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Evaluation of Ferromagnetic Thin Film Noise Suppressor Applied to On-Chip Transmission Lines

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1. Introduction

Recently the chip level electromagnetic interference (EMI) has become a serious problem owing to the switching current of the digital circuits and the increasing density of transistors integrated onto LSIs [1]. Noise suppression sheet (NSS) is a major noise suppressor used in electronic devices. NSS uses FMR for generating power losses and these losses are used for the noise suppression [2]. Soft magnetic thin film is an interesting candidate for the next generation RF electromagnetic noise suppressor on chip level EMI countermeasure because of the high FMR and Joule losses in the RF range [3][4].Alloy and granular thin films have μ" as much as 1000. As a result, films of thickness one tenth to one hundredth of present day films can be obtained if alloys and granular thin films are used.

This paper discusses the power losses in the magnetic film integrated onto a 2.5 × 2.5 mm^2 size chip fabricated using SOI-CMOS technology for the purpose of in-line noise suppression in semiconductor devices. Additionally, the noise suppression on the coplanar and microstrip line is demonstrated to find out the difference in loss from the structure of transmission line.

2. Experimental

The coplanar transmission line has been fabricated using a 0.15 μm five metal (4M + Thick Metal) SOI-COMS technology on a high resistivity substrate. Metal layers are made of aluminum alloys. Permittivity of insulator between each metal layer is about 4. Fig.1 shows cross sectional view of the transmission line and ferromagnetic film. A signal line of width similar to that of power distribution line in chip is designed. Moreover, in order to avoid impedance mismatch, the characteristic impedance is made 50 Ω using coplanar line and microstrip line. The signal line of the coplanar line is 8.0 μm wide, 1964 μm long and 2 μm thick. The signal line of microstrip line is 11.5 μm wide, 1964 μm long and 2 μm thick.

Fig.2 shows the photograph of the ferromagnetic thin film noise suppressor. The CoZrNb film is formed 0.86 mm wide, 1.91 mm long and 0.5 μm thick. The RF noise suppressor on transmission lines was composed with stacks of the CoZrNb/SiO_2/CoZrNb. These layers are deposited using RF sputtering. The thickness of each CoZrNb is 0.25 μm, the total thickness being 0.5 μm. The SiO_2 layer is 5 nm thick. The hard axis of the magnetic film is set in a direction perpendicular to the wave propagation of the coplanar transmission line. Fig. 3 shows the relative

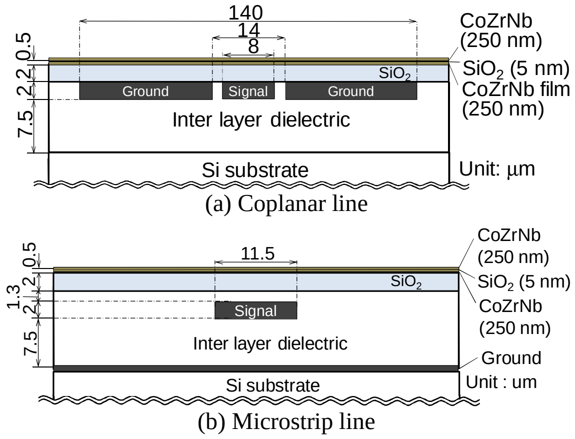

Fig. 1 Cross-sectional view of transmission lines with integrated ferromagnetic noise suppressor.

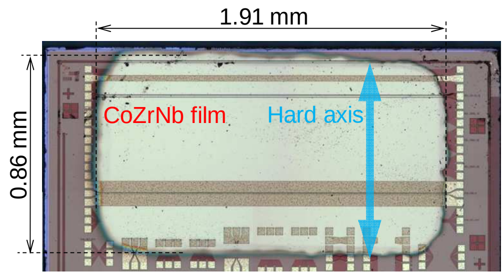

Fig. 2 Photograph of the on-chip integrated ferromagnetic noise suppressor.

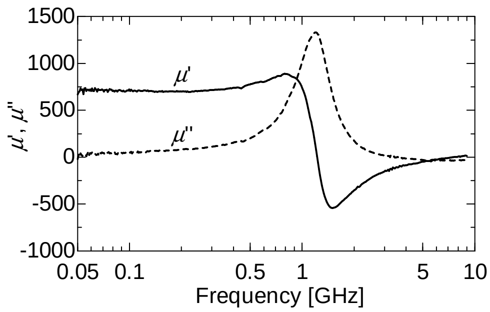

Fig. 3 Relative permeability of these films within the range of frequency 0.05 to 9 GHz.

permeability of these films within the range of frequency 0.05 to 9 GHz [5]. The magnetic property of CoNbZr film is as follows: saturation magnetization 1.15 T, magnetic anisotropy field 1.2 kA/m, resistivity 1.2×10^{-6} Ωm, FMR frequency 1.28 GHz.

The electric performance is measured with two ground–signal–ground pin (GSG) type wafer probes (Cascade Microtech I40-GSG-50) using network analyzer

(Agilent E8363B) from 0.05 to 40 GHz.

3. Result and Discussion

Fig. 4 shows the values of the S parameter (s_{11} and s_{21}) of coplanar line with the magnetic film in comparison with and without the film. The signal transmission (s_{21}) in the coplanar line with magnetic film is significantly decreased by -5.5 dB at the frequency of 7.0 GHz compared with the coplanar line without magnetic films. The dip point at the frequency of 7.0 GHz shifts to higher frequency as external magnetic field, H_{ex} along the easy axis is increased. When H_{ex} is strong enough compare to magnetic anisotropy field, FMR frequency shifts becoming proportional to H_{ex}. The dip is thought to be due to FMR. The signal reflection (s_{11}) for the coplanar line with CoZrNb film is larger than that without film because of impedance miss-matched due to the integration of the magnetic film. The dip point at frequency of 18 GHz is because of wave resonance while the signal line length is equal to 1/4 of the wave length.

Fig. 5 shows the ratio of power loss in the thin film noise suppressor $\Delta P_{loss}/P_{in}$. This is calculated as P_{loss}/P_{in} with film minus P_{loss}/P_{in} without film. P_{loss}/P_{in} is calculated using the reflection (s_{11}) and transmission (s_{21}) parameters as, $P_{loss}/P_{in} = 1 - (|s_{11}|^2 + |s_{11}|^2)$.

The $\Delta P_{loss}/P_{in}$ of 37% was obtained at the frequency of 7 GHz in coplanar line and 17% was obtained at a frequency 5.4 GHz in microstrip line. Comparing the losses in these two structures, the loss in coplanar line is larger than the loss in microstrip line, except of 17 GHz of the resonance frequency. The reason is thought to be that the distance between return current and the film is smaller in case of coplanar line than in case of microstrip line. In case of film above coplanar line, the magnetic flux entering the film is more, resulting to greater loss.

Below is the comparison between the result of this work and that of ref. [3]. We had made a coplanar line with signal line by using Cu onto a glass substrate. It's signal line is width of 50 μm and length 15 mm. The CoZrNb film is width of 4 mm, length of 15 mm and thickness of 0.5 μm. From ref. [4], the P_{loss}/P_{in} is proportional to (film length)$^{0.7}$. Fig. 5 shows the value calculated by considering this assumption. Table 1 shows the loss of each transmission line at the frequency of 2.4 GHz and 5.2 GHz, the standard frequency of wireless LAN, and the loss at the frequency of 7 GHz. The length of NSS [6] is 50 mm. Other transmission line losses are calculated on the basis of transmission line length of 1.964 mm. Result obtained from this study shows higher value than the result of ref. [3]. This difference will be the main theme of further research. Additionally, noise suppression similar to NSS, is obtained by coplanar line at the frequency of 7 GHz.

4. Conclusion

The noise suppression on the transmission line, fabricated in a 0.15 μm five metals SOI-CMOS technology with high resistivity substrate, has been demonstrated using the CoZrNb soft magnetic film. The power loss of 37% was obtained at the frequency of 7 GHz in coplanar line with film and 17% was obtained at the frequency of 5.4 GHz in microstrip line with film. As a result, a large loss was obtained by short length of the transmission line.

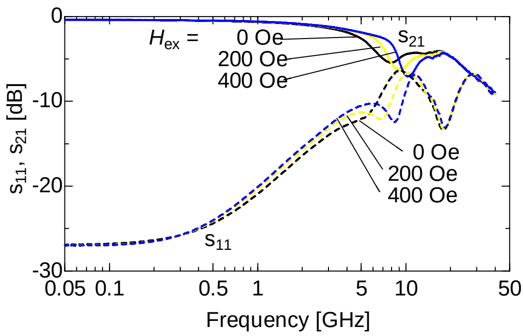

Fig. 4 Signal attenuation, s_{21} and reflection, s_{11} on coplanar line with the CoZrNb film are shown in comparison with that without film.

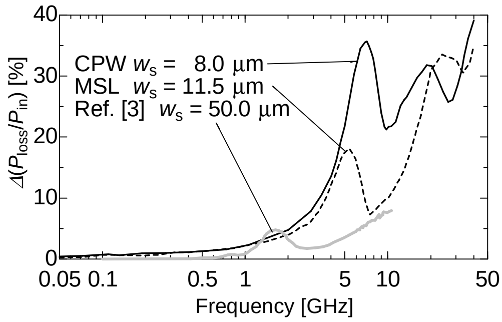

Fig. 5 The power loss on transmission lines with the CoZrNb film are shown in comparison with that without film.

Table 1 Comparison of the size and the power loss.

		CPW	MSL	Ref. [3]	NSS(E25)
Film	Length [mm]	1.96	1.96	15	50
	Thickness [μm]	0.5	0.50	0.5	25
P/P_{in} [%]	2.4 GHz	10	6	3	22
	5.2 GHz	23	17	4	31
	7.0 GHz	37	7	6	38

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