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Spiral Inductors on Silicon for Wireless Communications

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Abstract – This paper presents the design and fabrication of integrated micromachined inductors on silicon substrates. In order to reduce eddy currents in silicon substrates, bulk-micromachining technology is used to etch the silicon wafer. In this way, aluminum spiral micromachined inductors can achieve a quality factor Q of approximately 30 (0.6-2 nH @ 2-15 GHz). Also, the resistivity of the inductors material is discussed.

Introduction

The absence of very good inductors is a major drawback in a standard integrated circuit (IC) process. High-performance spiral inductors are the key components for the implementation of critical radio-frequency (RF) building blocks such as RF low-noise amplifiers (LNAs), voltage controlled oscillators (VCOs), low-loss impedance matching networks, passive filters, inductive loads for power amplifiers (PAs), baluns, transformers and tuned amplifiers. Although active circuits can be used to simulate the behaviour of an inductor, they always present greater noise, distortion and power consumption when compared to a passive inductor [2]. Critical parameters include inductance value, quality factor (Q), and self-resonant frequency (f_{SR}).

The low-ohmic silicon substrates can be used to develop spiral inductors. However, this type of silicon substrates suffers from the inherent problem of losses caused by eddy currents through the bulk substrate. An alternative solution is the use of high-resistivity substrates (HRS). Nevertheless, this kind of substrate is very expensive to build integrated CMOS circuits. In this way, silicon micromachined structures may become the solution to these RF devices.

By etching the bulk substrate, silicon micromachined inductors can be built using IC-compatible materials allowing their integration in a silicon chip, side-by-side with semiconductor circuits. Moreover, micromachined inductors would permit better front-end analog-frequency filtering than present-day filters improving power, sensitivity and reducing the physical size. In order to achieve such features, in this paper the silicon substrate is etched using micromachining techniques (wet bulk-micromachining in a KOH aqueous solution).

Aluminum is the standard material used to fabricate the metallization layers of integrated CMOS circuits and, as well, inductors because it is compatible with the silicon standard processing-steps. Another interesting material to be used for the fabrication of inductors is copper because of its lower resistivity, when compared to aluminum, leading to higher quality factors. The copper resistivity is 0.0179 Ω mm^2/m (20ºC), while the resistivity of the aluminum is 0.028 Ω mm^2/m (20ºC). However, the use of copper is not straightforward since it requires particular technology to obtain its deposition on silicon substrates.

Design and Circuit Implementation of Spiral Inductors on Silicon

The planar spiral inductor is the most implemented inductor on-chip as it can easily be built on silicon substrates [1, 2]. Such inductor can be built in IC processes, where at least two metal layers need to be used in order to form the main coil and an underpass contact that allows to reach the inner terminal of the inductance (see Fig. 1).

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