Microshield Transmission Line and Spiral Inductor Integrated On Polymer Thick Film.

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Abstract — **newly proposed microshield transmission line and spiral inductor are developed on CMOS grade silicon substrate using polymer thick film as a supporter for signal line. The fabricated microshield line shows maximum available gain of less than -0.12dB/mm and return loss of larger than 17dB up to 40GHz. Due to its microshield structure, the coupling from the neighboring signal line is less than -70dB from 0.5GHz to 25GHz. For the inductor of 3.62nH, self resonant frequency of 14.5GHz, and maximum quality factor(Q) of 15.5 at 5.5GHz are obtained. Because the fabrication process is compatible with the conventional standard silicon IC process, it is applicable to silicon RF IC. Multichip module (MCM) package for high performance is also a good branch for these packaging devices.**

I. INTRODUCTION

The rapid expansion of wireless mobile communication market and operating frequency in the system has created a demand for low cost, high performance substrate materials for microwave ICs and MCM package. For the last several decades, GaAs and ceramics such as alumina had offered superior quality for this application.

Recently, there have been significant researches on polymer materials for use in electronic applications [1]. Especially, conventional microstrip line and coplanar waveguide on polymer film have achieved low loss characteristic, low cost, and high design flexibility [2]. But the planar structure of the above transmission lines generated the fringing in the electromagnetic fields such as radiation, dispersion, and crosstalk. These drawbacks impose serious limitations and degraded electrical performance in the high density circuit layouts. Up to now, there have been several approaches taken to overcome electromagnetic coupling and micorshield structured transmission line considered to minimize this corsstalk [3, 4].

This paper presents the microshield line proposed to solve the crosstalk problem in packaging applications of polymer film, as shown in Fig. 1. Using Upilex polymer film as a supporter and dielectric spacer, the microshield line can be simply fabricated on CMOS grade silicon substrate and applicable to silicon MMICs and MCM package. The spiral inductor which has fabrication process compatible to that of microshield line is also proposed and characterized

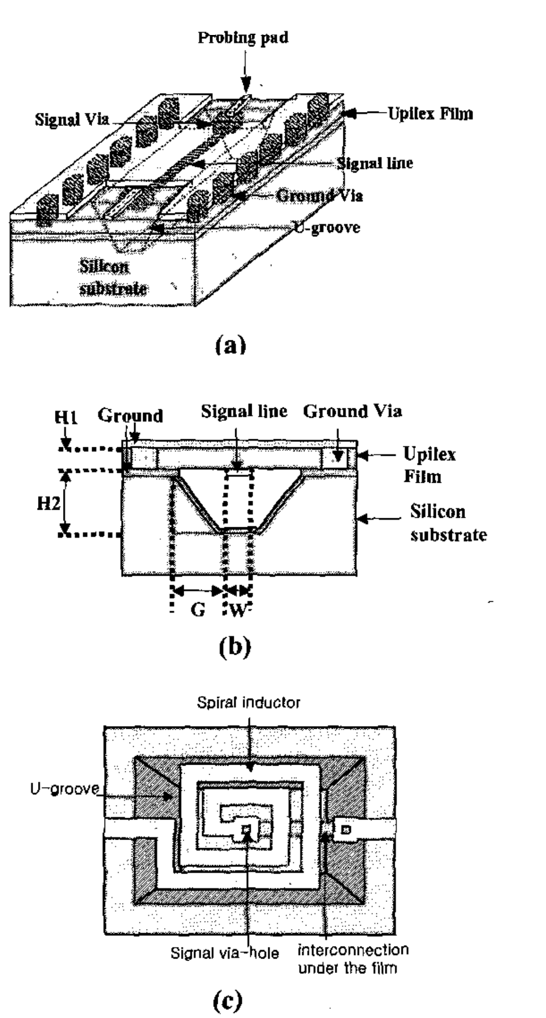


Fig. 1 Schematic diagrams of microshield line:.
(a) Schematic diagram of microshield line with explanation of elements. (b) Cross sectional view of microshied line with dimensional parameters to fit to 50Ω. (c) Top view of the schematic diagram of spiral inductor on film.

II. EXPERIMENT

The microshield line was implemented as a straight line of 5 mm length. Upilex-50S was used as the dielectric spacer and supporter for signal line. Its dielectric constant and dissipation factor are 3.4 and 0.003, respectively. The dimensions of the microshield line were decided by the value.of the characteristic impedance. In this experiment, the microshield line was designed to achieve 50Ω characteristic impedance. It is simulated by Ansoft HFSS with four parameters W(signal line width), G(spacing between signal line to ground line), H1(film thickness : 50μm), H2(silicon substrate etching depth : 100μm). Fig. 2 shows its process steps. There are four main steps in realizing the microshield line.

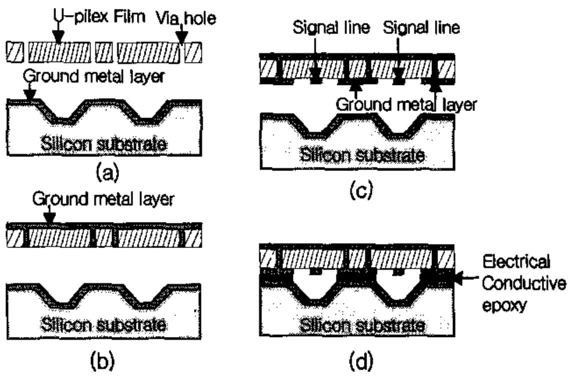


Fig. 2 Fabrication procedure of the microshield line:
(a) Defining the lower cavity region and ground metalization and via-hole formation in U-pilex film. (b) Ground metalization on upper side of film and via-hole. (c) Formation ground and signal line on lower side of film. (d) Attaching two layers with electrical conductive epoxy.

The first step is the formation of the lower cavity region and the metalization of the surface for signal ground. Via holes are made in polymer film for signal and ground connection between the upside and the downside. The second step is formation of ground plane on top of the film and in via holes by gold plating. The third step is to make signal and ground line on the downside of the film, and the last step is to attach the two layers pasted with electrical conductive epoxy as shown in Fig. 2. To form the lower cavity region [Fig. 2(a)], the p-type silicon with low-resistivity (8 – 12Ω-cm) was etched by KOH at 70°C. The etching depth is 100μm. And then lower ground metal (Au ; 5μm) was electrically plated. The RIE etching process (O_2 ; 300 sccm) was performed with metal mask (Cr ; 2000Å) to make 50μm thick via-hole in the film. In the signal line, the size of via-hole is 50μm x 50μm. In the ground plane, 100μm x 100μm via-holes are arrayed every 100μm. The second step is ground plane, probing pad, and spiral inductor line formation on the top of the film. The metal layer was fabricated by conventional Au electroplating [Fig. 1 (b)]. The thickness of metal layer is 3.5μm. The third step is to form the signal line, ground plane, and the via-hole interconnection of inductor on the downside of the film by Au electroplating. [Fig. 1 (c)]. The thickness of metal layer is 5μm. Finally, the silicon substrate pasted with electrically conductive epoxy (Amicon 929-72-9J) was attached to the ground metal layer on the downside of film by flip-chip bonding machine. Thereafter, it was cured at 120°C for 1hr. Fig. 3 shows the pictures of the fabricated microshield line and spiral indutor.

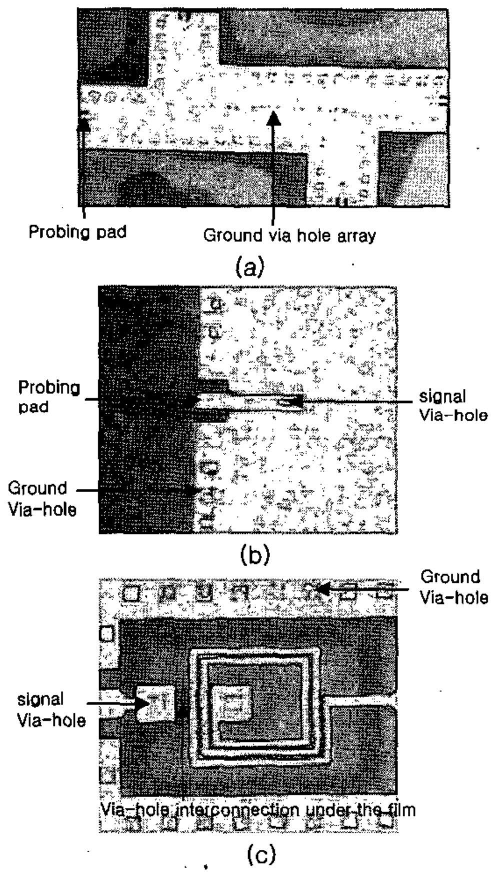


Fig. 3 Pictures of fabricated microsield line and spiral inductor ; (a) Coupling test pattern (coupling length:2mm, distance:250μm). (b) Probing pad on top of the film. (c) Spiral inductor on top of the film and interconnection line underneath the film.

III. RESULTS OF MICROSHIELD LINE

In the measurement, the set-up consists of HP 8722ES network analyzer and GGB INDUSTRIES ground-signal-ground (GSG) probes that have a probe pitch of 150μm.

This calibration is achieved using GGB CS-5 calibration kit with short-open-load-through (SOLT) calibration technique, and the parasitics are not de-embedded.

In Fig. 4, the return loss and maximum available gain of the 5mm long microshield line is shown with the simulation result (done by Ansoft HFSS). The return loss is larger than 17dB and the maximum available gain is smaller than -0.65dB (W=110μm; G=565μm; H1=50μm; H2=100μm) over the frequency range (from 0.5GHz to 40GHz). Due to its micorshield structure, there is cavity characteristic as shown in Fig. 3.

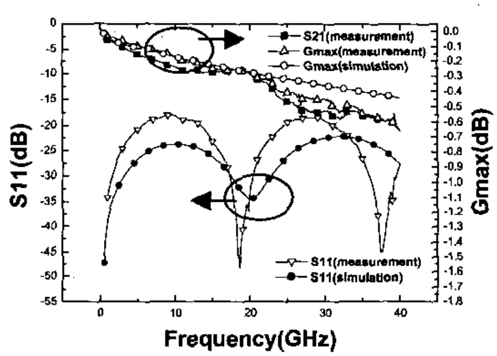


Fig. 4 The return loss and maximum available gain of the 5mm long microshield line with the simulation result (W=110μm; G=565μm; H1=50μm; H2=100μm)

In Fig. 5, the maximum available gain of anonther microshield line is shown and it is lower than -0.1dB/mm (W=60μm; G=95μm; H1=50μm; H2=100μm) over the frequency range (from 0.5GHz to 15GHz) in contrast to that of the conventional ground coplanar waveguide with 50μm thick dielectric layer which is above -0.15dB/mm. To investigate the cross-talk characteristic which is important for high-density integration, the couplings of micorshield line to microshield line and conventional ground coplanar waveguide (GCPW) to GCPW was measured and campared. The length of the coupling part is 2mm and the line spacing, which is the distance between the two signal lines of the two neighboring transmission lines is 250μm.

Fig. 6 shows the coupling between the two coaxial lines versus frequency.

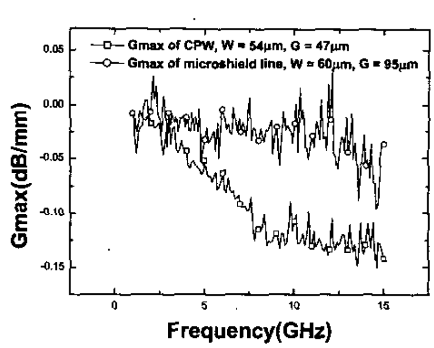


Fig. 5 Comparison of maximum available gains of microshield line (W = 60μm, G = 95μm and H1 = 50μm, and H2 = 100μm) and conventional ground coplanar wave guide (W = 54um, G = 47um, and dielectric thickness = 50um)

The microshield line shows coupling of lower than -70dB from 0.5GHz to 25GHz, on the contrary, the coupling of conventional ground CPWs is lower than –50dB over the frequency range. In fact, the coupling is so low that it is close to the measurement noise level up to 20GHz. The coupling is highly dependent on the size and spacing of the ground via-holes located between two signal lines. In this experiment, the ground via-holes of the size of 50μm x 50μm are arranged every 50μm along the ground plane between the two signal lines. Over 25GHz frequency range, there is crosstalk in the film layer which does not has ground via-holes to be located between ground via-holes. Therefore, it is necessary to change the ground via-hole array to ground via-hole bar to shield the signal line entirely.

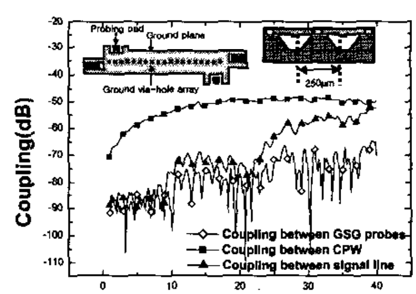


Fig. 6 The coupling of two coaxial lines (distance: 250μm; coupling length: 2 mm). Each microshield line has W = 70μm, G = 85μm, H1 = 50μm, and H2 = 100μm.

IV. RESULTS OF INDUCTOR ON POLYMER FILM

The inductor (2.5turn; inner diameter = 200μm x 200μm; line width = 10μm; line spacing = 10μm) had an inductance value of 3.62nH and an estimated resonant frequency of 14.5GHz. These values were calculated from the modeled s-parameters using HP ADS simulator. The value of the quality factor (Q) is given by

$$Q = Im[Zin]/Re[Zin]$$

where Re[Zin] is the real part of the input impedance of spiral inductor and Im[Zin] is the imaginary part of the input impedance of spiral inductor. In Fig. 7, the quality factor of the inductor fabricated on film is compared with that of airbridge inductor which uses 4μm thick metal layer on GaAs substrate. The quality factor of the inductor on film is slightly better than that of inductor on GaAs semi-insulating substrate.

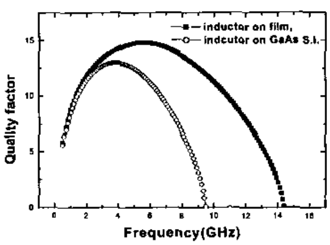
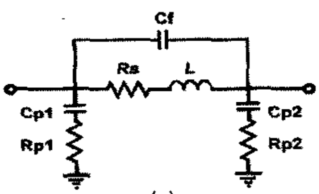


Fig. 7. Comparison of quality factors of inductors as a function of frequency:
The inductance values of inductor on film and conventional inductor are 3.62nH and 3.57nH, respectively.



(a)

Model parameters	This work Inductor on film	Conventional spiral inductor
Cf(fF)	5.262	20
Rs(Ω)	2.96	3.09
Ls(nH)	3.62	3.57
Cp1(pF)	0.03	0.05
Rp1(Ω)	50.49	53
Cp2(pF)	0.03	0.03
Rp2(Ω)	50.14	156

(b)

Fig. 8 (a) An equivalent circuit and (b) the extracted equivalent circuit parameters

conventional spiral inductor with an airbirdge is 3.09Ω (4μm thick metal layer). Compared to this work (Rs = 2.96Ω : 3.5μm thick metal layer), the conventional inductor has slightly larger series resistance, in spite of more thick metal layer, because of the drawback of thin first metal layer under the airbirdge. As playing a dominant role in determining the quality factor, the thick via-hole interconnection under the film layer improves the quality factor and gives a solution for the problem.

V. CONCLUSION

A new microshield line and spiral inductor are proposed and fabricated on silicon substrate using polymer film as supporter for signal line and dielectric spacer. Due to its shielded structure, this microshield line provides lower attenuation and higher isolation even with CMOS grade silicon substrate. The Gmax of 5 mm-long microshield line is smaller than –0.65dB and the return loss is larger than 17 dB at all measured frequency. The coupling level is below -70dB to 25GHz, with 2-mm long coupling length and 250μm spacing. A spiral inductor is also fabricated by the same process. For a 3.62nH inductor, resonant frequency of 14.5GHz and maximum quality factor (Q) of 15.5 are obtained. Compared to the conventional inductor on GaAs semi-insulating substrate, it shows improved performance.

These results show that this package technology can be applied to silicon microwave integrated circuit and VLSI technology for direct interconnections. And it can be applied also to MCM-Si packaging technology.

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