歪みによる自己温度補償型窒化物 MEMS 振動子
Self-temperature-compensated GaN MEMS resonator through strain engineering

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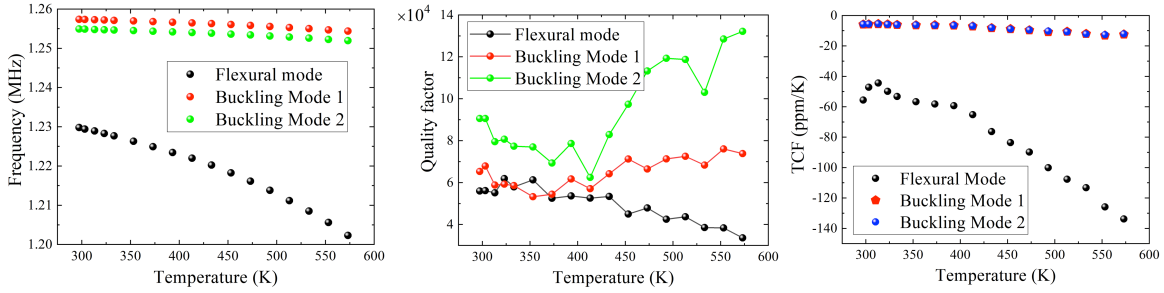
The micro-electromechanical or nano-electromechanical systems (MEMS/NEMS) for reference oscillators toward the millimetre-wave 5G systems represent a privileged way to achieve high resonance frequencies with less phase noise and high temperature stability. Unfortunately, due to the negative temperature coefficient of the elasticity, the Si-based MEMS resonator normally exhibits a large negative temperature coefficient of frequency (TCF) around -30 ppm/K [1]. The temperature compensation techniques have been proposed, for example, geometry modification, impurities doping, and multilayer structures, however, the quality (Q) factors of the systems were greatly degraded [2].

III-V nitride semiconductors are the excellent candidates for high-frequency electronics in 5G era. The integration of III-V nitrides MEMS with electronics are thus promising and timely important for IoT sensors and communications. The great progress of the high-quality GaN on Si substrates with large scales further makes the possibility of the GaN-based MEMS/NEMS integrated with the semiconductor technology.

In this work, we demonstrate a marked improvement of the TCF of several ppm/K for the GaN MEMS resonators without losing the Q factors up to 600 K by using elastic strain engineering for the self-temperature compensation. The double-clamped GaN resonators were fabricated from GaN on Si substrate. To introduce the stress in the epitaxial GaN layer, the GaN layer was directly grown on the AlN/Si (111) buffer. A high Q factor more than 10^5 for the MEMS resonator was achieved. Both ultra-low TCF and high Q factors are tailored by using stress induced bulking resonance modes[3]. Different from the conventional flexural modes, the internal thermal stress improves the TCF of the GaN resonator by over 10 times to be as low as ~ppm/K even at 400K, without losing the high Q factor even up to 600 K.



(a) (b) (c)

Fig. 1 Temperature dependent (a) frequency, (b) quality factors and (c) TCF of the GaN double-clamped resonator with the length of 100 μm.

References

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