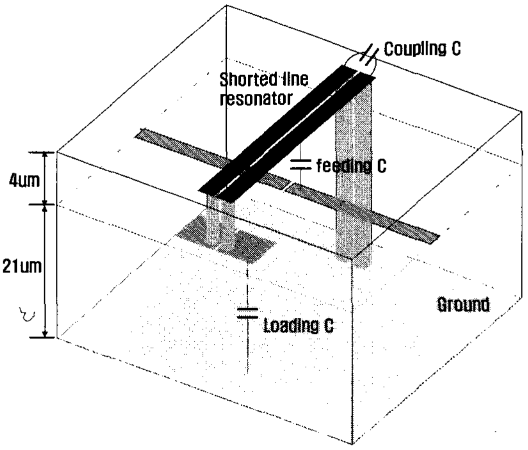

그림 3. 대역 통과 필터 구조
Fig. 3. The structure of band pass filter.

In the design of band pass filter, 2nd order circuit with J-inverter was used. For the evaluation of parallel resonant tank, just one transmission line which was terminated to ground in one side and open ended with loading capacitor in the other sidewas adopted as shown in Fig. 2.

This circuit has some advantages as follows. The length of resonator can be reduced below quarter wave, and frequency can be adjusted easily by controlling the size of loading capacitor. Based on this circuit, 3-dimensional filter structure was implemented adequate for the SNU's MCM-D technology and its actual shape is shown in Fig. 3

Suggested circuit and structure was implemented using SNU's MCM-D technology and its actual shape is shown in Fig. 4.

The gap between two resonators was 10 um, loading capacitor size was 70x70 um^2 and the length of resonator was 860 um. Feeding capacitor was formed

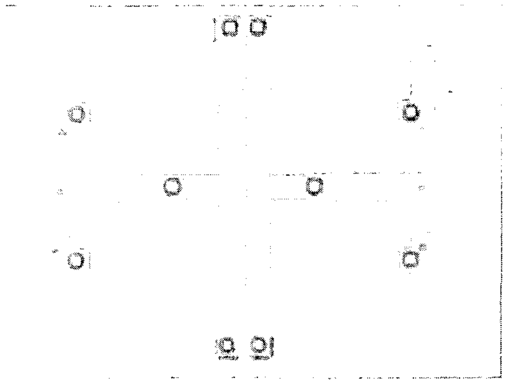

그림 4. BCB위에 형성된 필터 형상
Fig. 4. Band Pass Filter implemented on BCB layer.

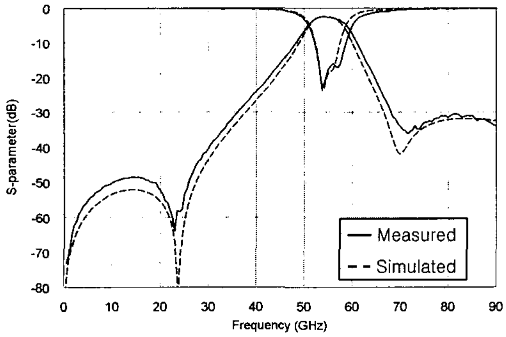

그림 5. 제작된 대역 통과 필터 거동
Fig. 5. The measured and simulated performance of band pass filter.

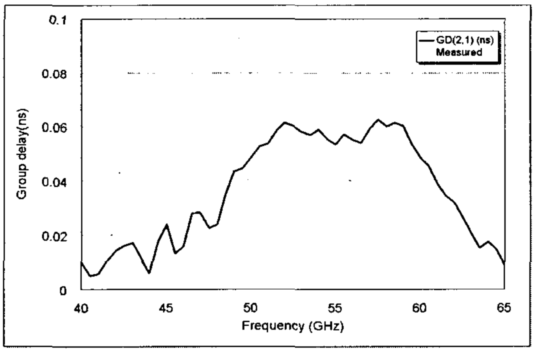

그림 6. 대역 통과 필터의 군지연 특성
Fig. 6. Group Delay of Implemented filter.

between resonator and feeding line placed in inner layer. The metal thickness was 1.8 um larger than 0.32 um, the skin depthat 60 GHz. The BCB layer thickness between the feeding line and resonator was 4 um and the distance from resonator to bottom ground was 25 um.

Fig. 5 shows the measured and simulated performance of bandpass filter. The simulated result considering the actual material properties like effective dielectric constant of BCB and electrical conductivity of metal was in accord with the measured performance. The insertion loss at center frequency was 2.6 dB and the attenuation near 70 GHz used in car radar system was over than 30 dB.

Fig. 6 shows the group delay of the filter, its value was below 0.06 ns and the variation in passband below 0.01 ns. This result is expected to be adequate for wireless communication.

Ⅳ. BPF Using Edge Coupled Structure

Second, the band pass filter using edge coupled structure was designed and implemented. In MCM-D technology, the line and space can be evaluated to about 10 um, so tightly coupled line structure can be implemented easily. Fig 7 shows the structure of edge coupled band pass filter. The gap between coupled lines was 8 um and line width 60 um, respectively.

The 2nd order filter with 3-gap coupled structure was evaluated and each line was formed in meander type to minimize the total dimension.

The performance of this type filter is shown in Fig. 8, the insertion loss was about 3 dB and the attenuation was below 20 dB at 55 GHz and 65 GHz, but as shown in Fig. 9, the group delay was below 0.1 ns in passband.

The group delay of this type filter was larger than that of first type using distributed resonator, but this

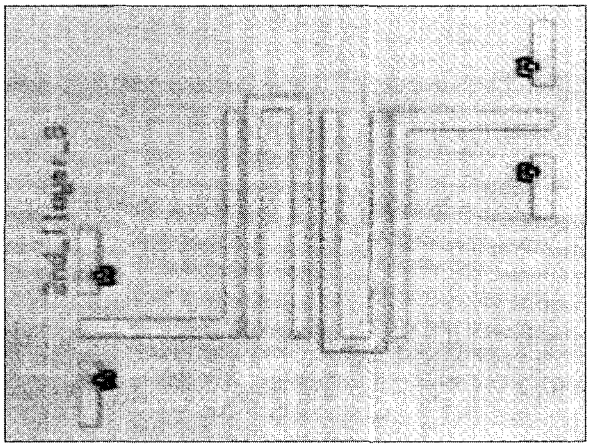

그림 7. Coupled line을 이용한 필터 형상
Fig. 7. The structure of band pass filter using edge coupled structure.

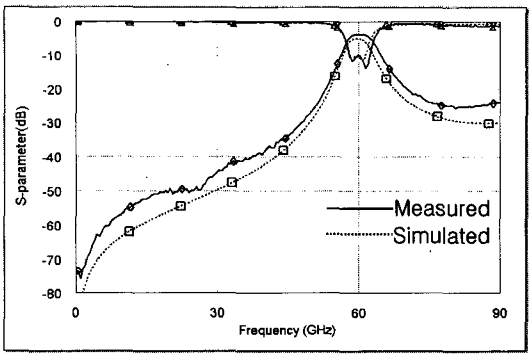

그림 8. Coupled line 필터 거동
Fig. 8. The measured and simulated performance of band pass filter.

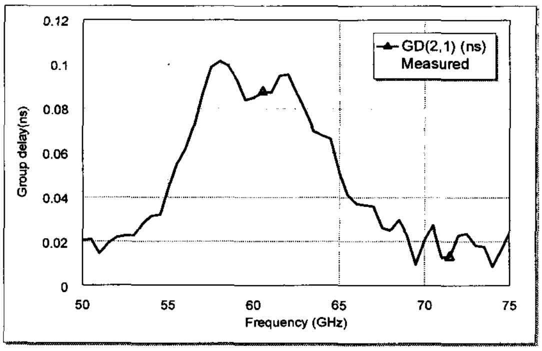

그림 9. 제작된 필터의 군지연 특성
Fig. 9. Group Delay of Implemented filter.

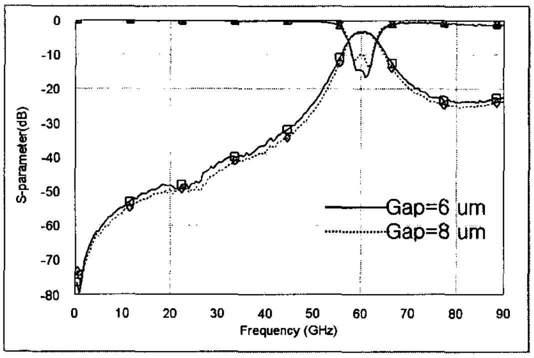

그림 10. 선간 간격에 따른 필터 특성
Fig. 10. The filter response in the variation with the gap between the lines.

value was suitable for the telecommunication system.

Fig. 10 shows the performance of filter with regard to gap distance between coupled lines. As the gap increased, the band width became smaller and the attenuation better, the gap can be used to adjust the band width and attenuation of filter.

V. Conclusions

The novel multilayer MCM-D substrate using BCB as a dielectric was suggested. 2-metals and 3-BCB layers were used in this technology for the evaluation of passive devices. The two types of band pass filters for V-band application with unique circuit and structure were designed and implemented. The first type with distributed resonator had an insertion loss 2.6 dB, group delay 0.055 ns at 55 GHz and good attenuation over than 30dB at both stopband especially near to 70 GHz of car radar system. And for the second type using edge coupled structure, the insertion loss and group delay was 3 dB and 0.1 ns, respectively. Novel MCM-D substrate in this paper with V-band filter can be used to evaluate the millimeter wave system including flip-chip bonded MMIC.

References

[1] G. Carchon, S. Brebels, O. Vendier "Multilayer thin film MCM-D for the realization of Q- and V-band functions," in 2003 *IEEE MTT-S Int. Microwave Symp. Dig.*, pp. 1151-1154, June 2003.
[2] J. S. Izadian et al., "A new 6-18GHz, -3dB multisection hybrid coupler using asymmetric broadside, and edge coupled lines" in *1989 IEEE MTT-S Int. Microwave Symp. Dig.*, pp. 243-247, June 1989.
[3] M. C. Tsai et al., "A new compact wideband balun," in *1993 IEEE MTT-S Int. Microwave Symp. Dig.*, pp. 141-143, June 1993.
[4] K. Takahashi et al., "A Compact V-Band Filter/Antenna Integrated Receiver IC Built on Si-Micromachined BCB Suspended Structure," *IEICE Trans. Electron*, vol. E84-C, No.10, pp. 1506-1514, 2001.

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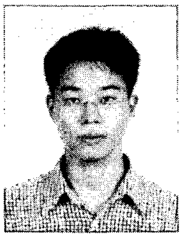

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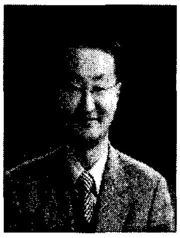

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