Encapsulated MEMS Resonators – A technology path for MEMS into Frequency Control Applications

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MEMS Resonators have been studied for more than 40 years, with continuous interest in their use as frequency references. Unfortunately, the promise of MEMS resonators for these applications has always been limited by observations of drift in frequency, which has been understood to arise from the temperature coefficient of the modulus of Silicon, as well as the role of adsorbed molecules from the environment of the resonator.

The temperature coefficient of the modulus of Silicon is a well-known parameter, giving rise to a ~30 ppm/C error in frequency. This error can be reduced by temperature control of the resonator, and by use of compensating materials, such as SiO2 [1], or by electronic compensation methods. The adsorbate-induced drift in MEMS resonators can only be addressed by the development of ultra-clean, hermetic packaging for the resonators.

Our group has developed a wafer-scale MEMS encapsulation process that enables a solution to many of these problems with MEMS resonators.

In this presentation, we will discuss the encapsulation process, and the opportunities for implementation of temperature compensation and control. The encapsulation process is inherently clean, and directly enables long-term stability. Taken together, we believe we have a pathway to the development of high-performance frequency sources that feature excellent long-term stability and temperature stability, and which can be considered for commercial and defense applications.

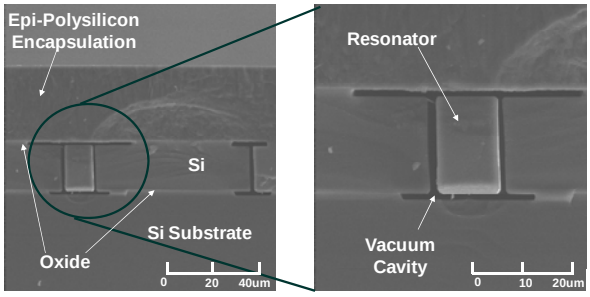

Fig. 1: SEM photos of encapsulated MEMS tuning fork resonators. The MEMS device is buried in an epitaxial silicon deposition process, released with a HF vapor etch, and then sealed at 950C in a second epitaxial silicon deposition. The resulting devices operate in an exceptionally clean environment and do not exhibit aging, fatigue or adsorbate-induced frequency drift.

In parallel with our efforts, commercialization of encapsulated resonators for commercial applications is underway at SiTime [2]. The concurrent development of device and encapsulation process within manufacturing process compatibility constraints helped enable a transition to large-scale manufacturing at SiTime, and (hopefully) is helping MEMS resonators find their way into large-scale commercial applications.

[1] B.S. Berry and W.C. Pritchet, "Temperature Compensation for Constant-Frequency Electromechanical Oscillators", IBM Technical Disclosure Bulletin, Vol. 14, #4, P. 1237-8 (1971).

[2] www.sitime.com