

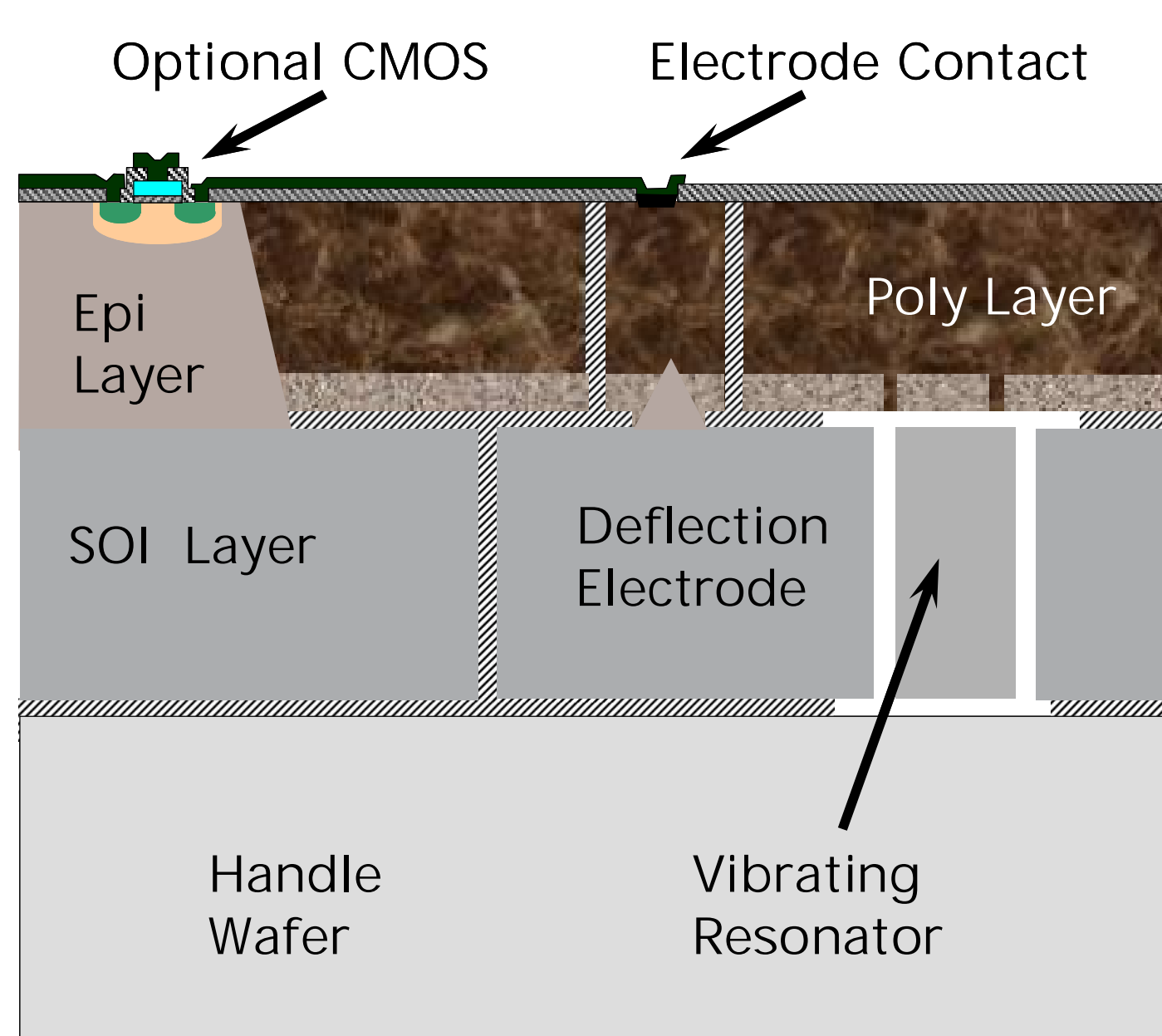
# LEVERAGING STANDARD IC PACKAGING FOR MEMS OSCILLATORS

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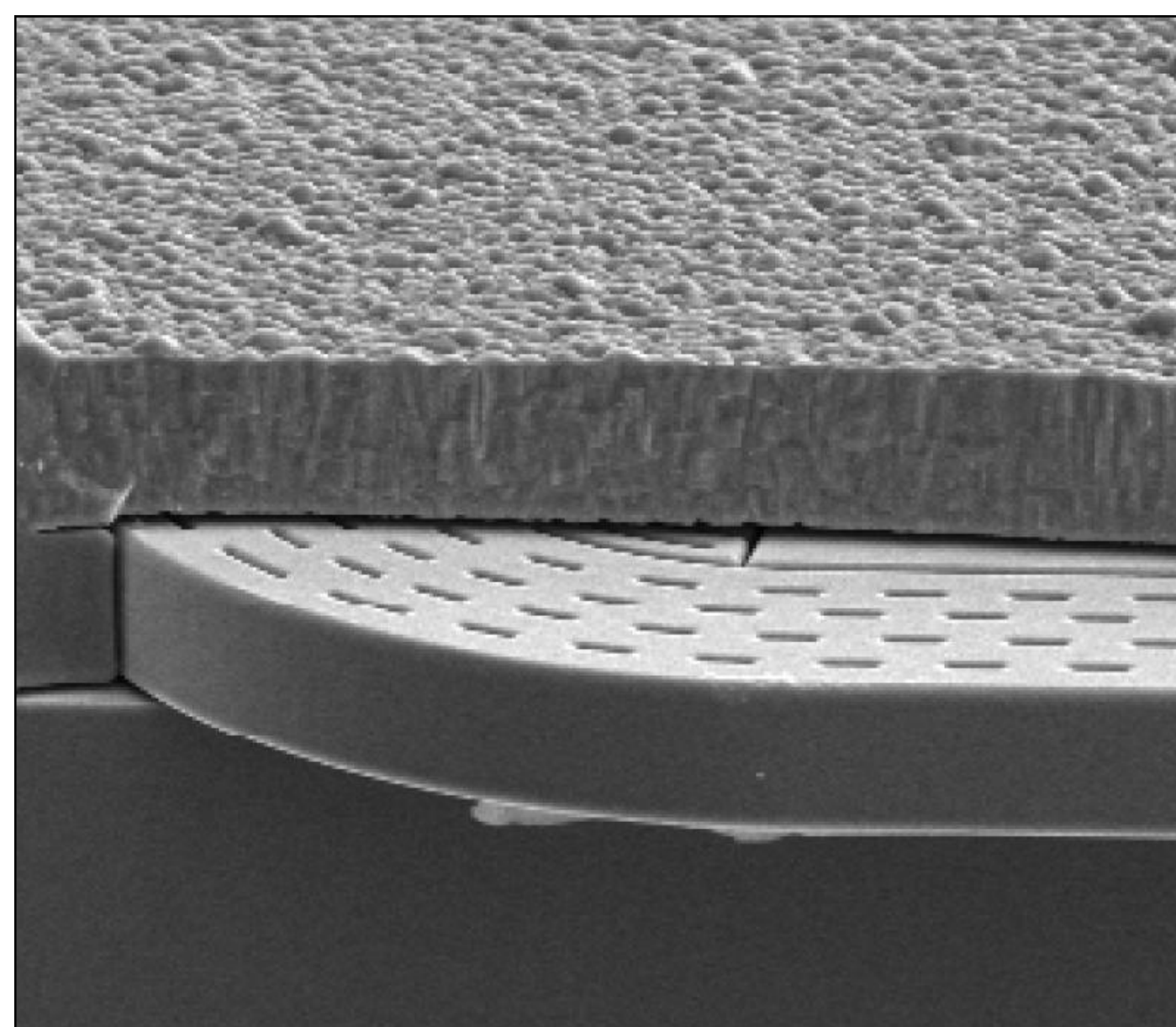
(1) SiTime Corporation, (2) SiTime, now Stanford University.

Packaging has been one of the largest barriers to commercialization of MEMS timing references. To ensure commercial viability and long-term stability, MEMS resonators must be hermetically sealed in an inexpensive and contaminant free environment. SiTime's thin film encapsulation process [1-2] creates robust vacuum cavities for each resonator below the surface of the wafer, protecting the devices from contamination and handling damage. This supports backend processes such as dicing, die attach, and molding, allowing the use of standard IC packaging and leveraging the investments in process and equipment made by the mainline semiconductor industry.

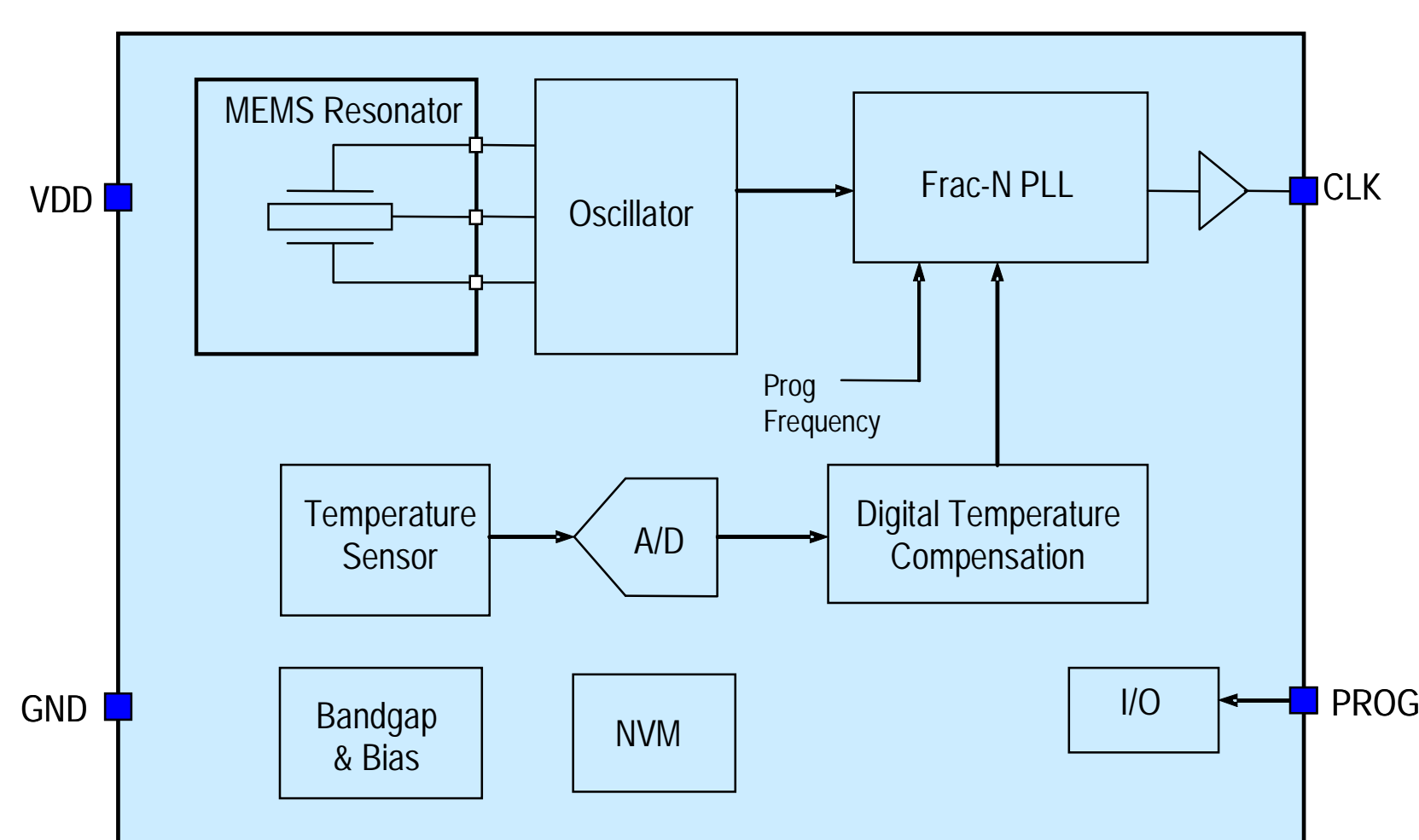
## MEMS and CMOS



MEMS Cross Section: Resonators are built into 200mm (8-inch) silicon wafers.

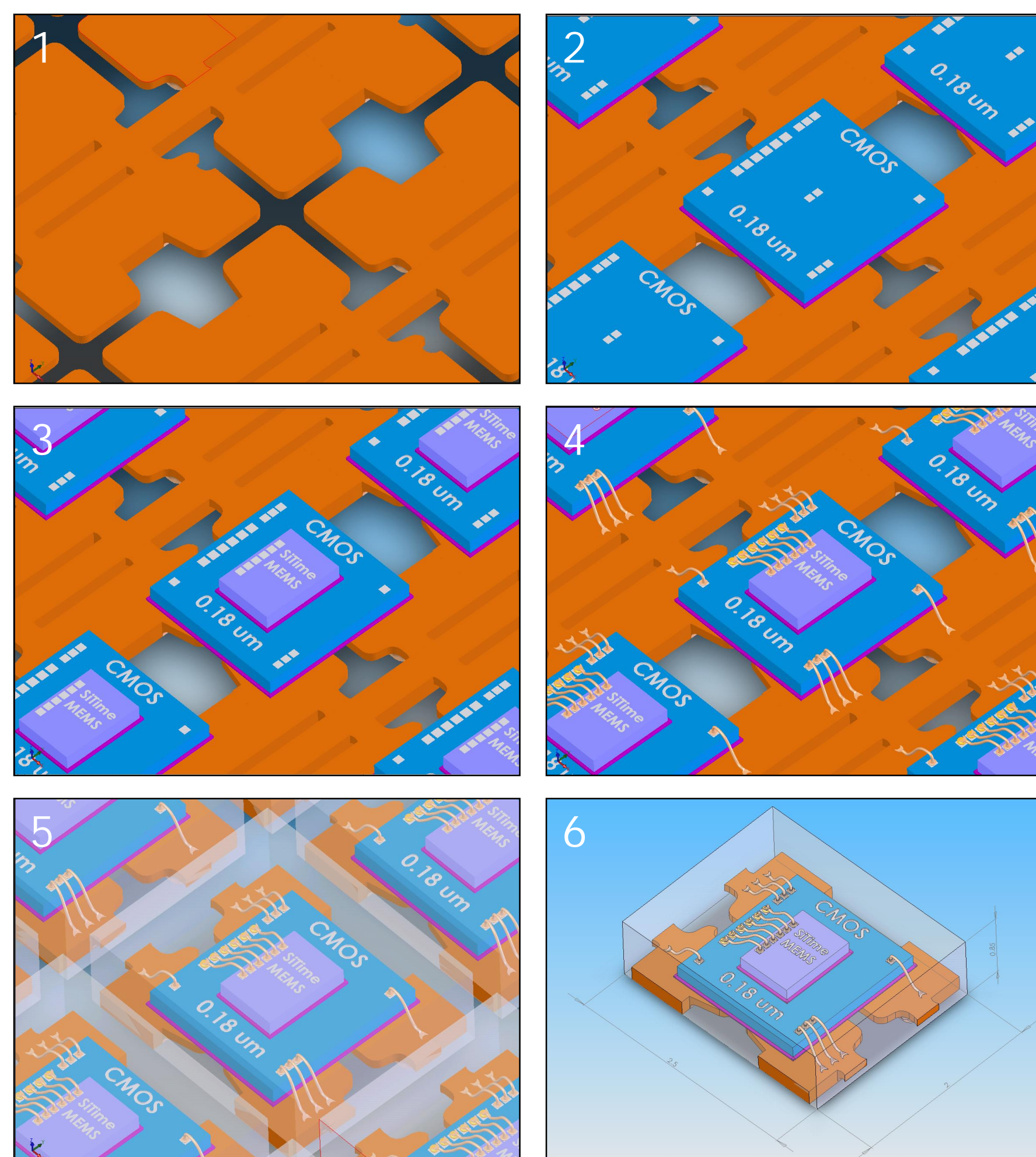


SEM of Cleaved MEMS Wafer: Resonator is shown at edge of cleave prior to surface CMP and metal interconnect fab.

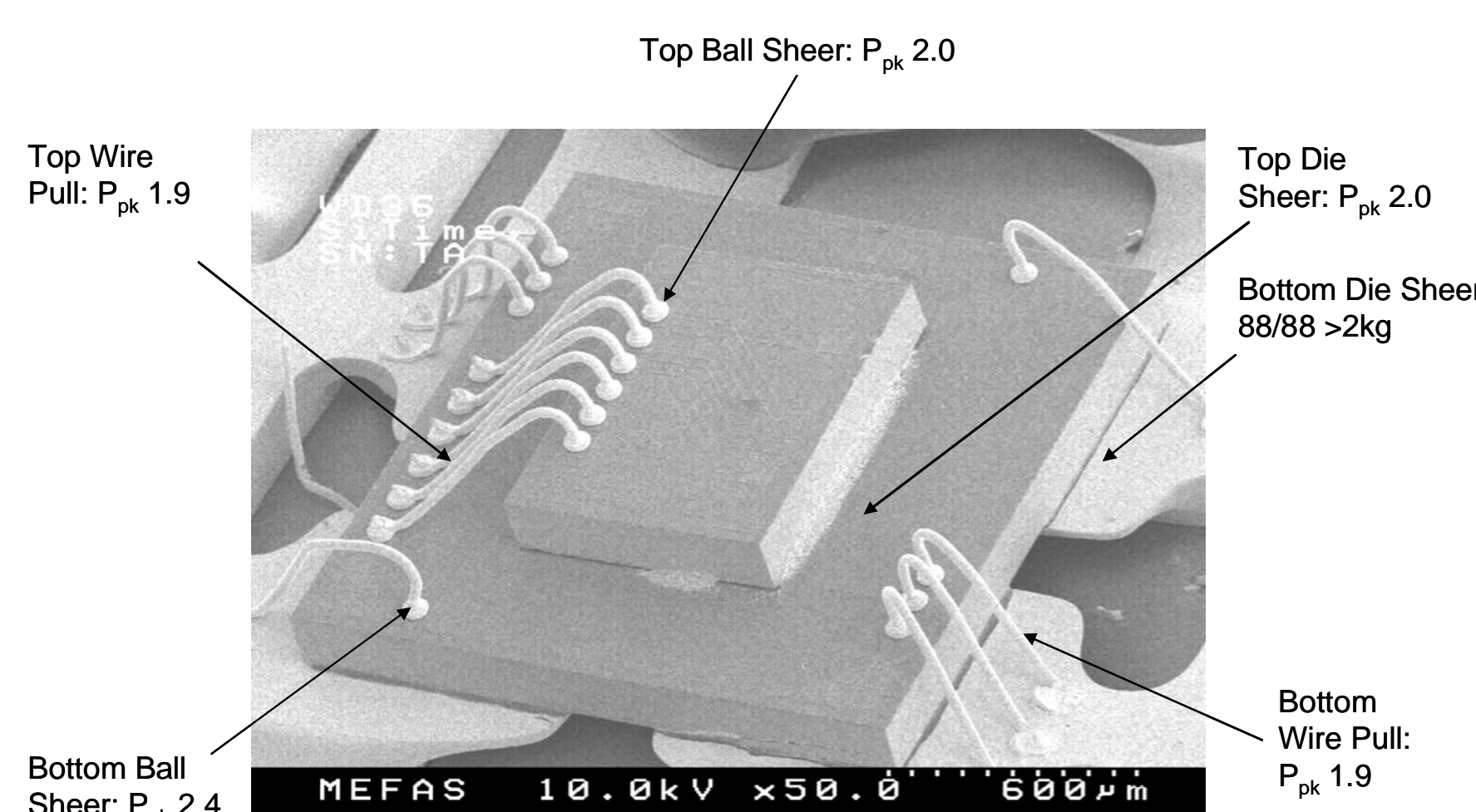


System Architecture: The control circuits are fabricated in standard 0.18um CMOS.

## Packaging Assembly



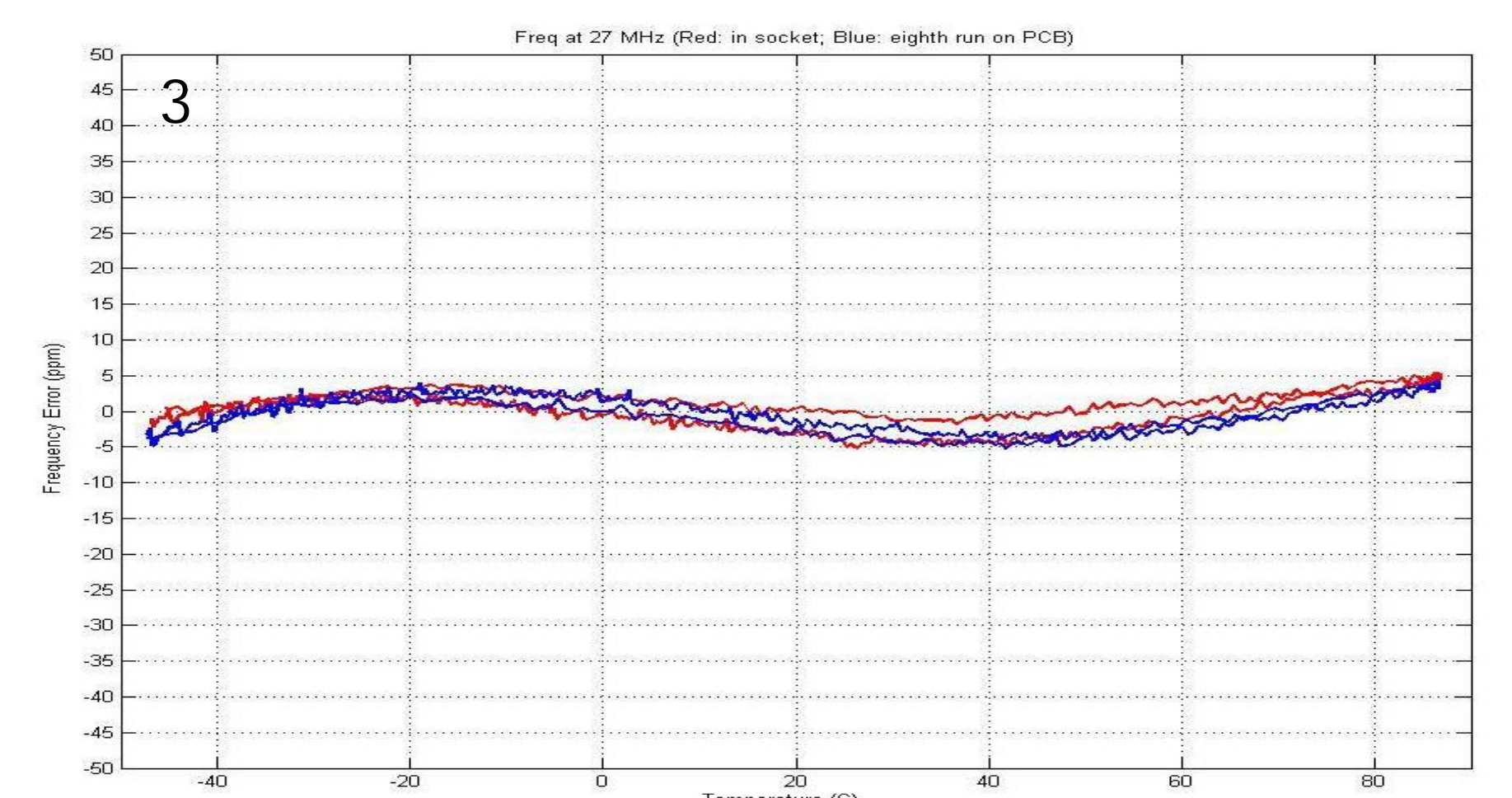
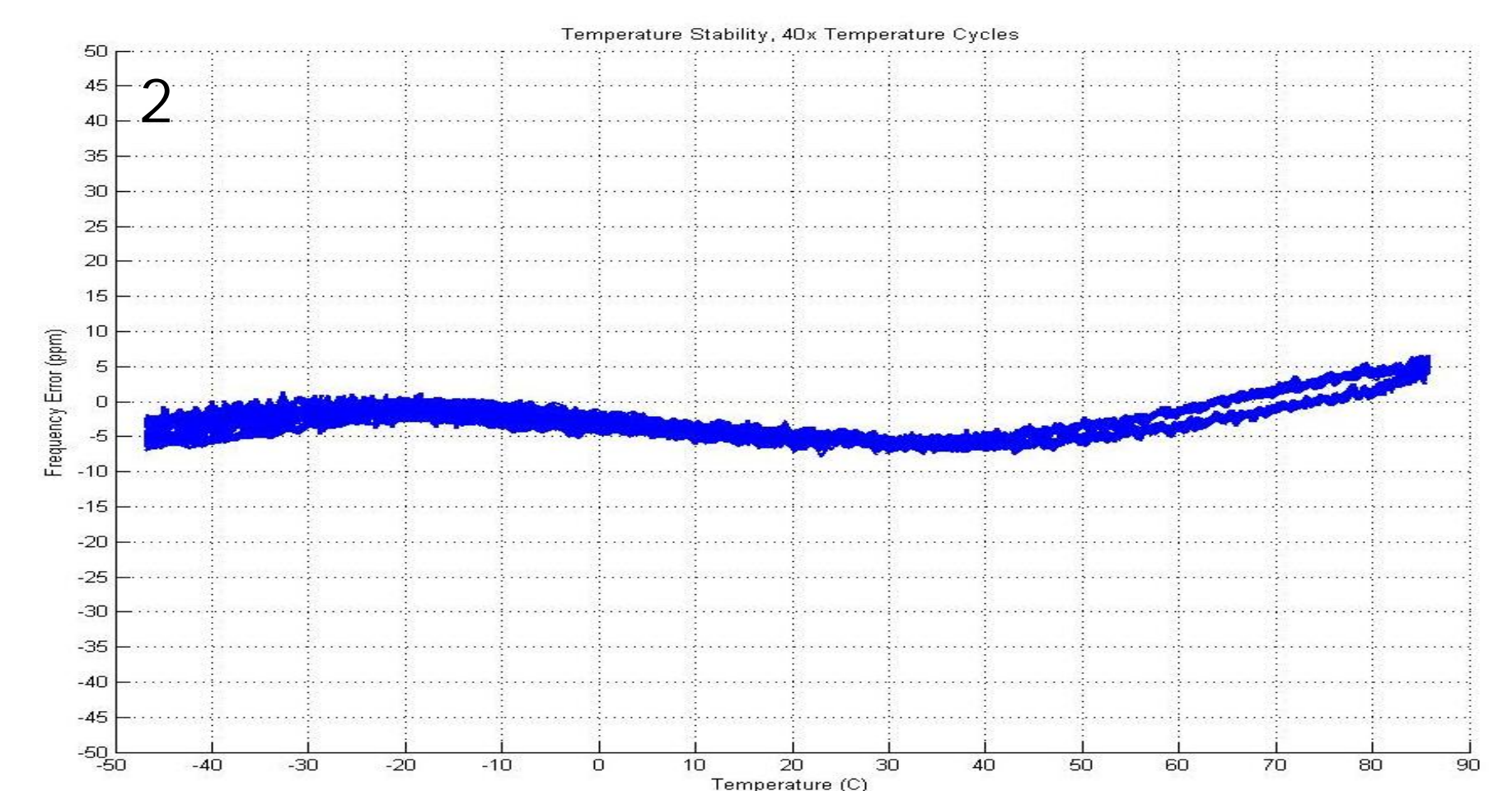
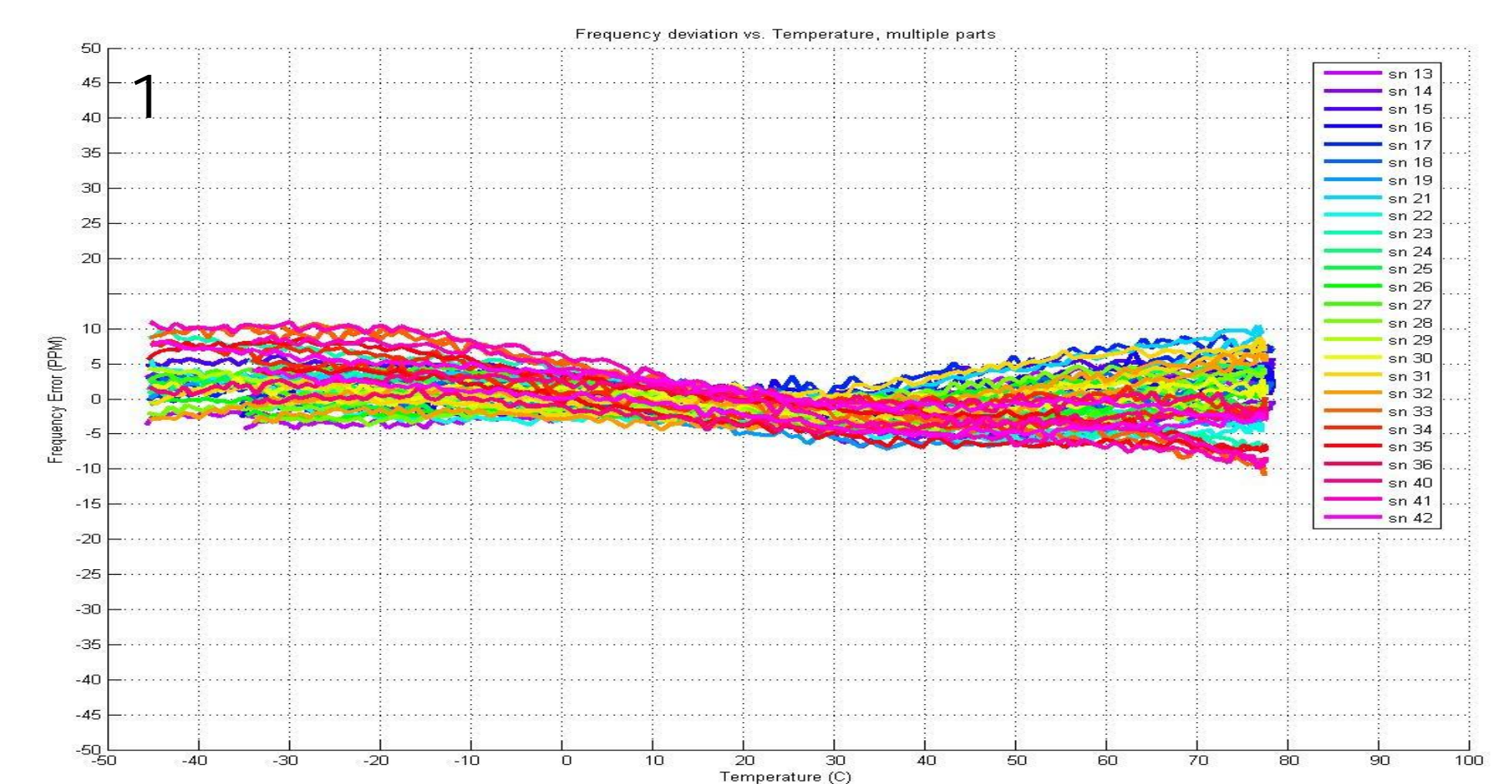
Fabrication: MEMS oscillators packaged in arrays: (1) Copper lead frames are patterned and etched, (2) CMOS die are attached, (3) MEMS die are stacked on CMOS die, (4) MEMS and CMOS are wire bonded, (5) array is molded and packages are singulated. (6) A finished 2.0 x 2.5 x 0.85 mm<sup>3</sup> chip.



Stacked Die SEM: Six sigma design rules are strictly adhered to so >1M units per day can be produced consistently with high quality and yield.

References: [1] R.Candler, et al, "Hydrogen Diffusion and Pressure Control of Encapsulated MEMS Resonators," Transducers'05. [2] B.Kim, et al, "Frequency Stability of Wafer-Scale Encapsulated MEMS Resonators," Transducers'05.

## Results



Frequency Stability: (1) Frequency error of 26 parts cycled over temperature, (2) one part over 40 temperature cycles, (3) one part socketed and tested, then soldered to a PCB and retested.

Reliability: The oscillators have passed ESD, latch-up, MSL1, thermal shock, and mechanical shock reliability qualification tests.