MEMSLand

Cost Effective MEMS to Develop a Sustainable High Tech Business

Point-One

Pole of innovative technology on nanoelectronics and embedded systems

Business carrier: MEMS oscillators

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Project leader MEMS-XO, NXP Semiconductors

Corporate Innovation & Technology, Research

MEMS Oscillator team, partners

Partners:

- NXP I&T, Eindhoven, Leuven, Nijmegen
- TU Eindhoven + Stan Ackermans Institute (TOIO’s)
- Bruco
- TU Delft

Quartz resonators:
the "beating heart" of electronics

THE electronic timing reference for:

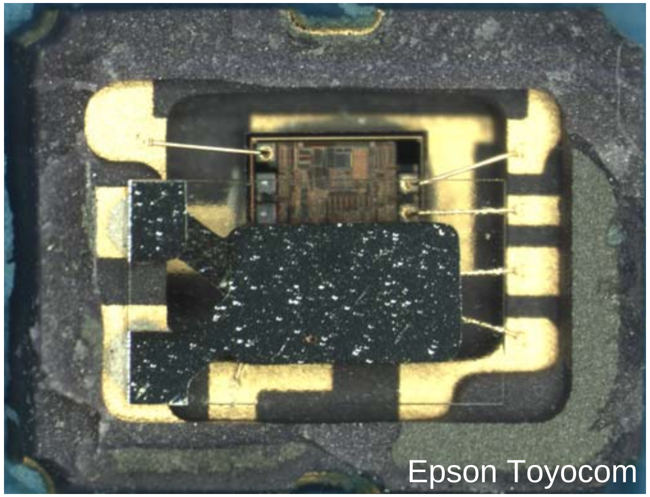
- Radio broadcasting (since 1926)
- Watches (since 1969)
- Clock signal for logic circuits

Pros

- Crystals can be cut to have (almost) zero temperature drift
- Very high Q-factor
- Piezoelectric

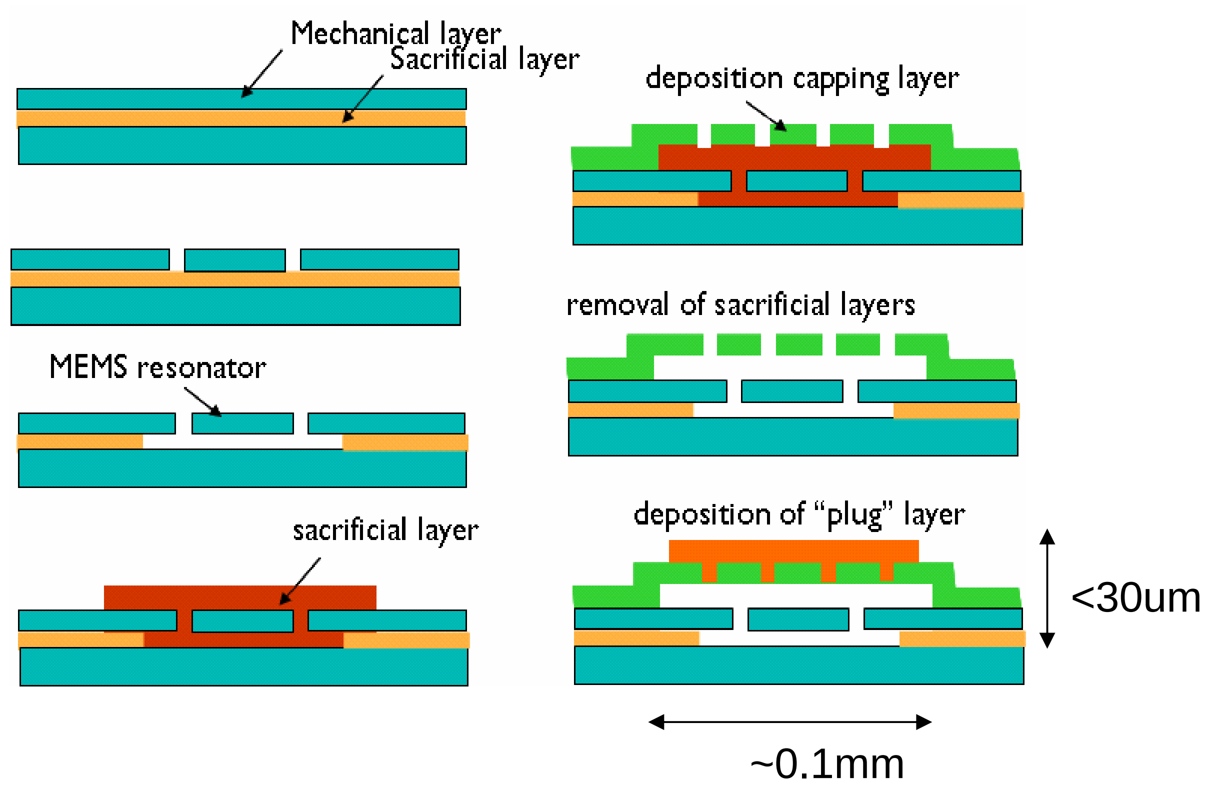
Cons:

- Relatively large due to crystal size and packaging
- Relatively expensive
- Problematic integration in SoC or SiP
- Single frequency
- Limited to ~100MHz



How do you make a MEMS resonator?

- Inexpensive process flow small no. mask layers
- No impact on packaging and assembly
- No special materials required
- Hardly any equipment investments
- Can be embedded in existing CMOS flow



Technical Progress Summary

- Phase noise measured of 56 MHz osc demo
- Temperature drift cancelation demonstrated
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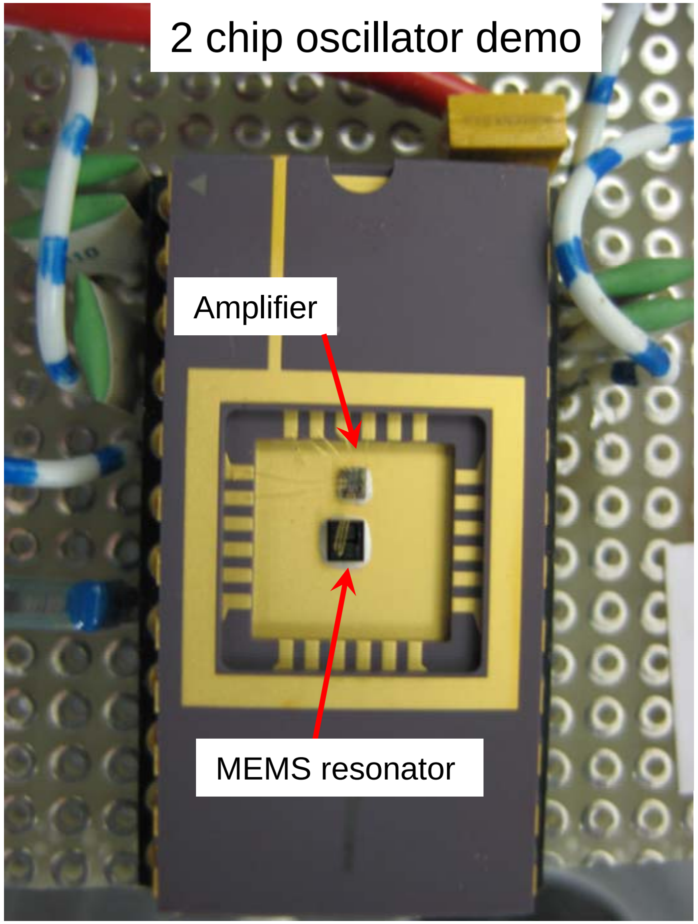
56 MHz oscillator demonstrator



Source: Joep Bontemps, SAI,
Alessandro Murroni, NXP

Noise benchmark

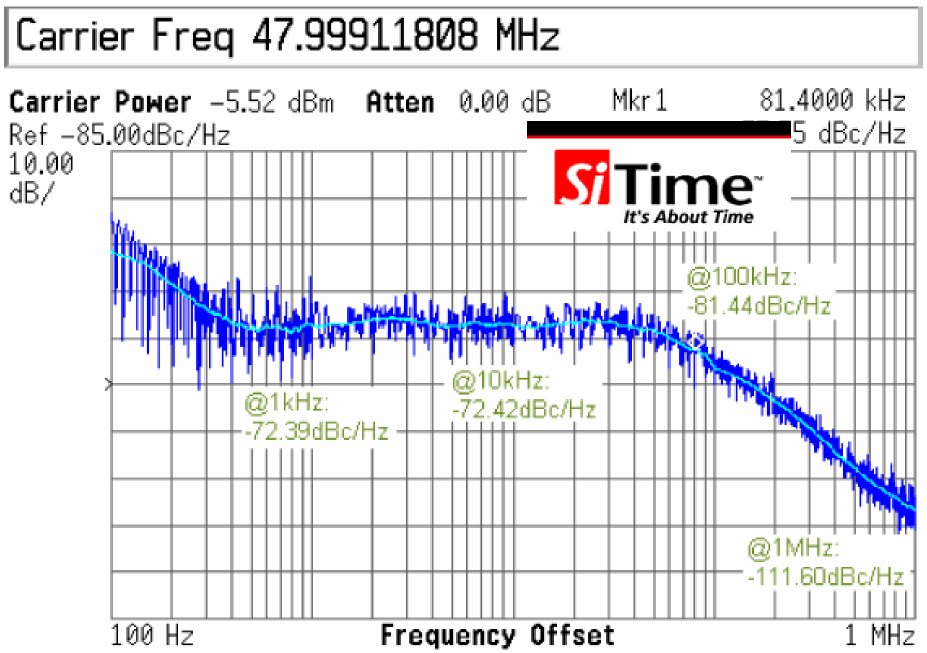
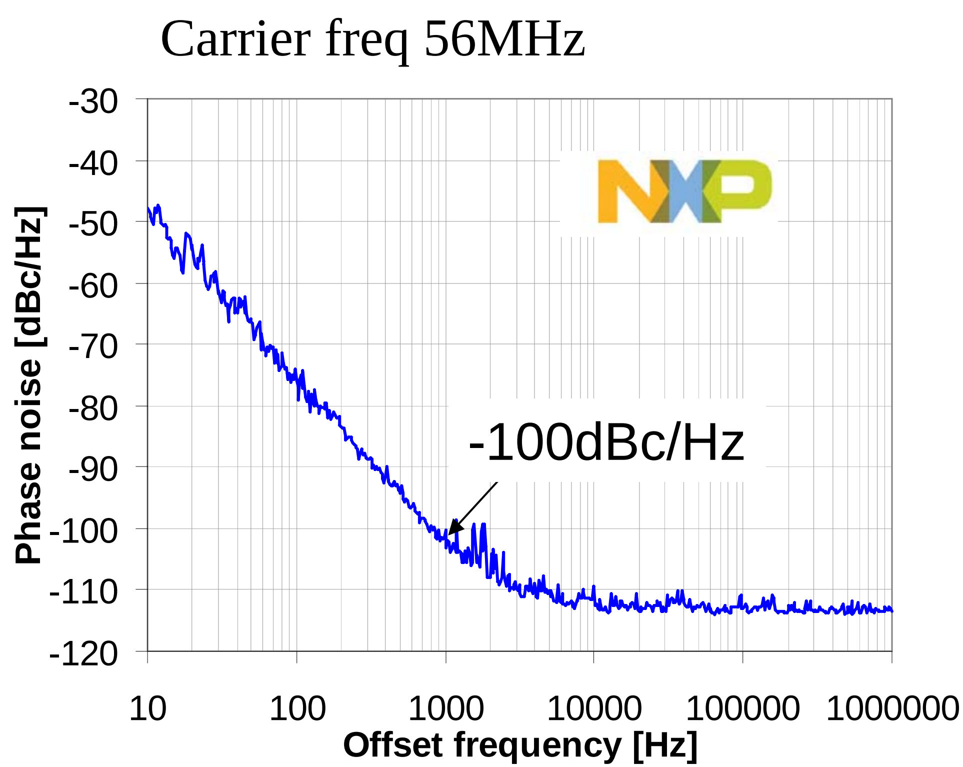


Figure 4 - Noise figure for 48MHz oscillators

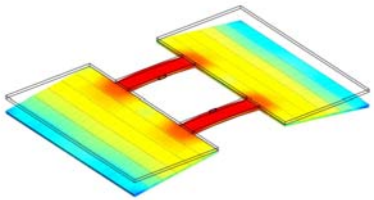


Source: Joep Bontemps, SAI, Alessandro Murroni, NXP

Measurement results resonant pressure sensors

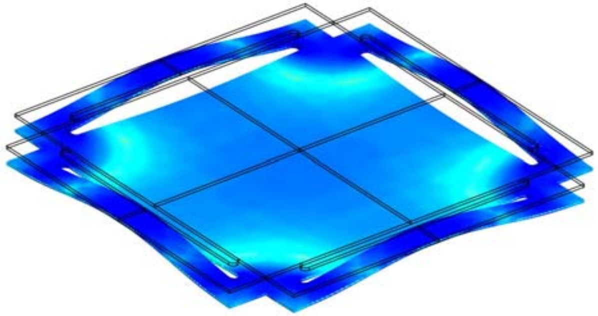
- Quality factor measurements on VibrantiN2 resonators as a function of nitrogen pressure.

'Dog bone'



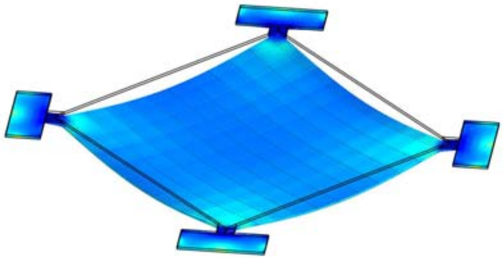
f_0= 175 kHz
Q_{vac}= $4.1\cdot10^3$

'Switch'



f_0= 173 kHz
Q_{vac}= $1.5\cdot10^3$

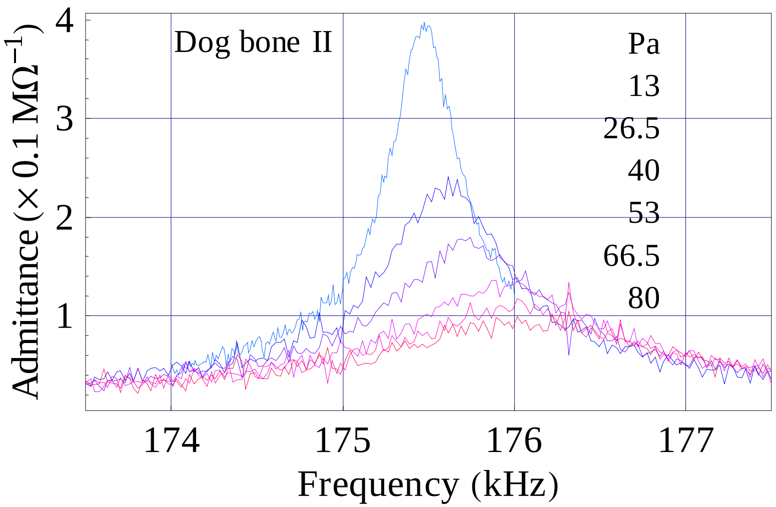
'Square plate'

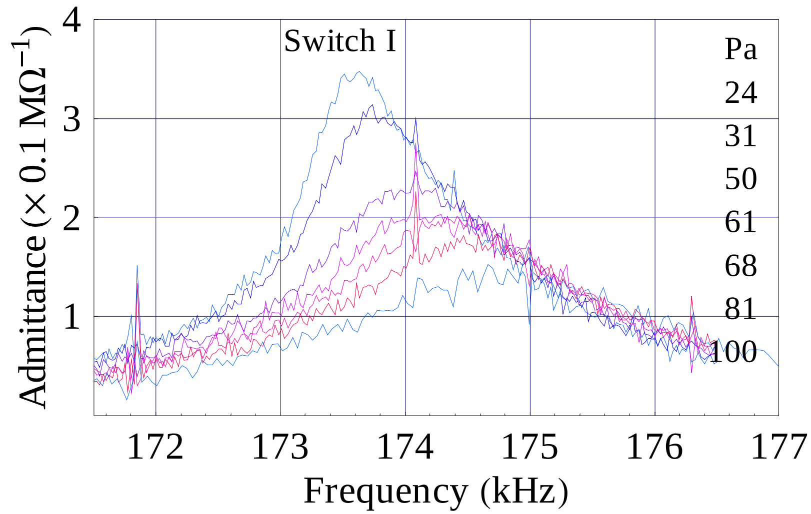


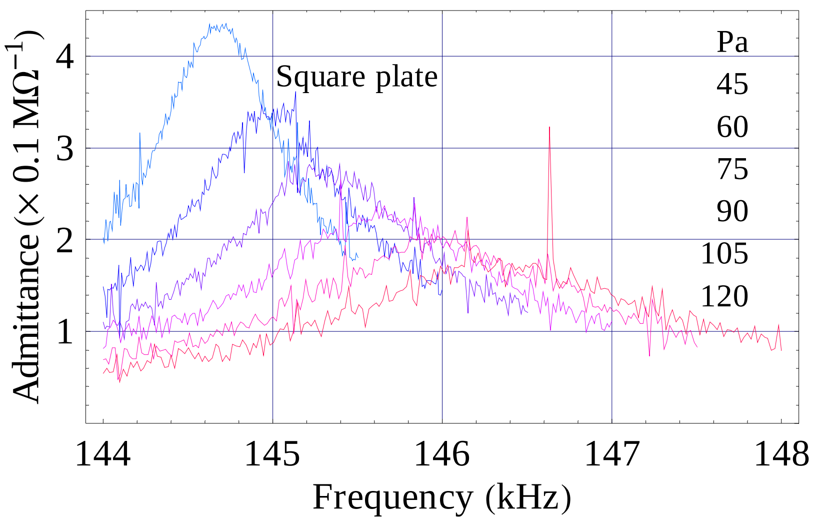
f_0= 144 kHz
Q_{vac}= $1.2\cdot10^4$

Source: Matthijs Suijlen, SAI

Results pressure sensitivity







Device	$1/f\ \Delta f/\Delta p$ (ppm/Pa)
‘Dog bone’	40
‘Switch’	80
‘Square plate’	140

Source: Matthijs Suijlen, SAI

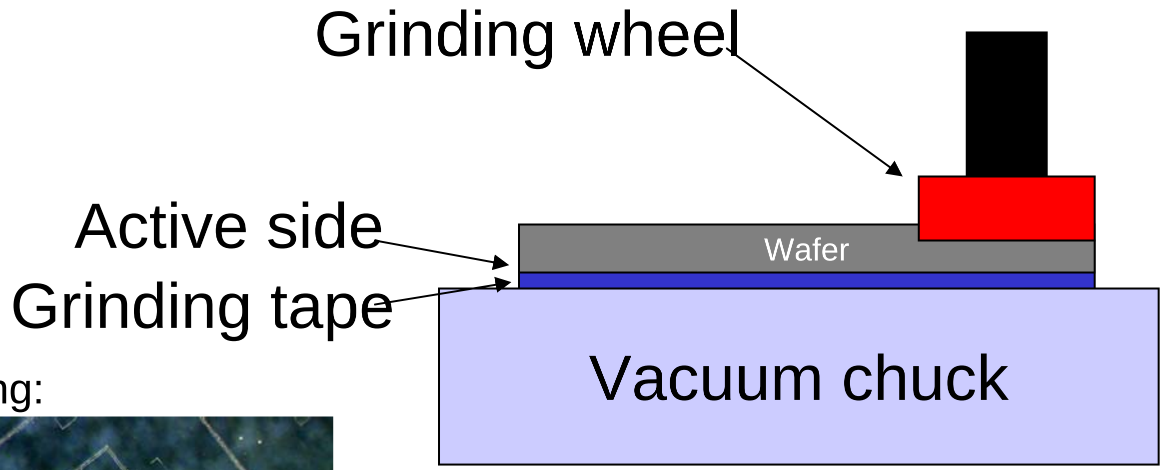
Other results

- Article analytical model for squeeze film damping at free molecular flow (accepted; to appear in Sens. Actuators A)
- Direct Simulation Monte Carlo (DSMC) routine for squeeze film diffusion – results showing very good agreement with observations on device Q-factors
- New device design on VibrantiN3 tape out featuring a.o. pressure read-out functionality on piezo-resistive demonstrator of Joep Bontemps

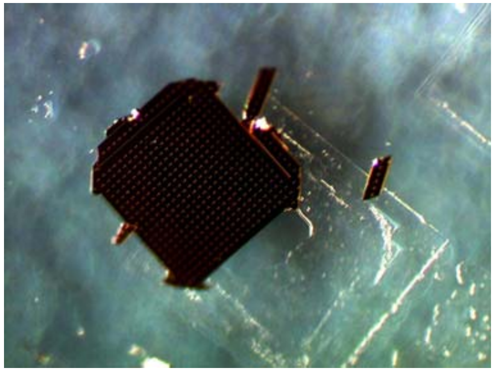
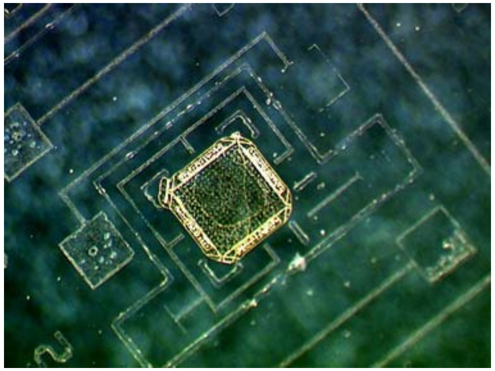
Wafer back grinding of WLTFP

Grinding process

- Apply tape to the **active** side of the wafer
- Flip the wafer on the grinding vacuum chuck (tape side down)
- Grinding operation
- Remove tape



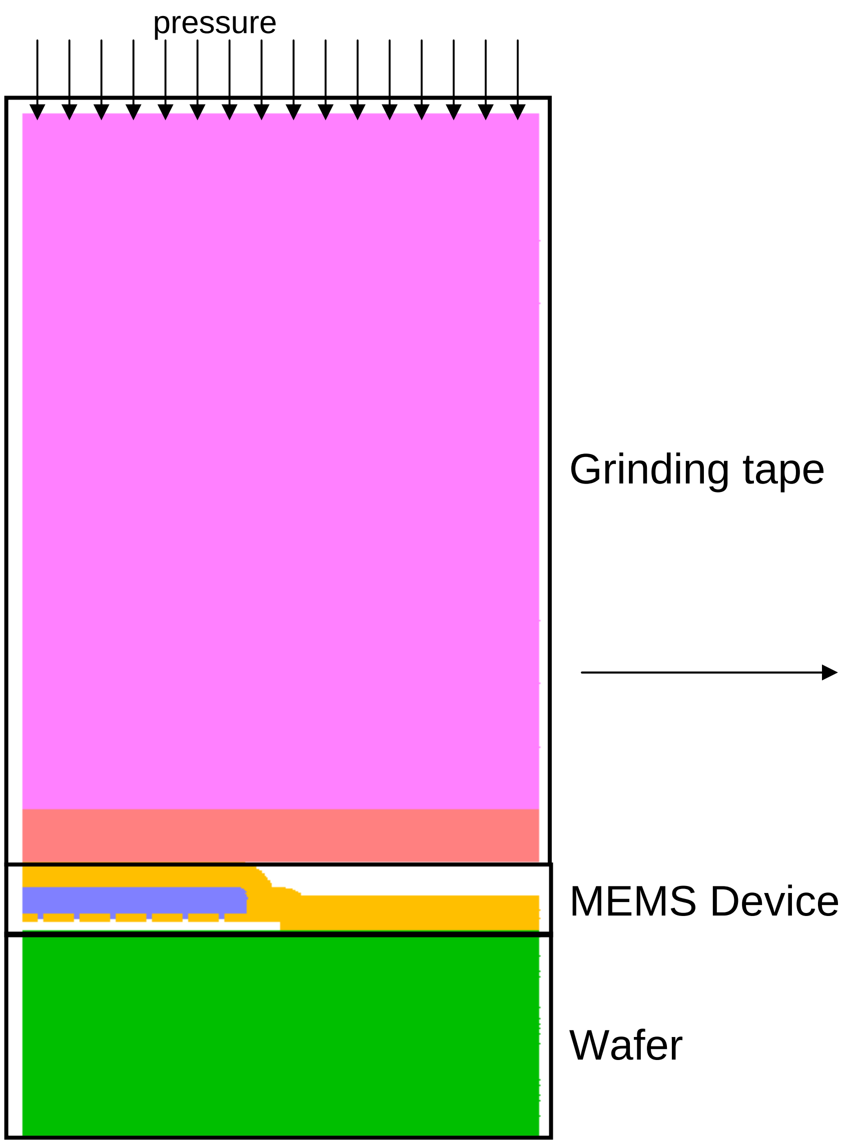
Damage due to taping and detaping:

Pictures depict the grinding tape with pieces of resonator sticking to them

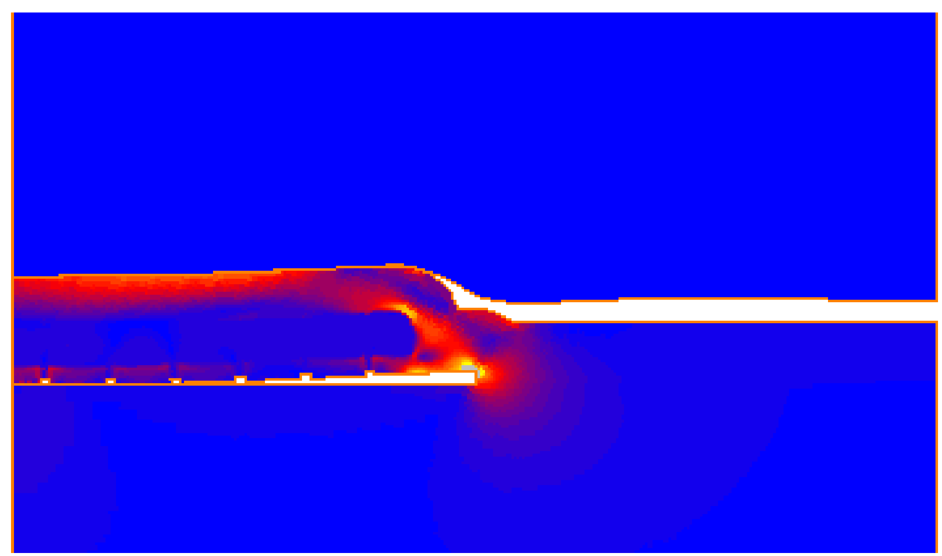
Source: Jeroen Zaal, TUD

Model: tape application



Possible improvement actions:

- Investigate different tapes
- Lower grinding pressure
- Strengthen geometry



Source: Jeroen Zaal, TUD

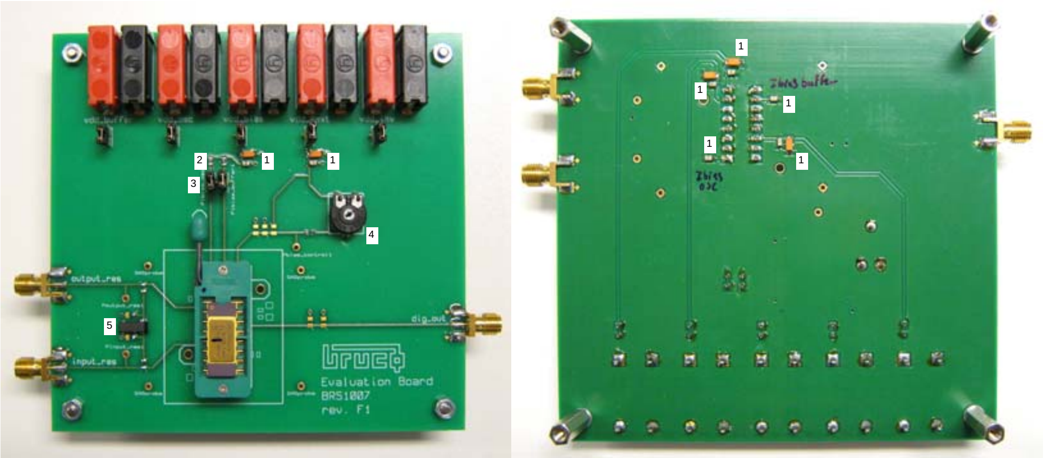
WP2 contributions by BRUCO for NXP (MEMS RTC oscillator)

- Activities since last consortium meeting:
  - Evaluation of an oscillator-core and buffer circuit for RTC applications.
  - Patent application text filed: “Ultra low power three points oscillator”.

- Chip is only functionally tested (because no MEMS resonators are available yet.)
  - Chip: CMOS14 process, 1.8V supply voltage.

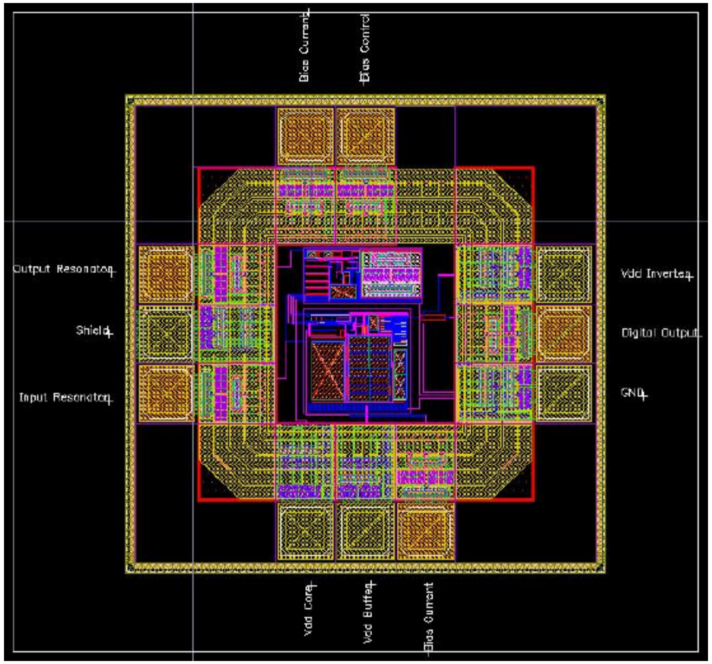
Cont'd WP2 contributions BRUCO

- Results of the evaluation:
  - Power consumption: less than 1 uW.
  - Can handle resonators in a frequency range of 30 kHz up to 1 MHz.



Cont’d WP2 contributions BRUCO

- Future improvements:
  - The stability of buffer-circuit.
  - More accurate amplitude control circuit.



Technical Progress Summary

- Phase noise measured of 56 MHz osc demo
  - Near carrier noise superior wrt. competition
- Temperature drift cancelation demonstrated
  - Temperature drift reduced to 170 ppm between 30-100C
- Vacuum packaging improved
  - Very high Q ~100.000 obtained under ambient conditions
- Back-end wafer process flow under development
  - Grinding tests on WLTFP on-going
- Ultra-low power driver IC for RTC designed and tested
  - Driver IC will be combined with 30kHz resonator in near future