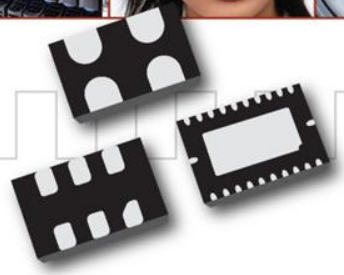
SiTime™
A MegaChips Group Company

MEF 2015
MEMS Engineer Forum

Industry-Leading Resonator Technology and Product Line

Markus Lutz



The Smart Timing Choice™

Timekeeping
Beyond-Exponential Improvement

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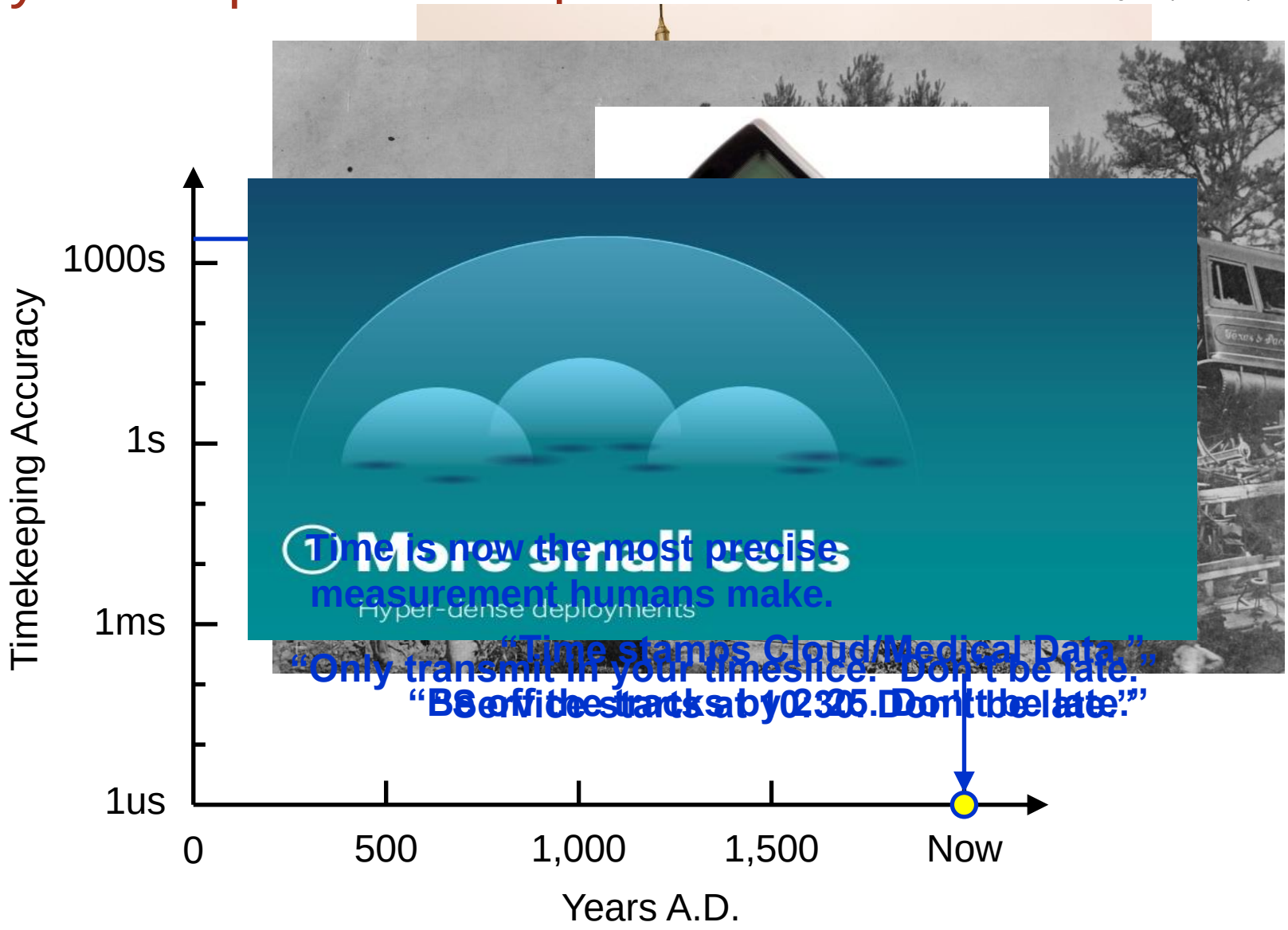

SiTime Locations and Manufacturing

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- Fabless analog IC company, founded in 2005, acquired by MegaChips Nov 2014
- 90 employees

- SiTime Locations
- Direct Sales
- Fabrication (MEMS: Bosch, Tower-Jazz, CMOS: TSMC)
- Assembly and Test (Carsem, UTAC, ASE)

MEMS Packaging is Key for Success

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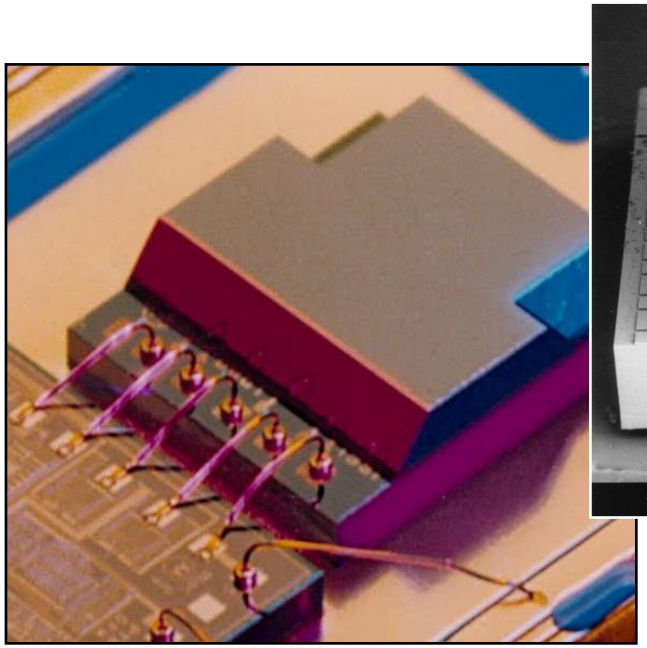
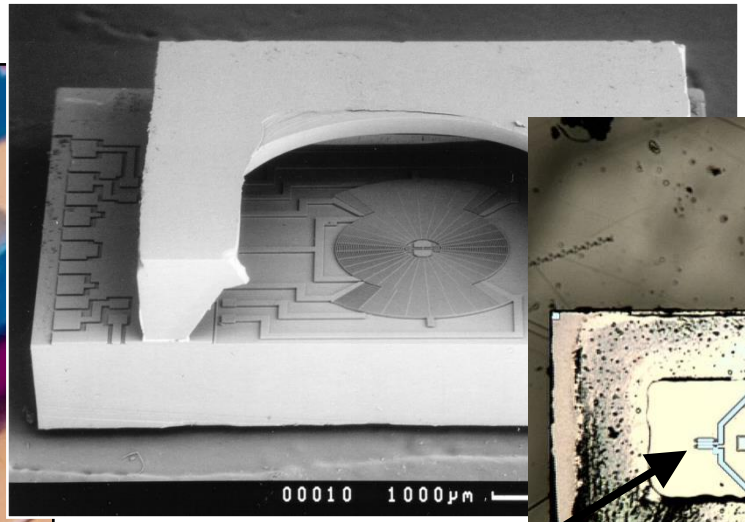
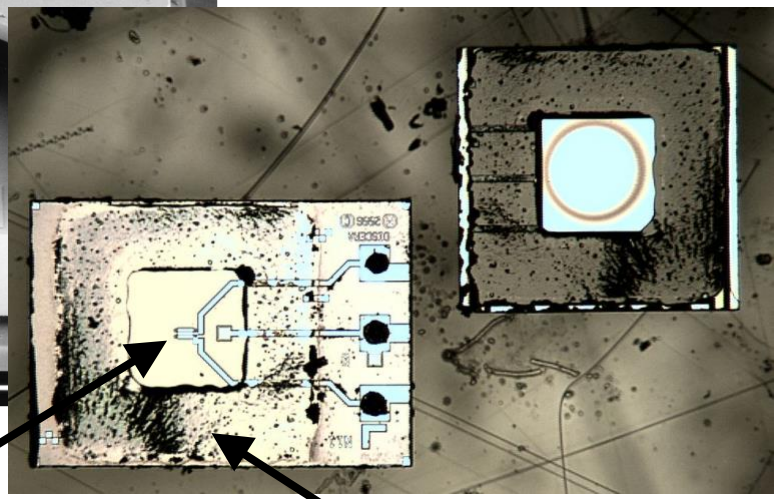
- Protect the parts in operation – no drift
- Protect the parts during manufacturing – yield
- Protect in back end packaging – manufacturability, low cost
- Small area for packaging – low cost, small size
- Standard materials and processes – manufacturability







Common MEMS Packaging Technology before SiTime

InChipMEMS™ Cross Section

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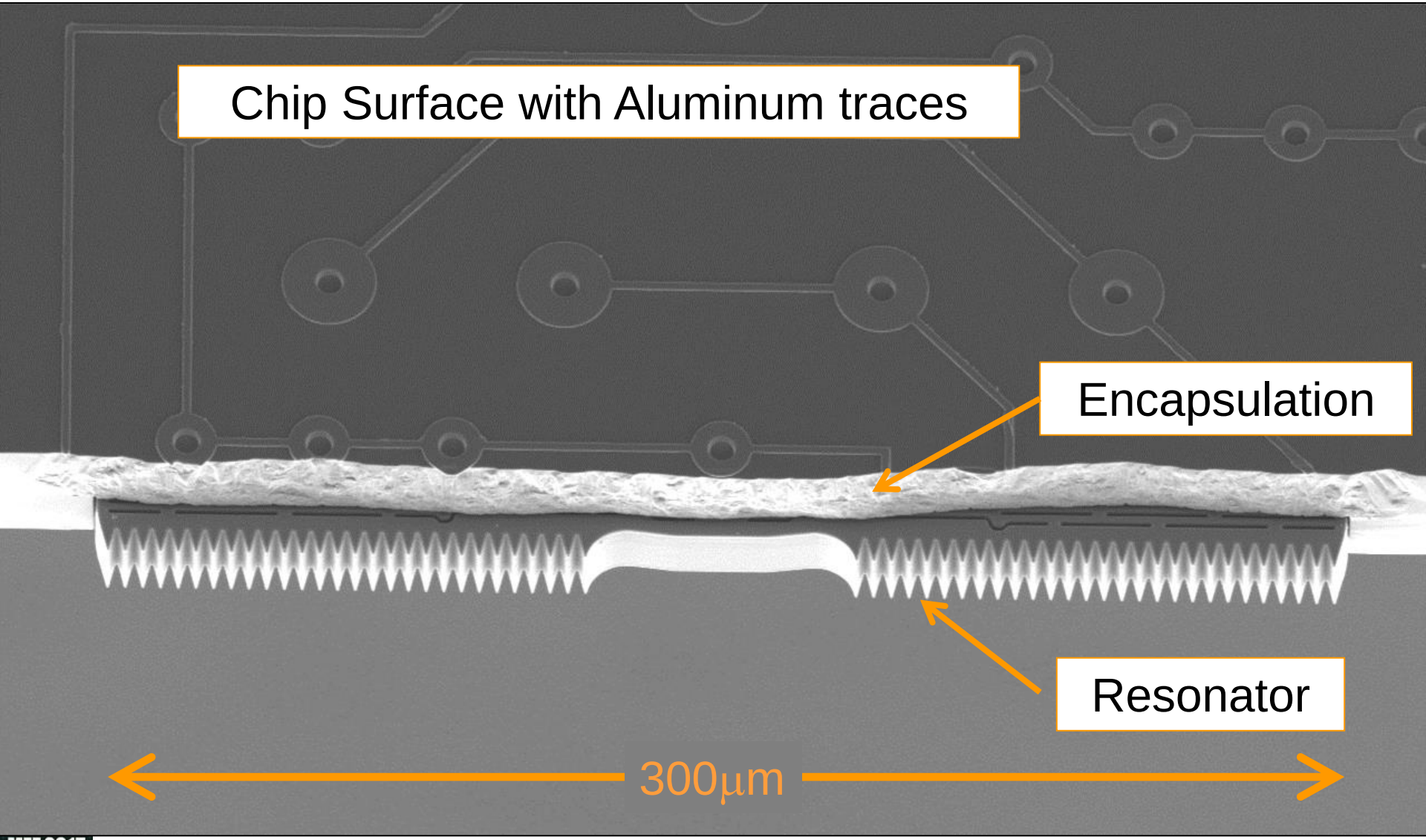

Advantages of MEMS First™ Process

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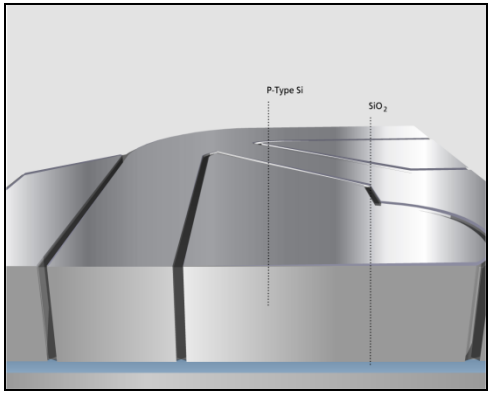
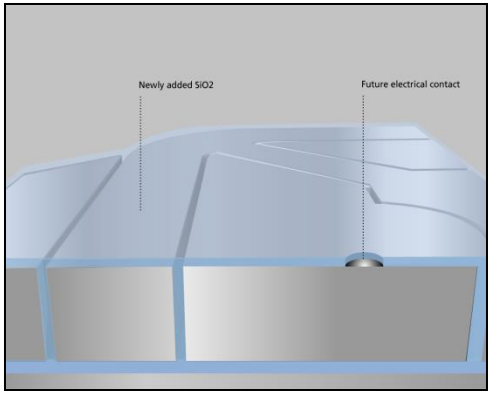
- Standard CMOS processes and materials
  - Widely available supply chain, low cost
- Industry standard process control and 6 sigma philosophy
  - Manufacturability, high yield, quality, reliability
- High temperature in-process encapsulation to protect MEMS structure
  - Best stability, ultra small drift, small size, reliability, quality
- Standard IC backend (packaging and test)
  - Scalable supply chain, multiple sources, lowest cost
- Monolithic integration CMOS with MEMS possible

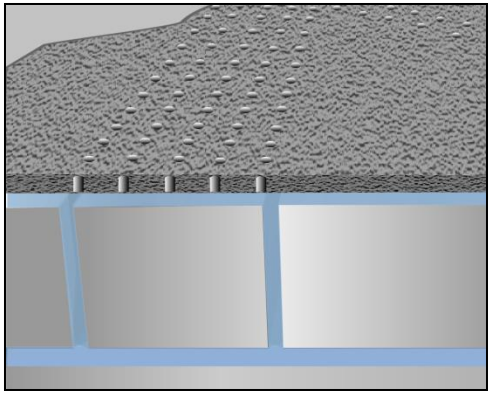
MEMS Resonator Fabrication



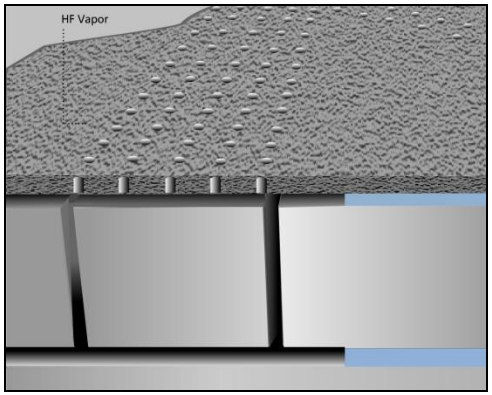
1. Etch SOI wafer



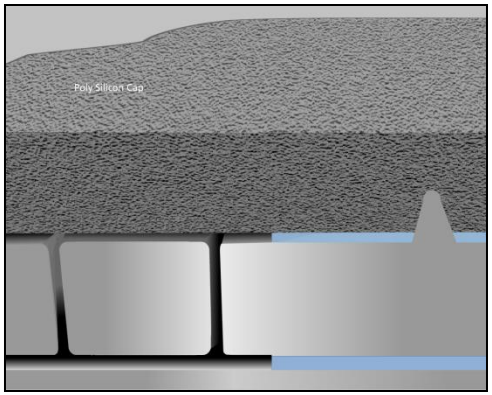
2. Protect under oxide



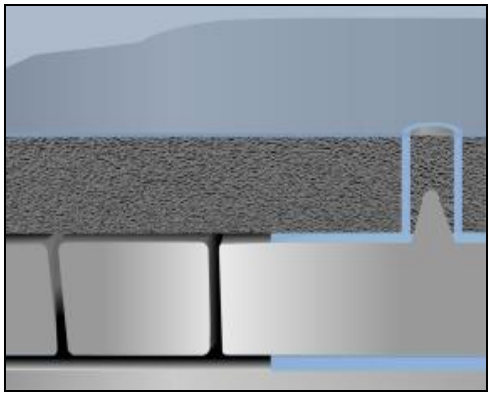
3. Cover and perforate



4. Remove oxide



5. Deposit thick silicon



6. Trench Isolation

MEMS Resonator Fabrication

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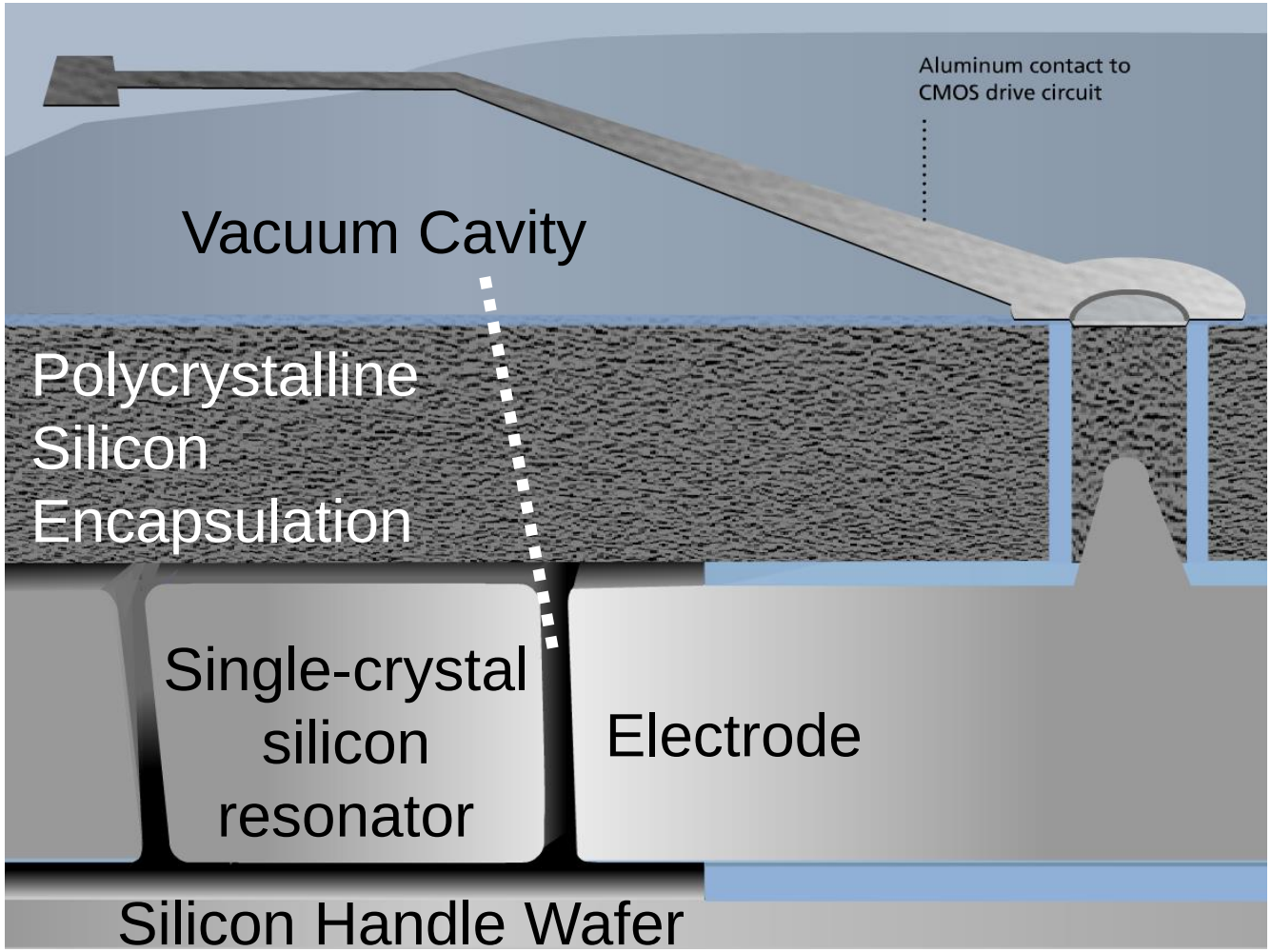

7. Metal and Scratch Mask

Single Crystal Silicon Resonator – ZERO Aging

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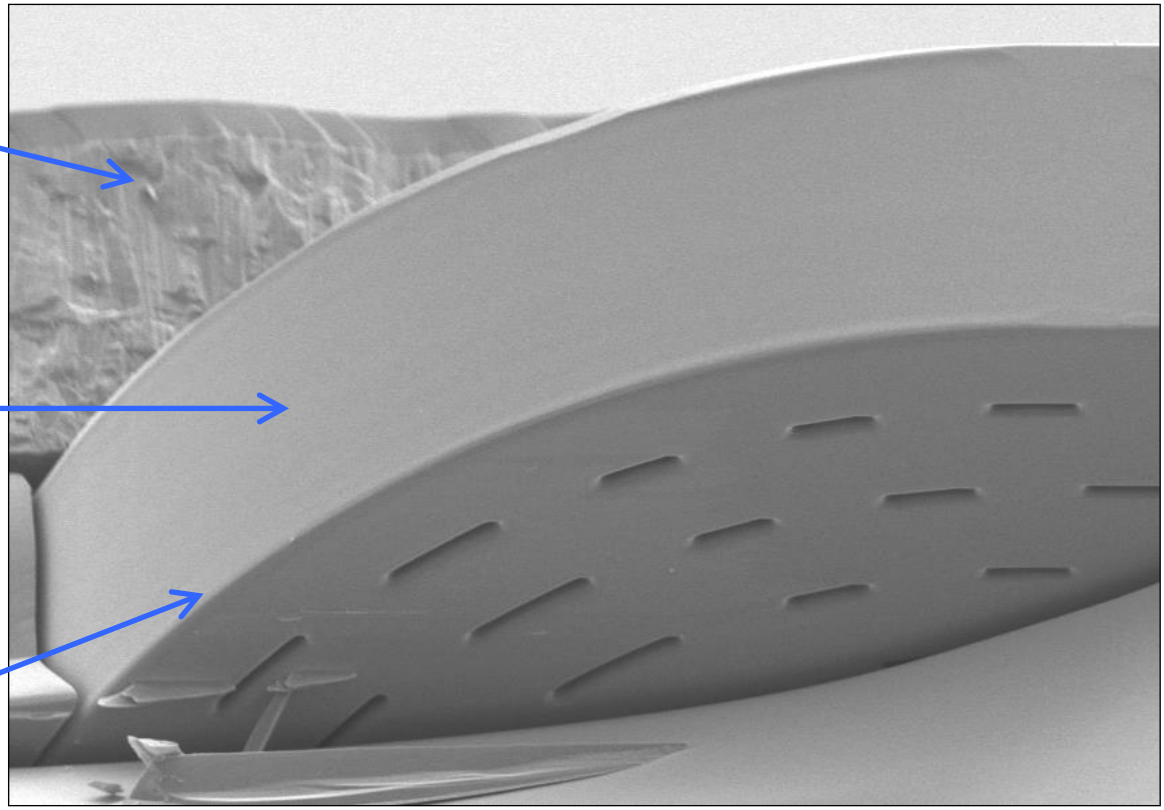
- EpiSeal™ at 1100C perfect clean vacuum
- High purity material, controlled to ppb levels
- No fatigue
- Single crystal silicon with reformed surfaces



High Performance Resonators

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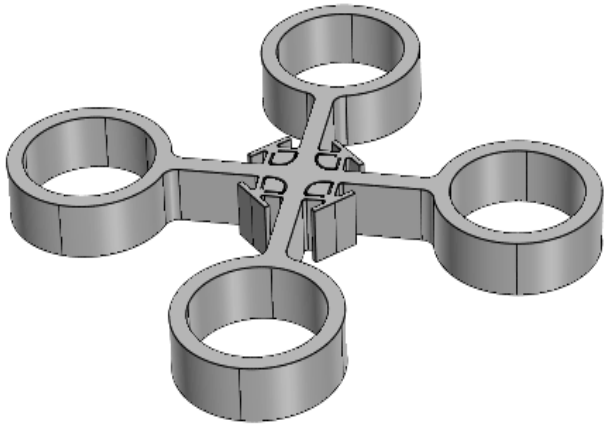
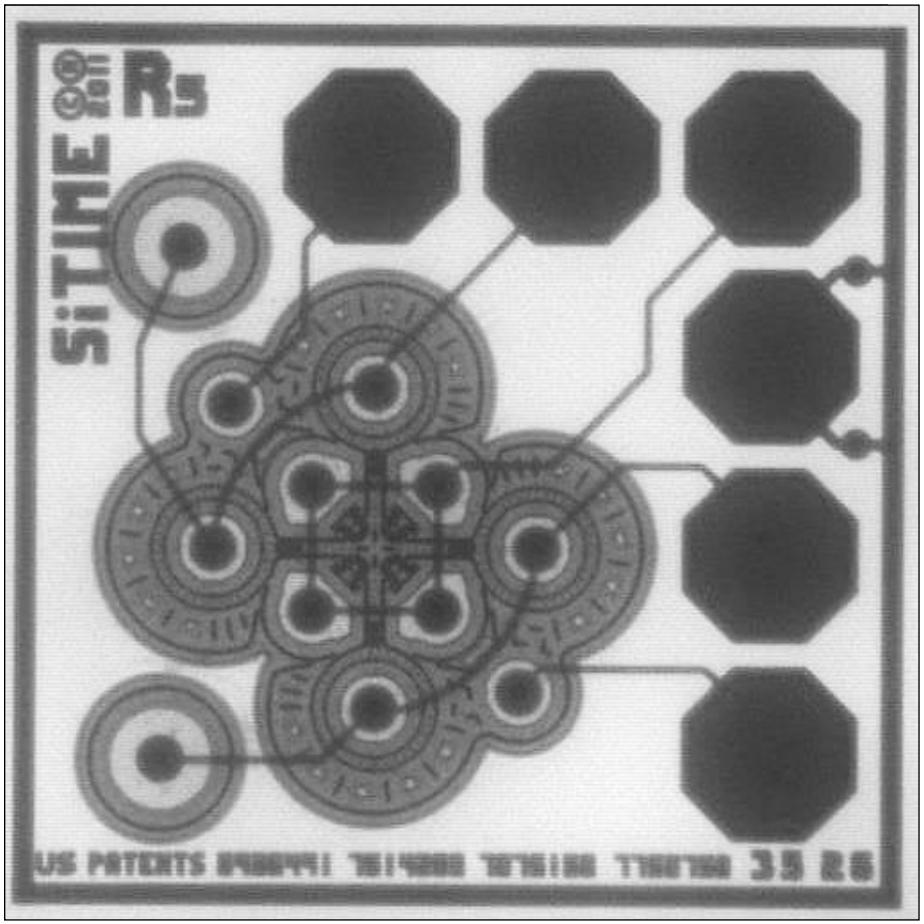
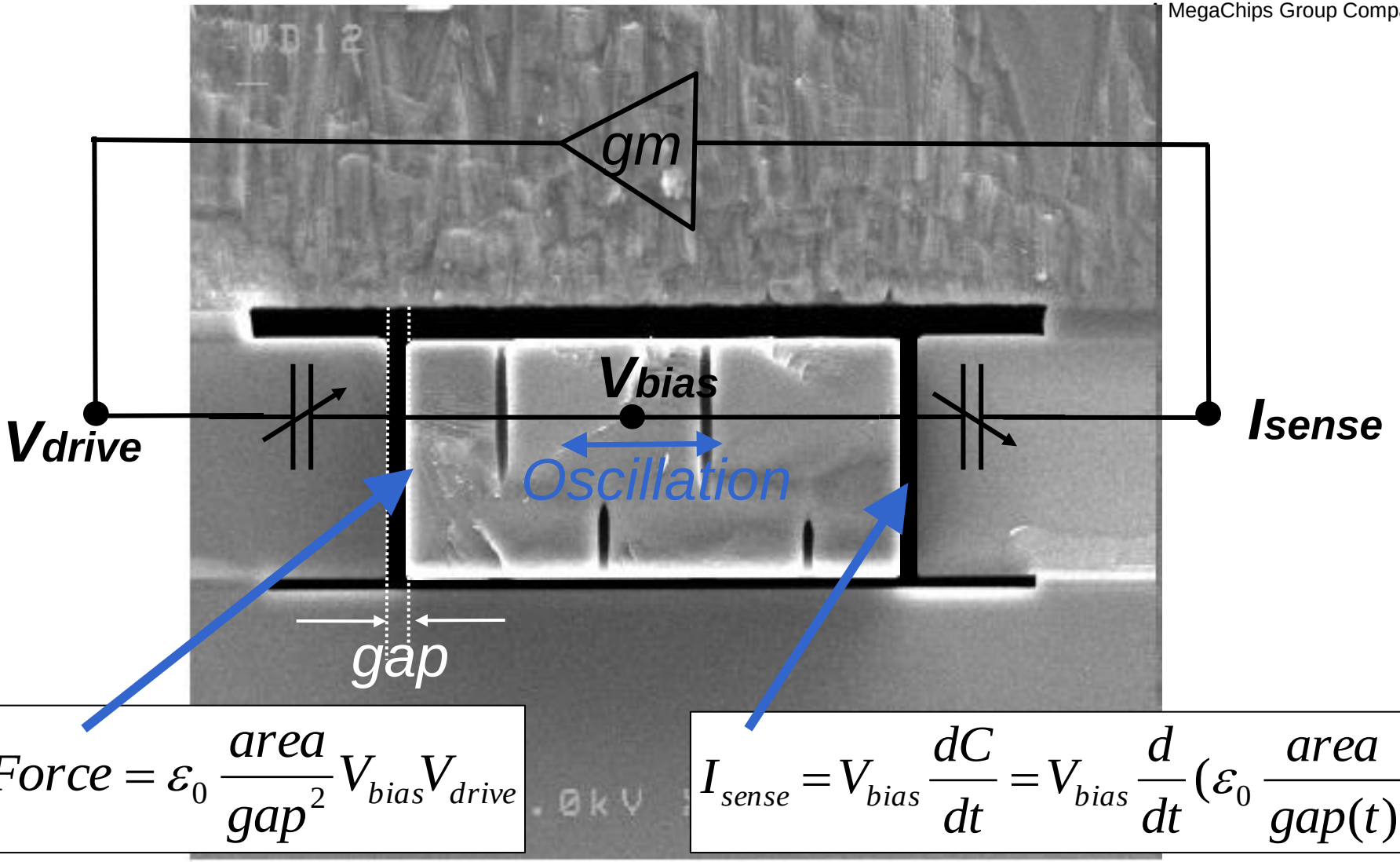




- f = 48MHz
- Q = 147k
- Smallest size: 400μm x 400μm

Capacitive Resonator Principle



$$Force = \varepsilon_0 \frac{area}{gap^2} V_{bias} V_{drive}$$

$$I_{sense} = V_{bias} \frac{dC}{dt} = V_{bias} \frac{d}{dt} (\varepsilon_0 \frac{area}{gap(t)})$$

Optimizing for High Q

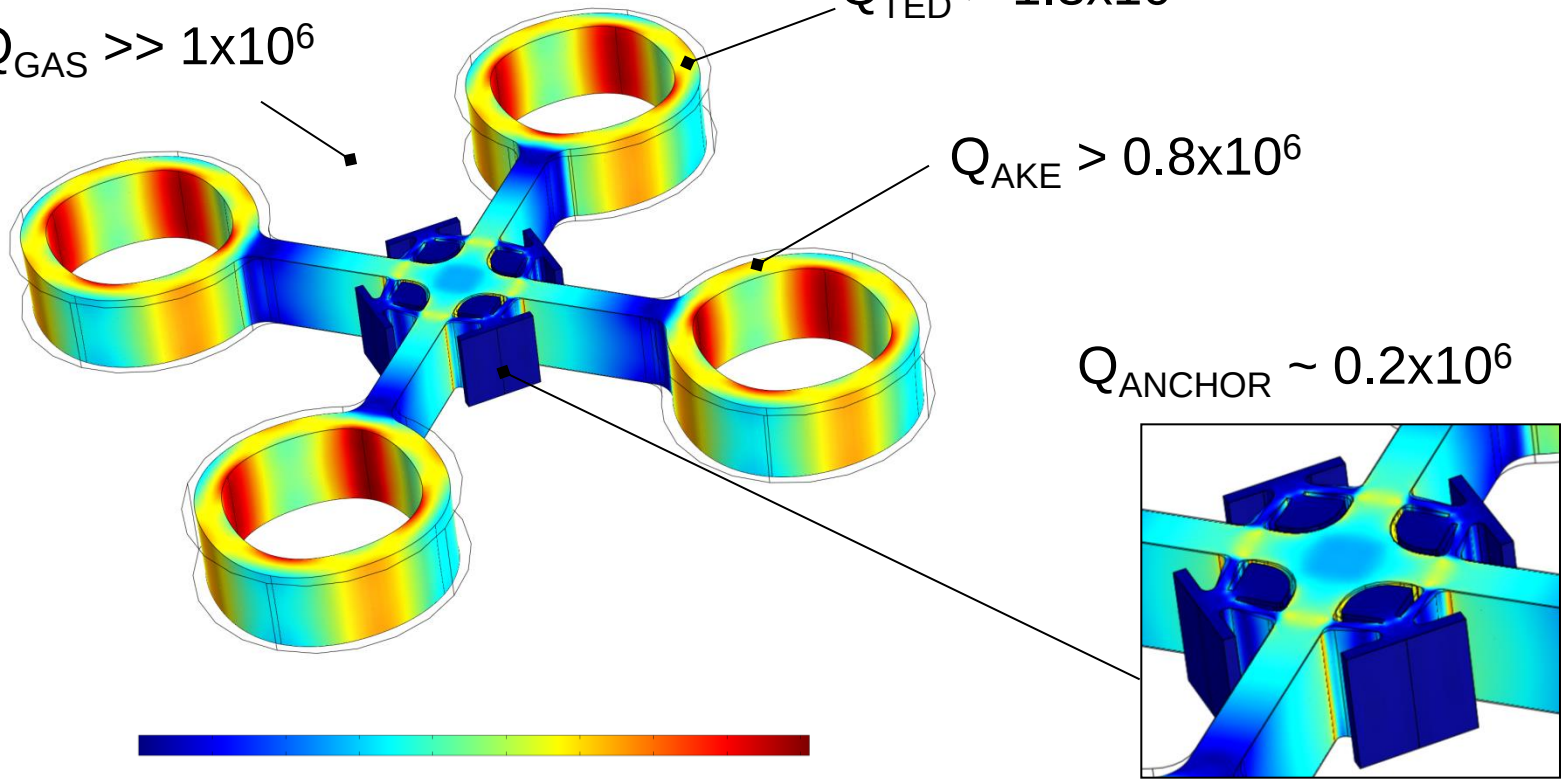
$$\frac{1}{Q} = \frac{1}{Q_{GAS}} + \frac{1}{Q_{TED}} + \frac{1}{Q_{AKE}} + \frac{1}{Q_{ANCHOR}} + \frac{1}{Q_{OTHER}}$$

$Q_{GAS} >> 1x10^6$

$Q_{TED} > 1.3x10^6$

$Q_{AKE} > 0.8x10^6$

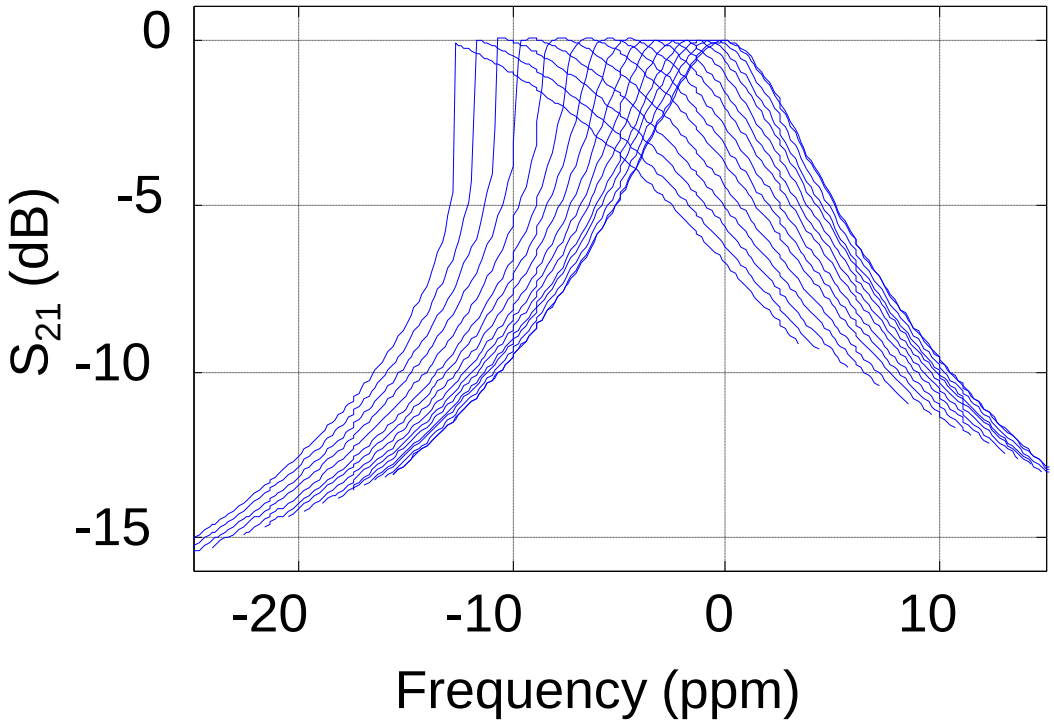
$Q_{ANCHOR} \sim 0.2x10^6$



Von Mises Stress @ Maximum Deflection

Optimizing for High Power Handling

- Resonator nonlinearities limit the drive amplitude
- Higher drive amplitude decrease far phase noise
- Overdriving increases near phase noise



SiTime's Products
Best MEMS & Performance & Quality

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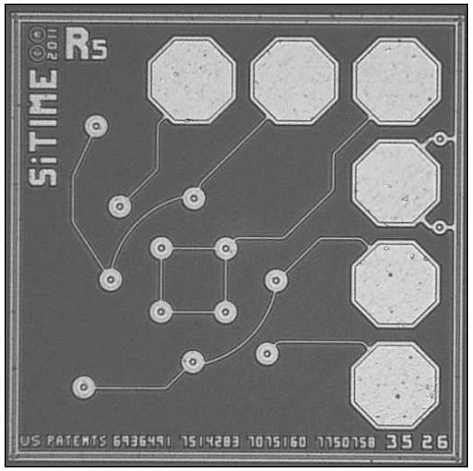
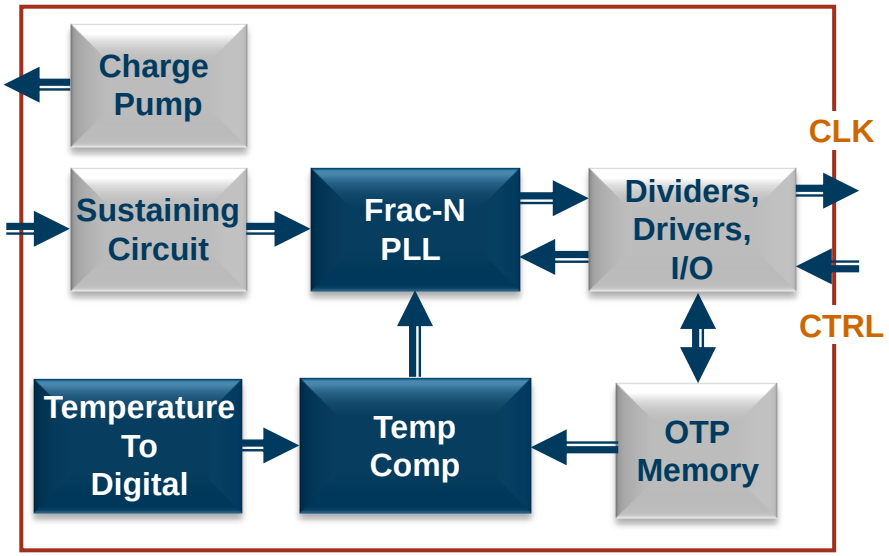
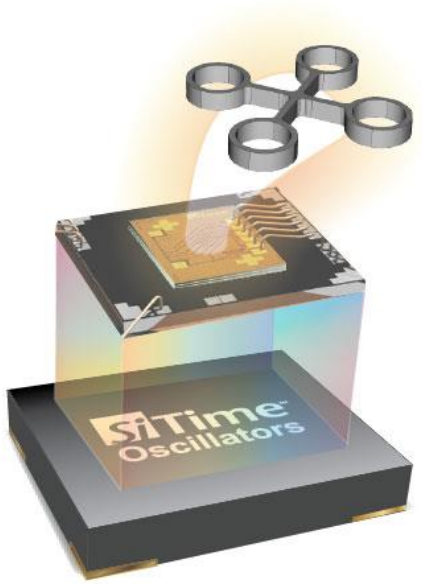
MEMS Die



Programmable CMOS IC



MEMS Oscillator



- 0.4 mm x 0.4 mm
- 99% yields
- Vacuum sealed die
- Standard CMOS fab

- Jitter – as low as 300 fs
- Stability - TCXO
- Low Power - 1μA @ 32kHz
- 180nm CMOS – fab TSMC

- Plastic packages
- Robust - MSL1
- 99% Yields
- 0.15DPPM, 2Fit

Temperature Stable MEMS Resonators

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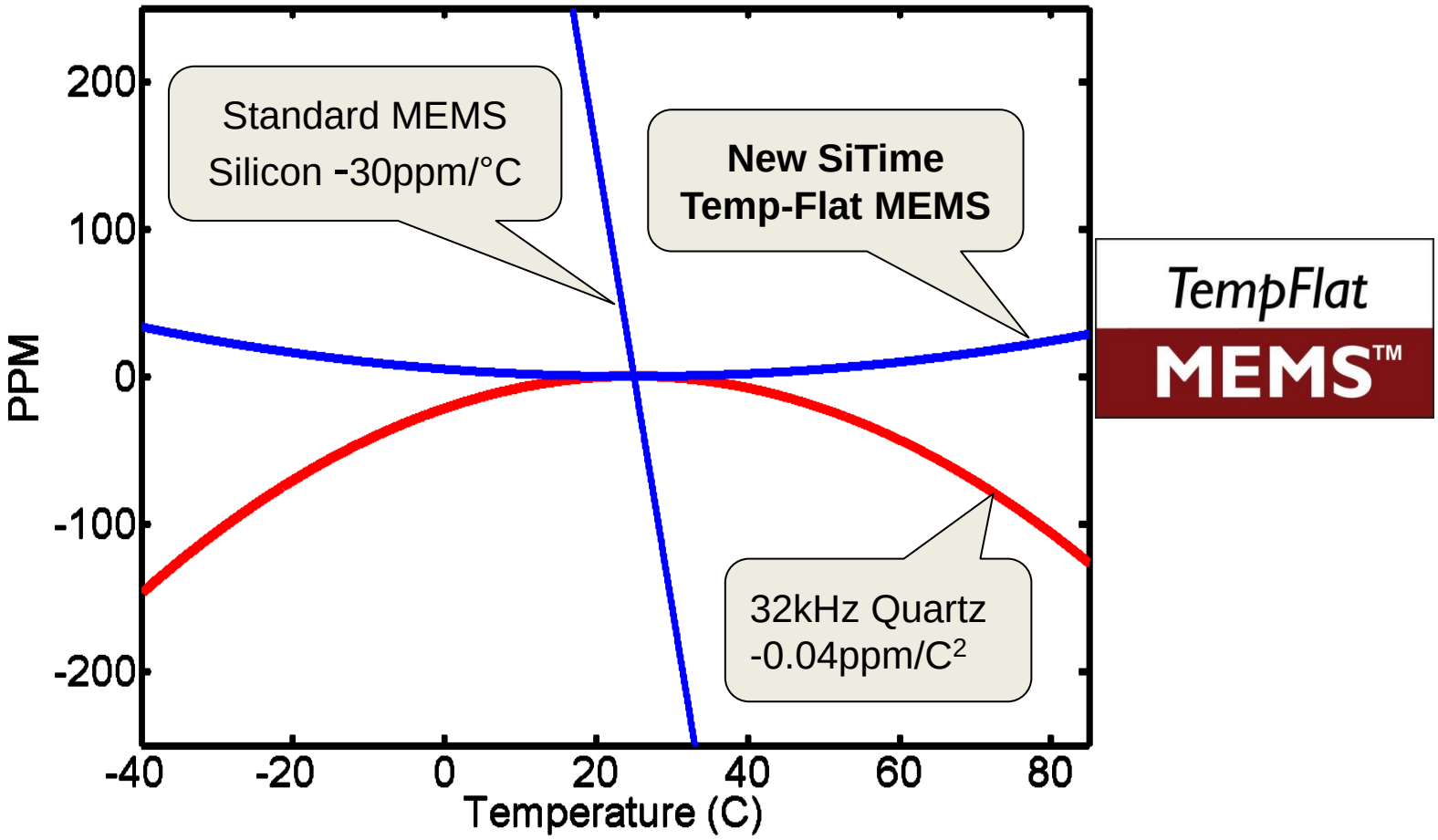

Mechanical temperature stability beats quartz

90% Correlation Simulation and Production

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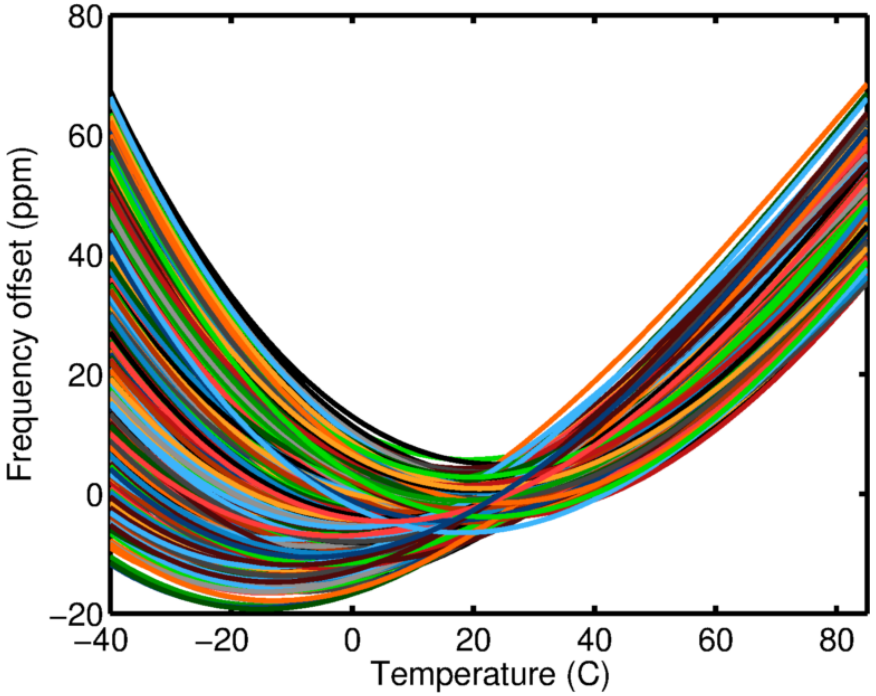
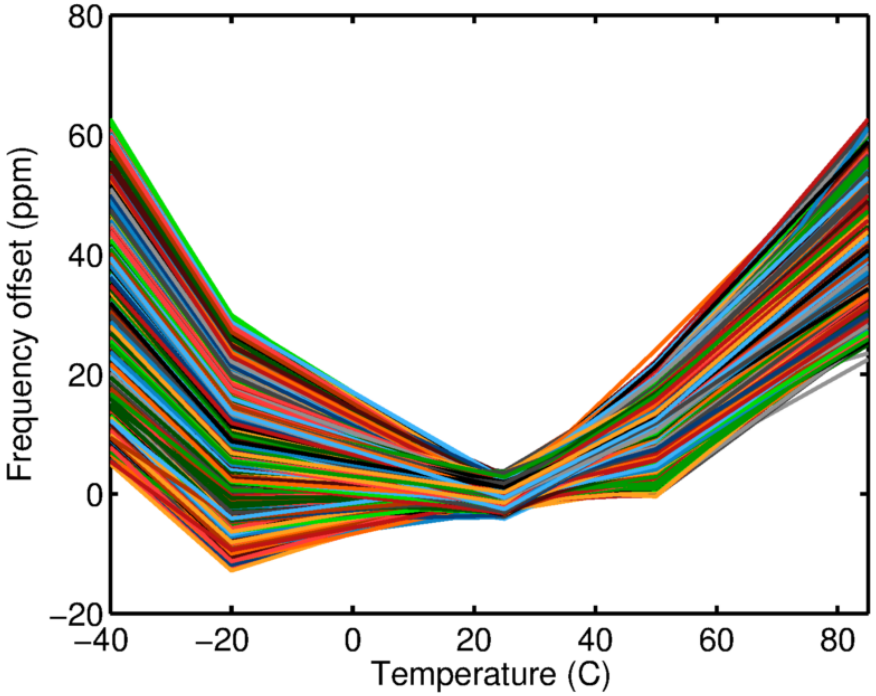
Monte Carlo Simulation



Simulation includes MEMS and CMOS variations

Measured
(30k production units)



Data of 20 production lots

32 kHz XO and TCXO for Wearables, Handsets

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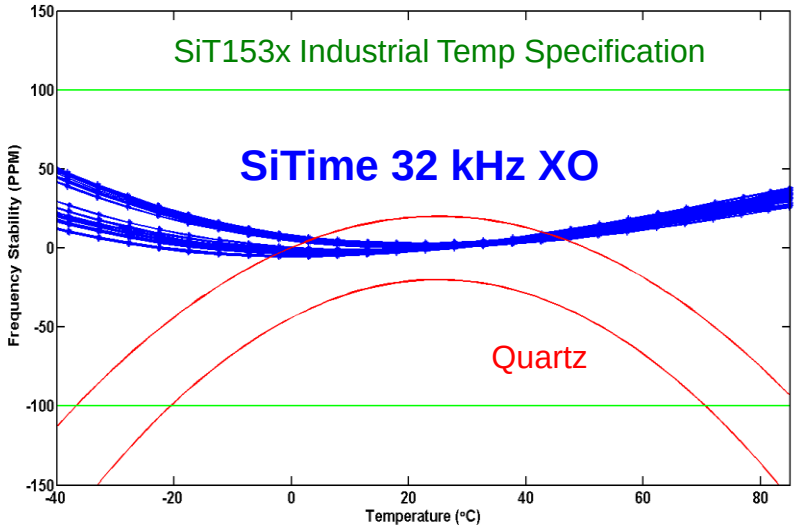
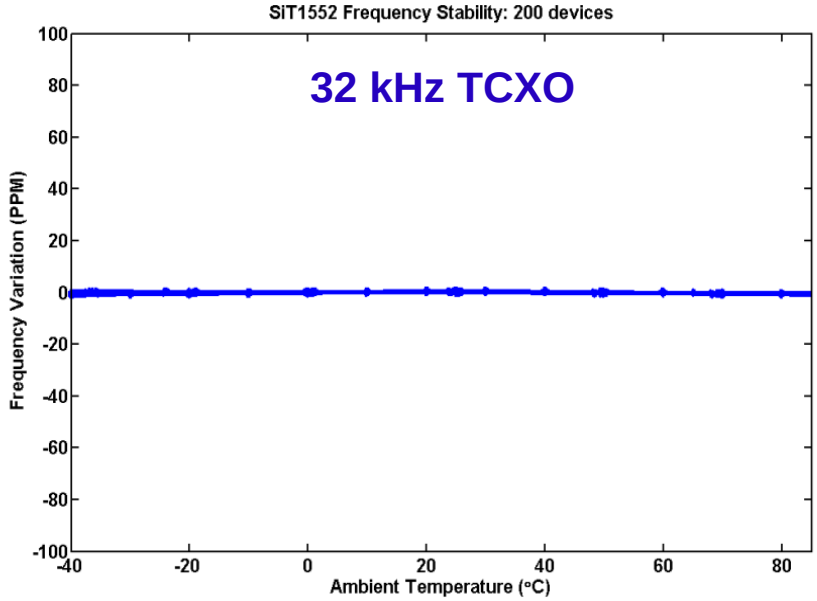
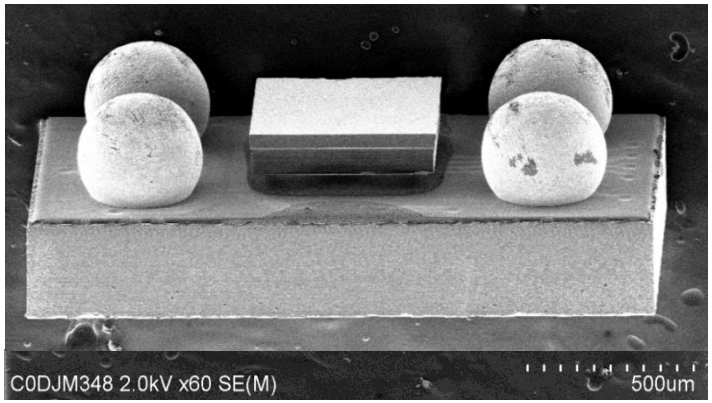




- Up to 80% smaller than quartz
- MEMS robustness and reliability
- Production volume 1M/week



Phase Noise Improvements

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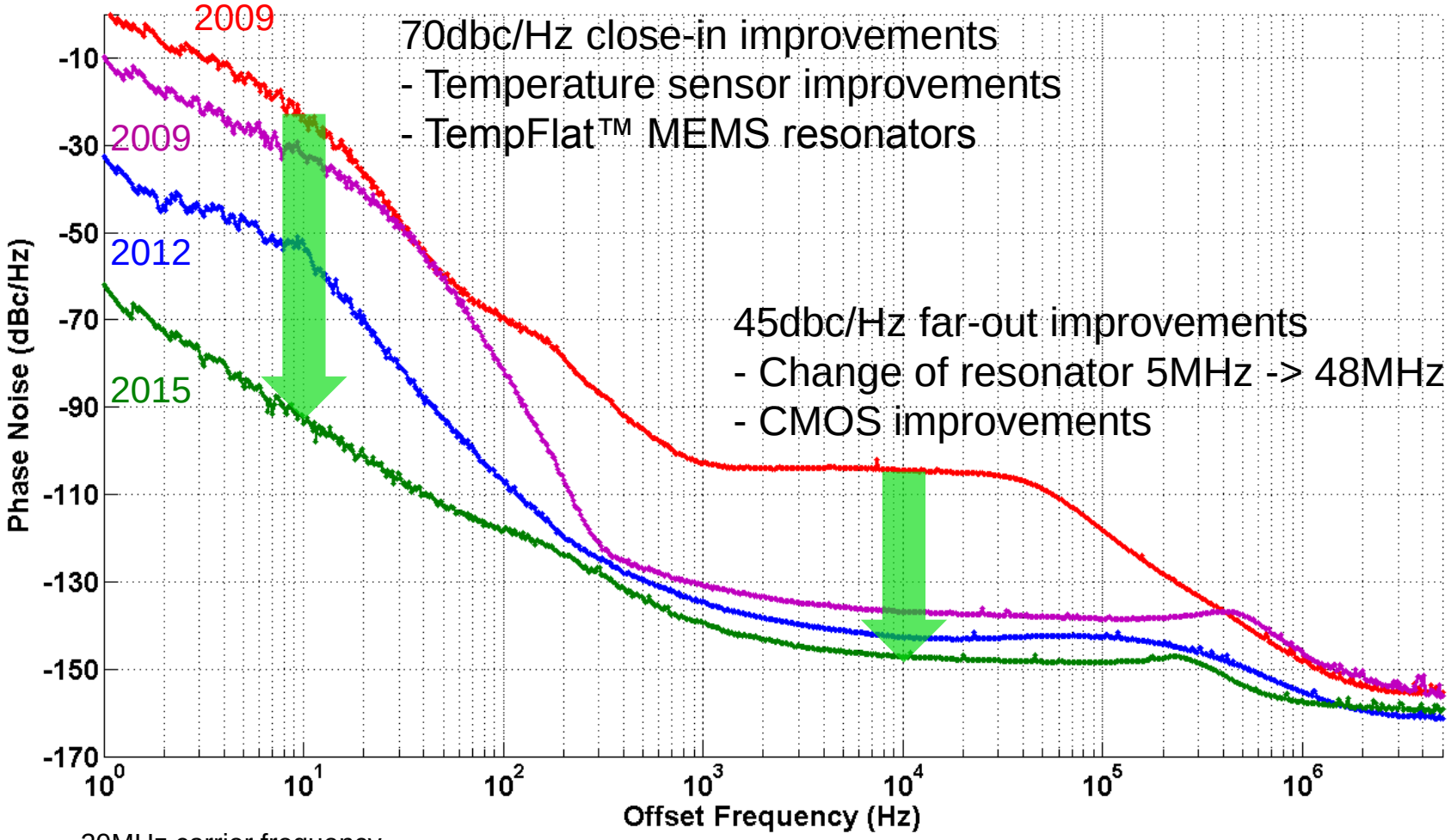

20MHz carrier frequency

Leading Innovation in Timing Marketplace

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270 Million Units Shipped

Production for over 7 years
>80% market share
100+ major OEMs

100+ Patents

First TempFlat™ MEMS
First nanopower™ oscillator
World's smallest CSP oscillator

0.15 DPPM Failure Rate

100X lower failure rate than quartz
Zero MEMS failures
Lifetime warranty

1 Hz to 800 MHz

XO, VCXO, DCXO, TCXO
-50°C to 125°C
CSP, SOT, 2016, 2520, 3225, 5032, 7050

Silicon Always Wins

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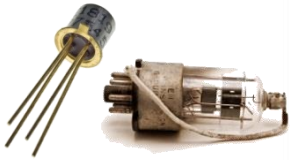
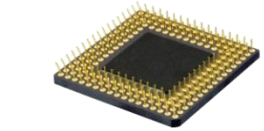
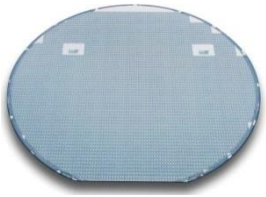
Highest Performance, Best Reliability, Smallest, Lowest Cost





Quartz



SiTime™
MEMS

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THANK YOU