Experimental Analysis of the Effect of integrated MEMS inductor on the 5GHz VCO performance

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Abstract

In this paper, MEMS inductor was integrated on a 5GHz VCO using BCB as low-k dielectric layer for MEMS inductor. The VCO core circuit is realized by IBM SiGe process. We varied the spiral inductor' s suspension height and position on circuit, and studied their circuit interference effect on VCO performance. The VCO with inductor placed on BCB with More height and the VCO with inductor that was not positioned above active area showed better characteristics.

1. Introduction

The VCO(Voltage Controlled Oscillator) is one of the key element in RF communication. The research on VCO has been carried out for a long time. RF designer is, however, still actively researching by the needs of the broad frequency band for communication and the request of integration for the possibility of miniaturization. In previous researches the integrated MEMS inductor was fabricated with air gap to reduce substrate coupling. Although the VCO with air suspended inductor showed good phase noise characteristics, they have mechanical stability problem because the spiral inductor is overhung by only two posts. We used BCB as a supporting material for suspended spiral inductor. Dry etch type BCB was used for this application, because dry type BCB can be spin coated up to tens of microns and has good critical dimensions

2. VCO Design

Figure 1 shows the schematic of VCO oscillating around 5 GHz. The inductance of the LC tank has been designed as 0.8 nH and these inductors are indicated as dot squares. The core VCO circuit without inductor was fabricated by IBM SiGe 5AM process with standard SiGe substrate. The pads were left out for the post process to fabricate inductors. The inductor integration process was performed using MEMS technology.

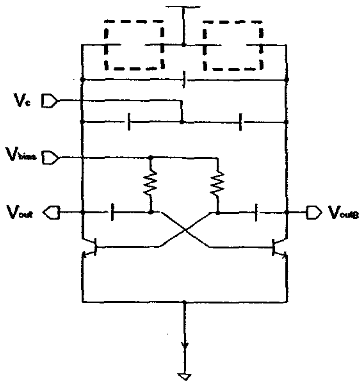

Fig. 1. The schematic of 5GHz VCO design. The position of MEMS inductor was indicated by dot squares

3. Design and Fabrication

Figure 2 shows the fabrication process flow of the MEMS inductor integration using BCB. Figure 3 shows the SEM photography of the fabricated MEMS inductor on a VCO using low-k BCB dielectric. The VCO core circuits are located below the fabricated inductor. Figure 4 shows the test concept to investigate the effects of the interference. The position of MEMS inductor on circuit is varied as shown in figure 4. In fig 4(a), inductors are arranged inside active circuit area. In fig. 4(b), the MEMS inductors are placed outside of the active circuit area, which is the same as conventional inductor arrangement. It is expected that the configuration of Fig. 4(a) will have more interference than the configuration of Fig. 4(b). To survey this effect according to its overhung height, the overhung heights of MEMS inductor were 5 μm and 20 μm, respectively. The results and analysis are performed in the next section.

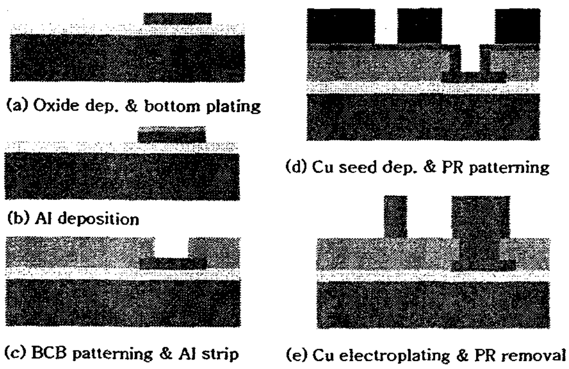

Fig. 2. The process flow of spiral inductor using low-k BCB dielectric on top of VCO circuit.

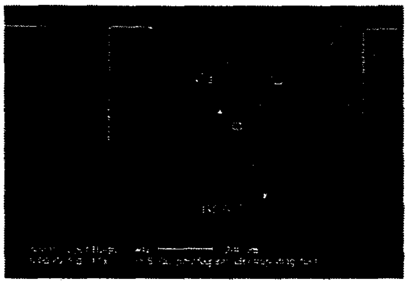

Fig. 3. The SEM photography of fabricated inductor using low-k BCB dielectric

4. Measurement

The VCOs with MEMS inductor using BCB are mounted on the PCB for the measurements. For the BCB height of 20 ㎛, the phase noise of type A (Fig. 4(a)) is - 74.2 dBc/Hz at 100 kHz offset. The phase noise of type B (Fig. 4(b)) is - 75.3 dBc/Hz at 100 kHz offset. Fig. 5 shows the measured phase noise characteristics of type A (inner) and type B (outer) VCO. The value of phase noise characteristics are almost the same. However, type B VCO shows smoother phase noise graphs. The spiral inductor of type B influences the active circuit on the bottom which causes jitters in the phase noise graph. The inductor with the BCB height of 5um is measured with HP 8593A spectrum analyzer. The measured phase noised is - 73.7 dBc/Hz at 100 kHz offset in Type B. Fig. 6 shows the measured phase noise characteristics of the VCO with the BCB height of 5 ㎛ and 20 ㎛. VCO with the BCB height of 20 ㎛ shows about 1.6dBc better phase noise characteristics than the VCO with the BCB height of 5 ㎛. The inductor with the BCB height of 20 ㎛ shows better Q factor because the height reduces substrate loss of the inductor. The phase noise of VCO is inversely proportional to the Q factor of the inductor. The relation of Q factor and the phase noise of VCO is verified by the measured results.

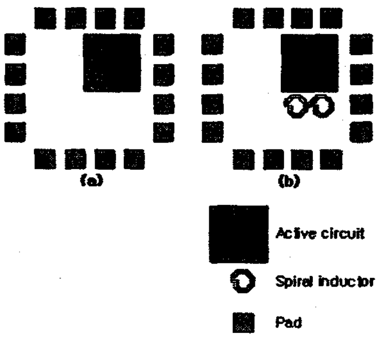

Fig. 4. The layout of inductor inside VCO.

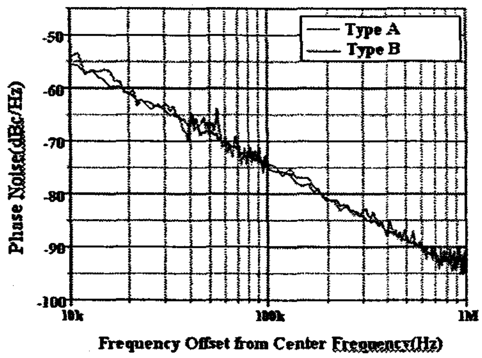

Fig. 5. The phase noise characteristics of the VCO with type A and type B inductor with the BCB height of 20 ㎛.

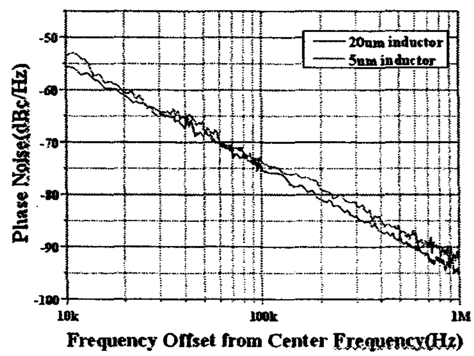

Fig. 6. The phase noise characteristics of the VCO with the BCB height of 5 ㎛ and 20 ㎛

5. Conclusion

We have designed and integrated VCO's with inductors, which are made by MEMS process using BCB low-k dielectric. The position and the BCB height of the inductor have been varied to see the influence of inductor on phase noise characteristics of VCO. The VCO that are integrated with inductor above the active circuit showed smoother phase noise graph and the inductor with BCB height of 20um showed better phase noise characteristics than that with the BCB height of 5um.

6. Acknowledgement

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