Effect of Filling Factor and Size of Dummy Fills in Microstrip Line on a CMOS Chip

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Abstract

The effects of filling factors and sizes of dummy fills were investigated by analysis and measurement. The loss increases as filling factor of dummy fills increases. The loss of the line with small dummy fills is smaller than that with large dummy fills. The loss decreases as the distance from the center of the signal line to the edge of dummy fills increases.

Keywords : On-Chip, Millimeter-Wave, Transmission Line, Dummy Fills, Filling Factor

1. Introduction

Millimeter-wave CMOS RF circuits have been received substantial attention in recent years, motivated by the advancement of CMOS process [1]. The RF circuit consists of several metal layers and vias. The metal filling factor must be satisfied, usually 50% to 75% to satisfy design rules in the semiconductor process, especially chemical mechanical polishing (CMP) rule. Because of CMP rule, dummy metals with 2 μm up to 10 μm square are necessary all over the chip. The effect of dummy metals is not negligible in the millimeter-wave band though it has been ignored below the frequency range of a few GHz [2]. The authors developed the eigenmode analysis of propagation constant of a guided microstrip line on a Si CMOS chip [3][4]. In this paper, effects of filling factors and sizes of dummy fills are studied by analysis and measurement.

2. Guided Microstrip Line on a CMOS Chip

A transmission line, a guided microstrip line, on a Si CMOS substrate with dummy metals is shown in Fig. 1. The transmission line consists of several metal layers and vias which connect them. Because of CMP rule, dummy metals with 2 μm up to 10 μm square are necessary all over the chip in the CMOS 65 nm or later process. SiO2 is used as insulator between metal layers. The ground plane and signal line are realized by the bottom and top metal, respectively. There are metal walls, or a guide, on both sides of the signal line which consists of metal layers and vias. Distance from the guide to the signal line is enough so that the guide does not affect transmission characteristic of the microstrip mode. Dummy metals and vias, which are small compared with a wavelength, are arranged periodically. Figure 2 shows micrographs of fabricated microstrip lines with several filling factors and sizes of dummy fills.

3. Results

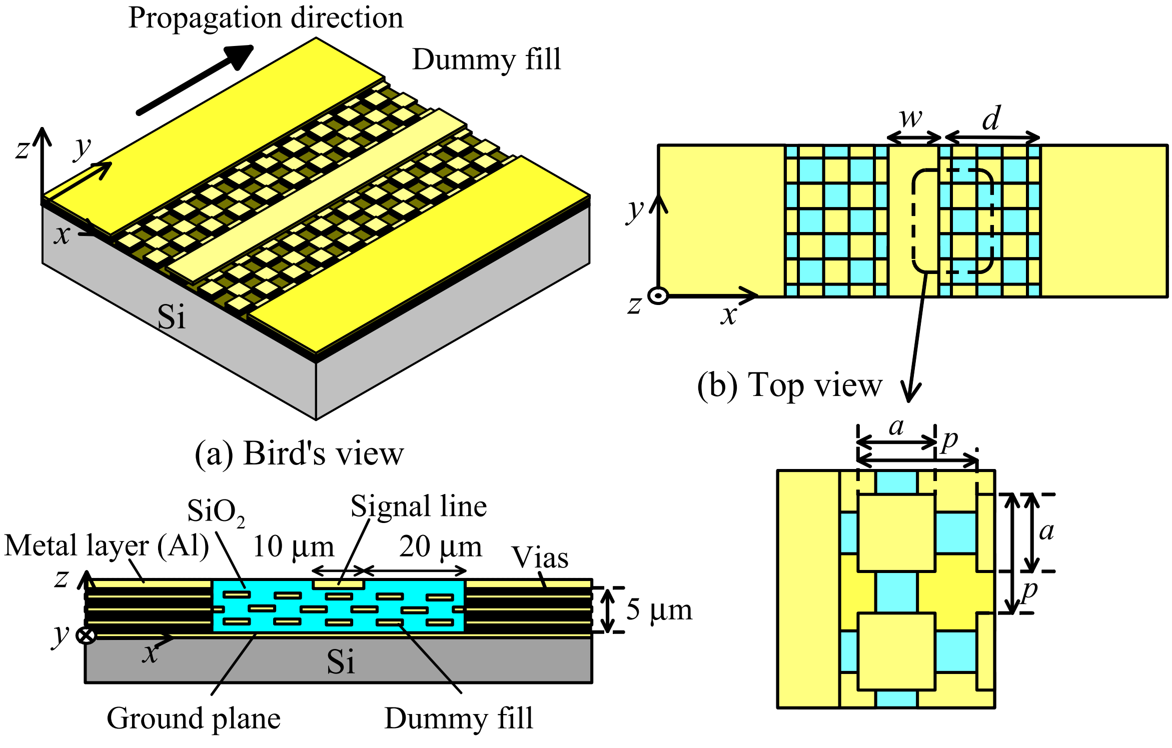
Figure 3 shows frequency characteristic of attenuation constant for several filling factors (25 %, 40 %, and 70 %) and sizes (5 μm and 3 μm) of dummy fills. Solid lines are calculated values by the method presented in reference [3][4]. Measured results are plotted with markers. Thru-Line (TL) de-embedding method [5] was used to remove effects of pads from measured data. The agreement between the analysis and measurement is reasonable. The loss increases drastically in the frequency range from DC to 5 GHz because thicknesses of metal layers are much smaller than skin depth. It is seen form Fig.3 that the loss increases as filling factor of dummy fills increases. At 60

GHz, the loss of the line with 70 % filled dummy fills is 1.8 dB, which is two times larger than that of the line without dummy fills (0.9 dB). The loss of the line with dummy fills with 3 µm square is smaller than that with 5 µm square.

Figure 4 shows calculated attenuation constant as a function of distance from the center of the signal line to the edge of dummy fills (d_{dmy}). It is seen form Fig.4 that the loss decreases as d_{dmy} increases. When $d_{\mathrm{dmy}} > 13$ µm, the loss becomes identical with that of the line without dummy fills.

4. Conclusion

The effects of filling factors and sizes of dummy fills were investigated by analysis and measurement. The loss increases as filling factor of dummy fills increases. The loss of the line with small dummy fills is smaller than that with large dummy fills. The loss decreases as the distance from the center of the signal line to the edge of dummy fills increases.



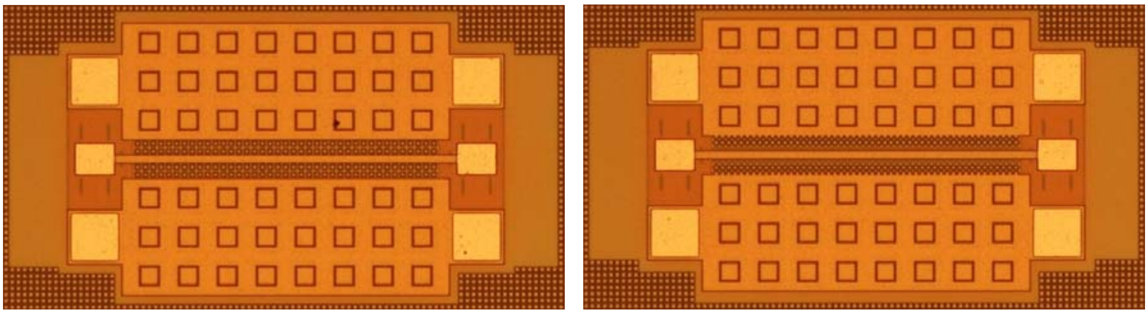
(a) Bird's view

(b) Top view

(c) Cross-sectional view

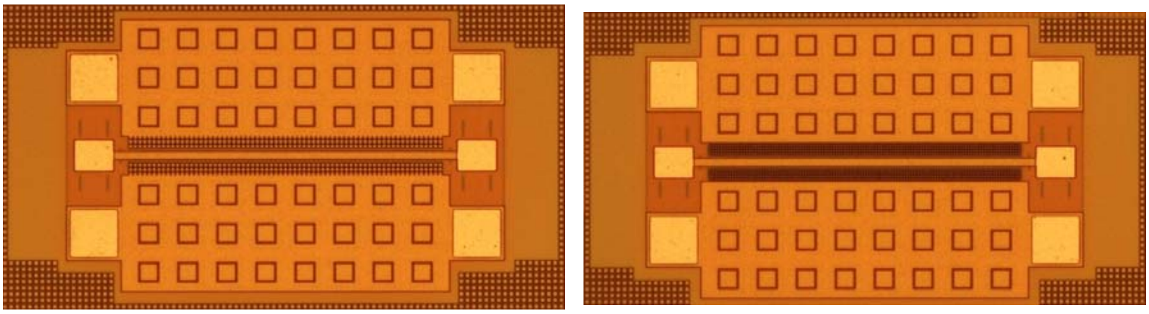
(d) Spacing of dummy fills

Figure 1: On-Chip Transmission Line with Dummy Fills.



(a) 25 % (5 µm square)

(b) 40 % (5 µm square)



(c) 70 % (5 µm square)

(d) 70 % (3 µm square)

Figure 2: Micrographs of fabricated microstrip lines.

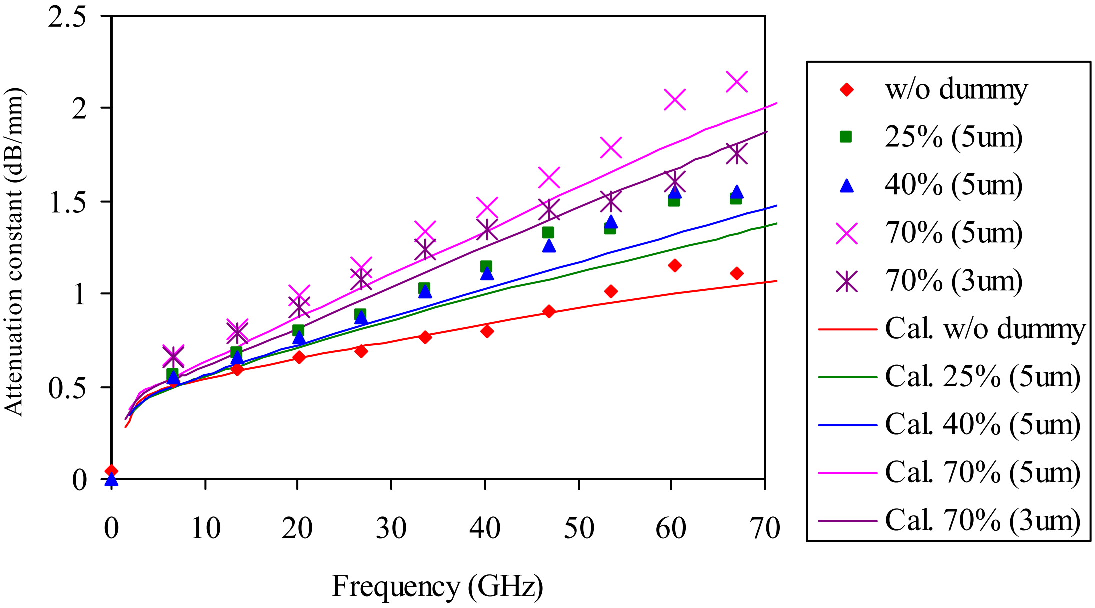


Figure 3: Frequency Characteristic of Attenuation Constant.

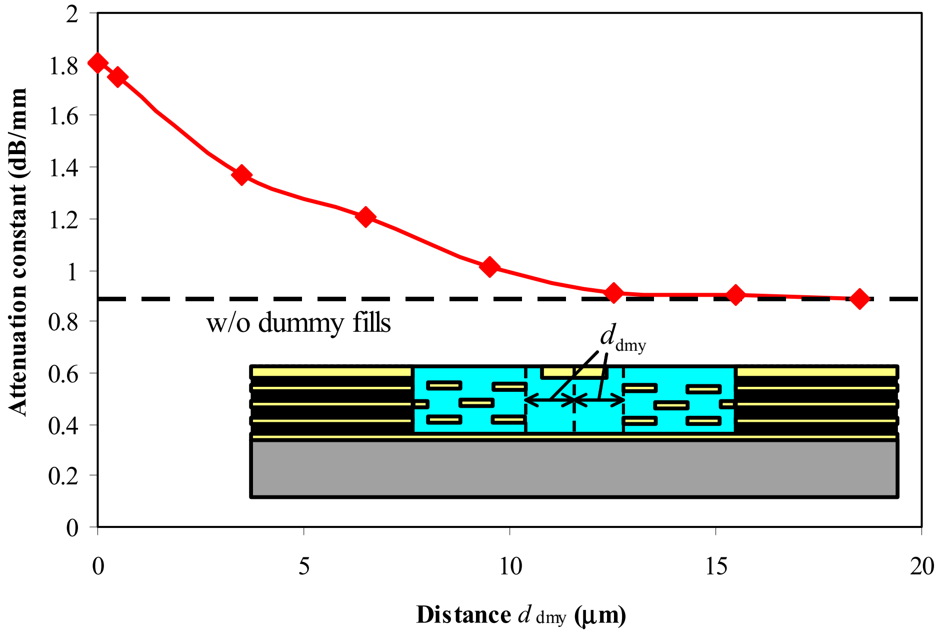


Figure 4: Calculated Attenuation Constant as a Function of Distance from the Center to the Edge of Dummy Fills.

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