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Experimental Investigation of the Temperature and Power Handling Performance of a 2.3GHz AlN Based LCAT Mode Resonator

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***Abstract*— This work reports the characterization results of the temperature coefficient of frequency (TCF), as well as the power handling capability of a 2.3GHz AlN based LCAT mode resonator, which is formed by sandwiching a 1µm-thick aluminium nitride (AlN) layer between two groups of top molybdenum (Mo) interdigitated electrodes (IDEs) and two groups of bottom Mo IDEs. The thickness of both top and bottom electrodes is 0.2µm. By having this type of electrode configuration, adjacent IDE fingers on the same side of AlN film are capable of exciting a lateral mode, while top and bottom IDE fingers are capable of exciting a thickness mode. Synergetic coupling of the constituting thickness mode and lateral mode yields high effective electromechanical coupling coefficient (k^2_{eff}). Experimental results show that when the input power to the resonator is set at 0dBm during testing, a TCF of 24.5ppm/°C across the temperature range of -40°C to 120°C is obtained. While the temperature for testing is fixed at 20°C, no bifurcation is observed up to the input level of +18 dBm, whereas minimum distortion can be observed in the frequency response of the resonator's impedance under different input power level, demonstrating excellent power handling capability and great potential in next-generation RF communication applications.**

Keywords*— *temperature coefficient of frequency, TCF, power handling, aluminum nitride, AlN, high frequency, plate mode resonator

I. INTRODUCTION

Over recent years, there has been a wide exploration in aluminium nitride (AlN) based plate mode resonators[1-7], due to their great potential in monolithic integration of radio-frequency front-end (RFFE) so lutions, thanks to their unique advantage in which fundamental operating frequency can be tuned by photolithography and therefore, multi-frequency devices can be integrated into a single chip. Although overcoming the challenge of not capable of monolithic integration, as faced by market dominating film bulk acoustic resonators (FBARs) and solidly mounted resonators (SMRs) [8]whose operating frequency is determined by film stack, the effective electromechanical coupling coefficient (k^2_{eff}), which determines the bandwidth of the filters constructed, is not as high as that of FBARs. Laterally coupled alternating thickness (LCAT) mode resonators [9-12] and Cross-Sectional-Lamé-Mode resonators (CLMR) [13, 14] have been reported to be the

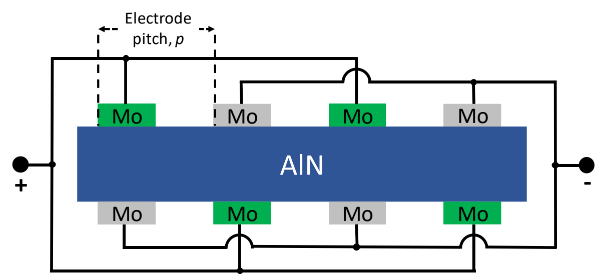

Figure 1: Cross-sectional view of the schematic drawing of the LCAT mode resonator. Two sets of 0.2µm-thick top Mo interdigitated electrodes (IDEs) and two sets of 0.2µm-thick bottom Mo IDEs are placed on the top and the bottom surface of a 1-µm thick AlN layer, respectively. The definition of electrode pitch (p), and the way which electrical signals are applied to IDEs are also illustrated.

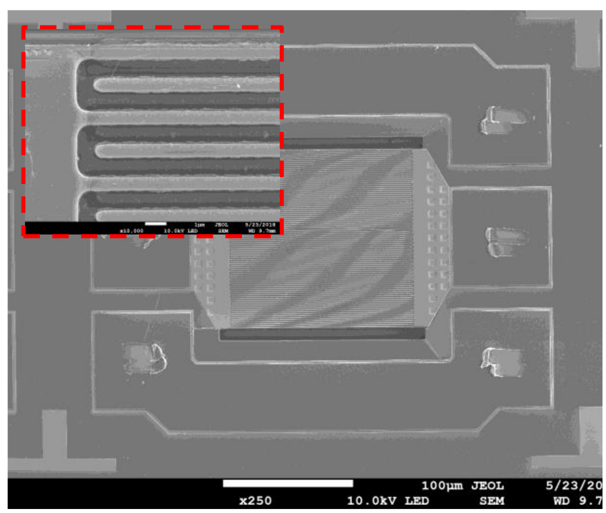

Figure 2: SEM image of the fabricated LCAT mode resonator reported in this work. Both top and bottom electrode pitch (p) of this resonator is 1.8µm. The inset depicts the zoom-in view of the IDE fingers.

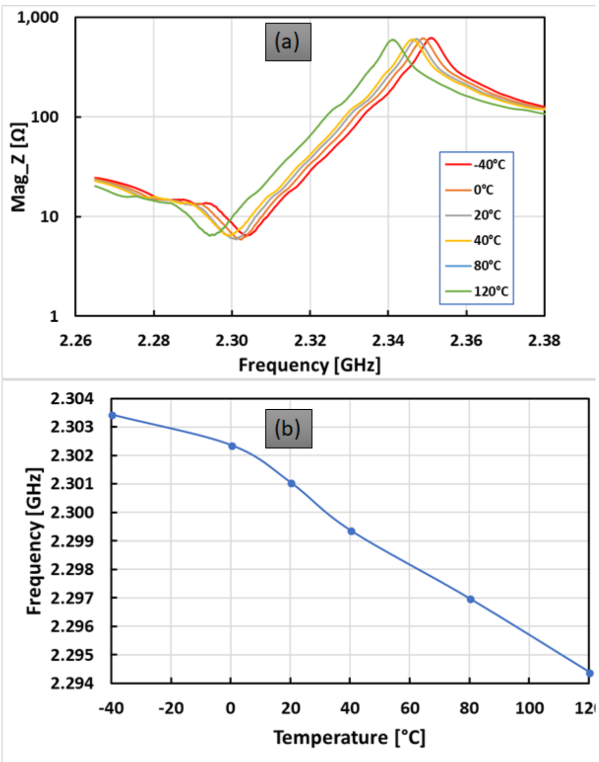

Figure 3: (a) Impedance magnitude's frequency response of the LCAT mode resonator under different temperature. (b) Plot of the series resonant frequency (f_s) against temperature, i.e., temperature coefficient of frequency (TCF), of the LCAT mode resonator. The input power level is fixed at 0dBm for all temperature.

potential candidate to overcome the challenge of low k^2_{eff} and the capability to integrate multi-frequency filters onto a single chip, their power handling capability and temperature response have not been reported.

Power handling capability and temperature response are two of the most crucial performance parameters of a resonator, because they define the phase noise and distortion of oscillators, or the application field of constructed filters [8]. Besides low k^2_{eff}, conventional plate-mode resonators also experience challenges in relatively lower power handling capability as compared to FBARs or SMRs in filter applications [15-17]. In this work, an LCAT mode resonator's temperature response and power handling performance will be characterized.

II. Resonator Design

The LCAT mode resonator characterized in this work is similar to our previous work [9], i.e., two sets of 0.2µm-thick top interdigitated electrodes (IDEs) and two sets of 0.2µm-thick bottom IDEs, both made of molybdenum (Mo), are placed to the top and the bottom surface of a 1-µm thick AlN layer, respectively, as shown in Fig. 1. The definition of electrode pitch (p), and the IDEs' electrical signal configuration are also illustrated in the figure. By having this type of IDE configuration, adjacent IDE fingers on the same side of AlN film are capable of exciting a lateral mode, while top and bottom IDE fingers at the same lateral position are capable of exciting a thickness mode. It is to be noted that the thickness mode excited by adjacent pair of top and bottom IDE fingers is of opposite polarity, thus "alternating" in nature. Synergetic coupling of the constituting alternating thickness mode and lateral mode yields high k^2_{eff}.

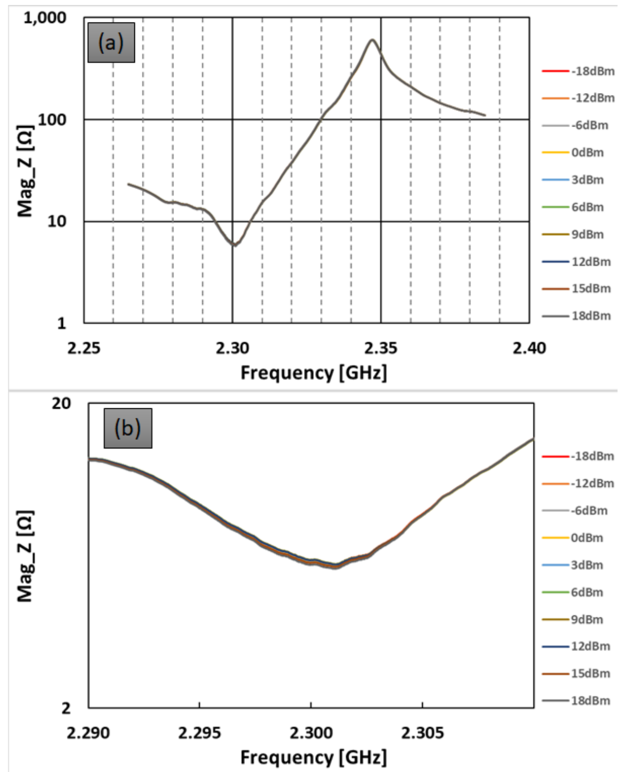

Figure 4: (a)Wide band, and (b) Narrow band near f_s frequency response of the impedance magnitude of the LCAT mode resonator under different input power level. The temperature of the chuck of the probe station is fixed at 20°C.

III. Fabrication Process

The proposed LCAT mode resonator is fabricated by the in-house 8-inch piezoelectric platform, in which the thickness of the AlN layer and Mo layer can be tuned and optimized. The fabrication process to realize the resonator in this work has been reported [9].

The reported LCAT mode resonator's scanning electron microscope (SEM) image is depicted in Fig. 2, with the zoom-in view of the top Mo IDE electrodes shown in the inset. The electrode pitch (p) is 1.8µm.

IV. Results and Discussioins

After performing a standard short-open-load-through (SOLT) calibration, a Keysight N5242B network analyzer is used to carry out the electrical characterization of the fabricated LCAT mode resonator, without any de-embedding structure. After obtaining the scattering (S) parameters from the network analyzer, the impedance of the resonator is then extracted from the S parameter.

Fig. 3(a) shows the impedance-frequency plot of the resonator under various temperature from -40°C to 120°C, with the input power level being fixed at 0dBm for all testing temperature. The extracted temperature coefficient of frequency (TCF) plot depicted in Fig. 3(b) shows the fabricated LCAT mode resonator exhibits a first-order TCF of 24.5ppm/°C over the temperature range of -40°C to 120°C.

Fig. 4(a) shows the impedance plot of the LCAT mode resonator under different input power level, from -18dBm to +18dBm, at the fixed temperature of 20°C. Fig. 4(b) zooms into the series resonant frequency. no bifurcation is observed up to the input level of +18 dBm, which is the output limit of the network analyzer. The frequency response under different input power level is very similar to each other with minimum distortion at different input power levels, demonstrating excellent power handling capability. Therefore, the reported LCAT mode resonator is a very promising candidate in next-generation RF communication applications.

V. Conclusions

In this work, the characterization results of the TCF, as well as the power handling capability of a 2.3GHz AlN based LCAT mode resonator is reported. Experimental results show that when the input power to the resonator is set at 0dBm during testing, a TCF of 24.5ppm/°C over the temperature of -40°C to 120°C is obtained. While the temperature for testing is fixed at 20°C, no bifurcation is observed up to the input level of +18 dBm, whereas minimum distortion can be observed in the frequency response of the resonator's impedance under different input power level, demonstrating excellent power handling capability and great potential in next-generation RF communication applications.

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