Symmetrical Planar IPD Balun for WLAN and Wimax Application

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1. Introduction

Currently, the development of wireless communication technology is very rapid. The trend of the miniature wafer dimension is necessary. In the RF system, the passive components occupy an increasingly larger area and do not easily to integrate it in single process. In this paper, we design the symmetric planar balun and use the integrated passive device (IPD) technology to implement this design. The IPD process have thick-Cu metal layer, high dielectric constant embedded capacitor layers and high- resistivity glass substrate. The effect of series resistance can be reduced by the high conductivity of Cu and the sufficient metal thickness. We can use the embedded capacitor to perform the match network and improve the performance of circuit. The glass substrate is high- resistivity material, which can cut the path of the electromagnetic couple and decrease the eddy current.

In this study, the high balance, symmetric planar balun will be presented by IPD process. It exhibits a excellent performance from 2 to 4.2 GHz and can apply to the 2.4 GHz WLAN and 3.4 to 3.7 GHz WiMAX application. The return loss is better than -10dB within the pass band. The measurement results of magnitude and phase imbalance are lower 0.8 dB and 0.03 degrees, respectively.

2. Balun Design and Fabrication

Figure 1 show the cross-section of IPD process. It consists of dielectric layer, embedded capacitor layer and three metals. The first metal layer and the top electrode were Al, the second and third metal layers were Cu, and the dielectric layer was polyimide. The thickness of each layer is shown in table 1. The 3D structure of symmetric planar balun is shown in Figure 2. The main structure of planar balun were designed on thick Cu layer (M2). The bottom metal layer is the thin Al layer that underpass and ground path were build-up on it. The top metal layer (M3) was designed for the signal pad.

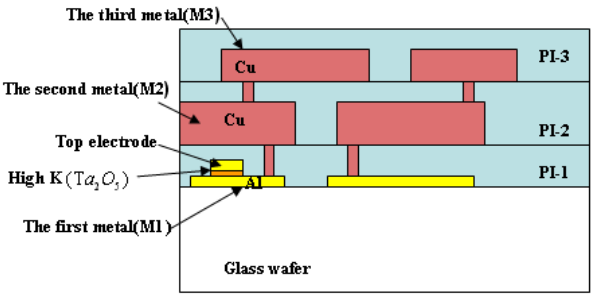

Figure 1. The structure of IPD process cross-section

Table 1. The thickness of each layer

Layer	Thickness (μm)	Layer	Thickness (μm)
Glass	700	PI-1	3.7
M1	1	PI-2	11
M2	10	PI-3	10
M3	5	Top electrode	1
High K	0.25		

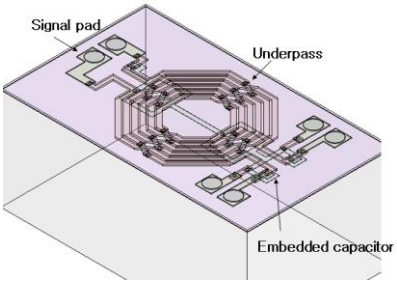

Figure 2. 3D structure of symmetric planar balun

The fabrication process flow is shown in Figure 3. The fine adhesion material of Al was directly deposited on the glass wafer. In figure 3(c) and 3(d), the Ti/Cu was sputtered and the Cu was electroplated above it. The Ti enhanced adhesion for the metal and polyimide. Next step, we can remove the Ti/Cu and spin coated the second isolation, which is shown in Figure 3(e) and 3(f). After coating PI-2, we repeat the step (c)~(e) of figure 3. Finally, we coat the isolation layer(PI-3) and open the outer connect.

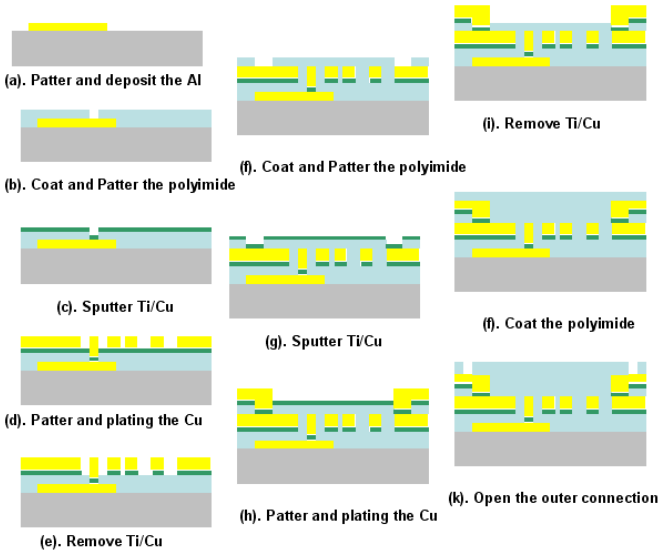

Figure 3. The fabrication process flow

3. Measurement Result and Discussion

The measurement results of the symmetric planar balun are shown in Figure 4. The measured return loss is better than -10 dB from 2 to 4.2 GHz and better than -13dB from 2.2 to 3.9 GHz. The magnitude imbalance (δ) and phase imbalance(θ) are both calculated by using the formulas (1) and (2):

$$\delta = 20\log\left|S_{21}/S_{31}\right| \quad (1)$$

$$\theta = 180 - \left|\tan^{-1}\left(\frac{\mathrm{Im}(S_{21})}{\mathrm{Re}(S_{21})}\right) - \tan^{-1}\left(\frac{\mathrm{Im}(S_{31})}{\mathrm{Re}(S_{31})}\right)\right| \quad (2)$$

By the above formulas, the measured magnitude and phase imbalance of this balun were shown in Figure 5. It exhibit electrical performance of high balance as low as 0.8 dB and 0.03 degrees from 2 to 4.2 GHz. The photo of symmetric balun is shown in Figure 6 and the overall chip dimension is 0.82 mm x 1.45 mm. The comparisons among other reports of balun are summarized in table 2.

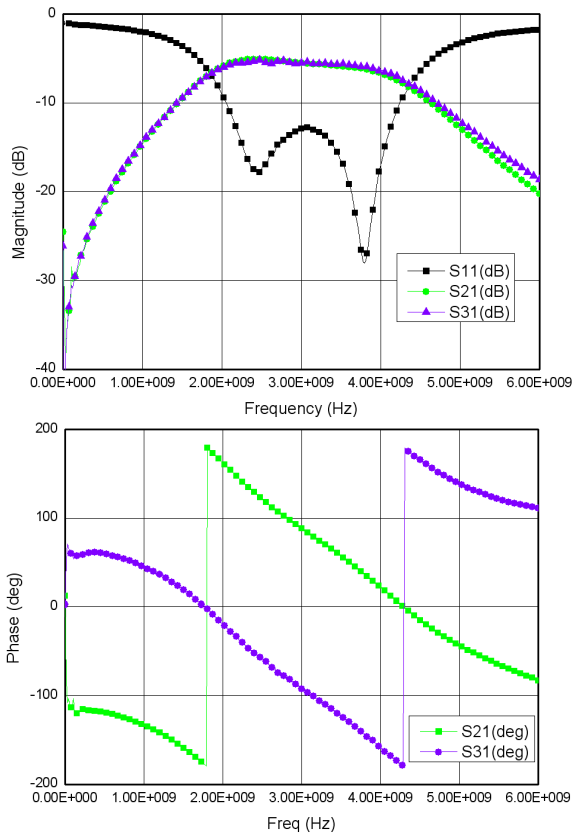

Figure 4. Measurement results of this balun

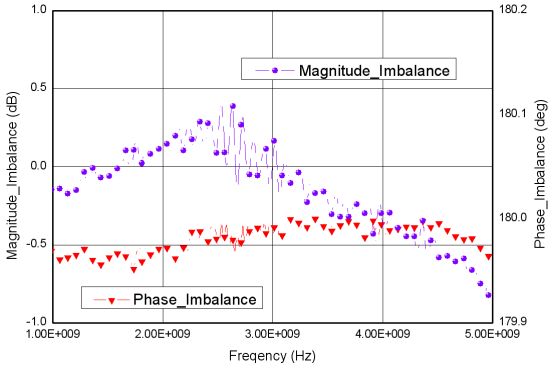

Figure5. Measured magnitude and phase imbalance of this balun

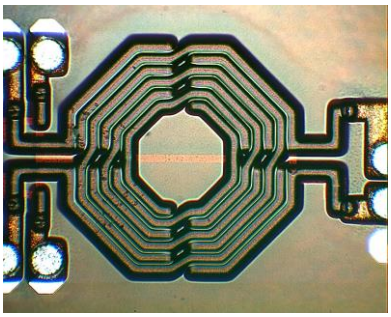

Figure 6. The photo of symmetrical planar balun

4. Conclusions

In this study, we presented the IPD technology for symmetric planar balun. The measurement results of magnitude and phase imbalance were as low as 0.8 dB and 0.03 degrees from 2 to 4.2 GHz and can apply to the 2.4 GHz WLAN and 3.4 to 3.7 GHz WiMAX application. It exhibit excellent electrical performance that compared with among other reports of balun design.

References

[1] X. Jun, W. Zhigong, and G. Xuefeng, "3-11 GHz Monolithic Balun in CMOS Technology for UWB Applications," in *Microwave and Millimeter Wave Technology, 2007. ICMMT '07. International Conference on*, 2007, pp. 1-3.

[2] E. Davies-Venn and T. Kamgaing, "LC-based WiFi and WiMAX Baluns embedded in a multilayer organic flip-chip ball grid array (FCBGA) package substrate," in *Electronic Components and Technology Conference, 2008. ECTC 2008. 58th*, 2008, pp. 169-174.

[3] E. Davies-Venn and T. Kamgaing, "Miniaturized rf transformer-based baluns for 802.11a/b/g WLAN modules embedded in organic package substrate," in *Radio and Wireless Symposium, 2008 IEEE ,pp. 359 - 362, 22-24 Jan. 2008* 2008, pp. 359-362

Table 2. Summary and comparisons among other reports of balun

Ref	Tech.	Frequency	Chip Dimension	Magnitude Imbalance	Phase Imbalance
This work (measurement)	IPD	2-4.2 GHz	0.82mm*1.45 mm	<0.8 dB	<0.03 degree
[1] (simulation)	0.13μm CMOS	3-11 GHz		<0.02 dB	<0.2 degree
[2] (measurement)	FCBGA	2.3-2.6 GHz	1.6mm*1.7mm	<1.45 dB	<3 degree
[2] (measurement)	FCBGA	4.9-5.9 GHz	1.35mm*1.43mm	<0.3 dB	<2 degree
[3] (measurement)		2-3 GHz	1.37mm*1.68mm	<0.5dB	<5 degree
[3] (measurement)		4-7 GHz	1.14mm*1.54mm	<0.3ddB	<6 degree