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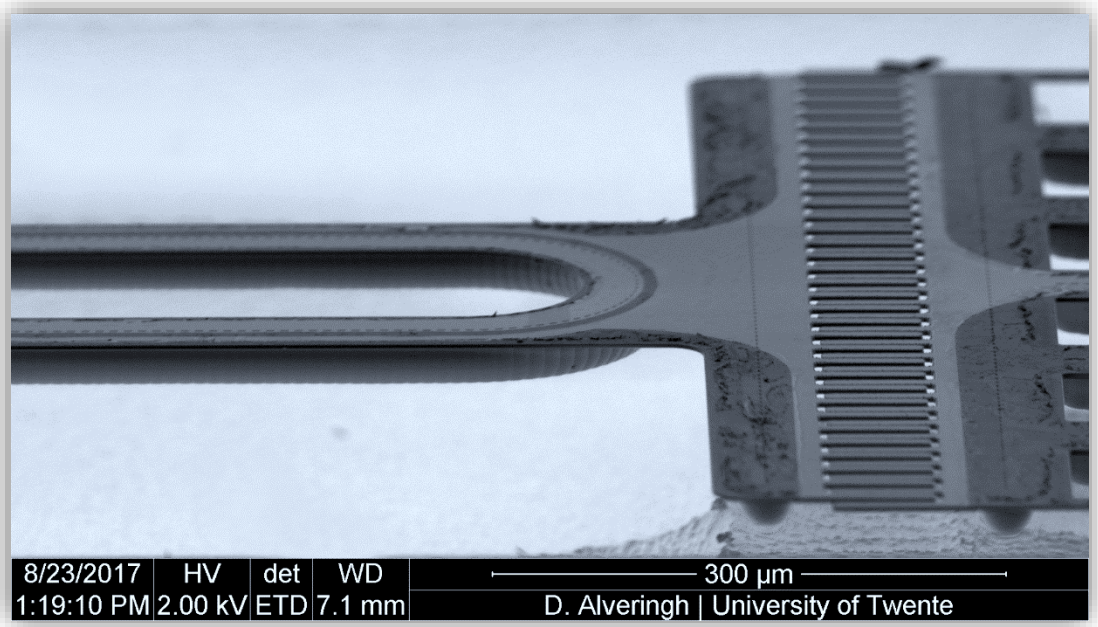
Exotic sensors *as exemplification of* the challenge in MEMS characterization

Dennis Alveringh



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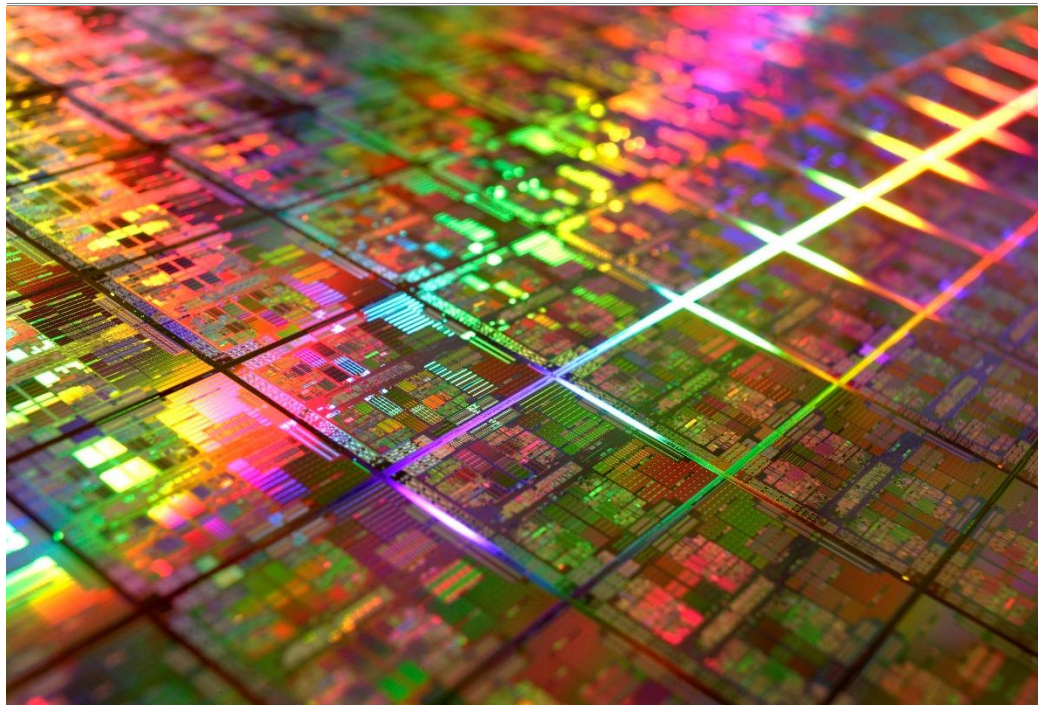
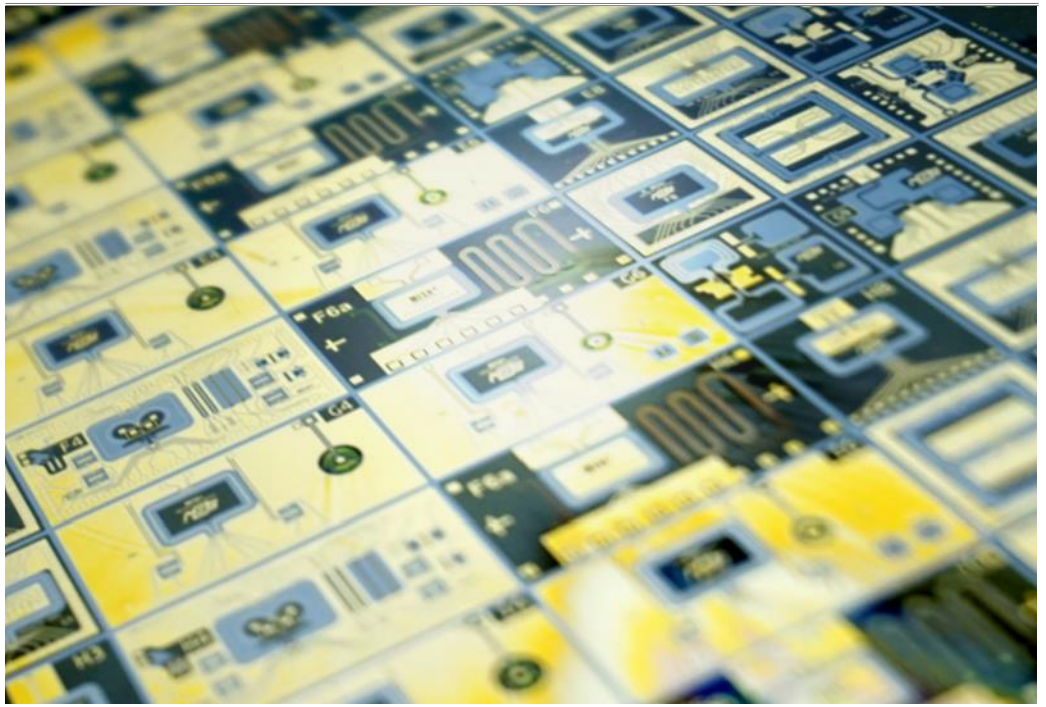
Introduction

Mindset difference between IC and MEMS designers

ICs



MEMS



Introduction

Mindset difference between IC and MEMS designers

ICs

- Input: electrical signal.
  Output: electrical signal.
- Designer does not really has to care about fabrication technology.
- A default package usually does the job.
- Testing on an ATE.

MEMS

- Input: physical/chemical quantity.
  Output: physical/chemical quantity.
- Fabrication technology and device design are inextricably linked.
- Custom designed package needed for each specific MEMS design.
- Custom designed test solution.

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- Four exotic MEMS devices
- First steps in large scale MEMS testing
- Conclusion

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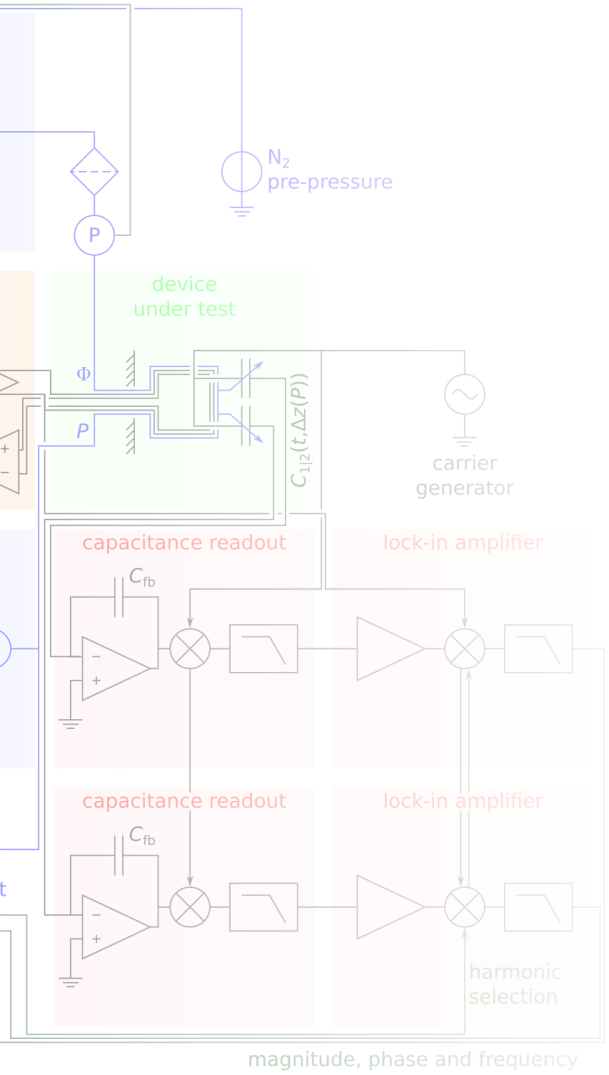
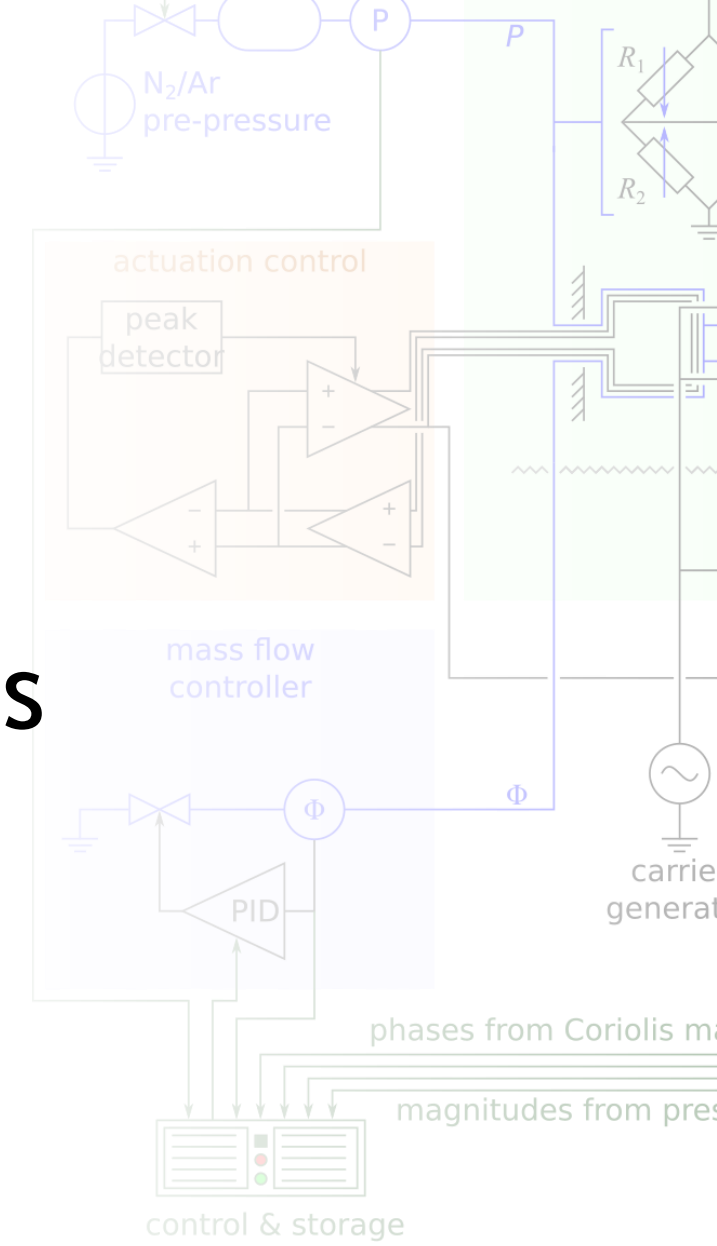
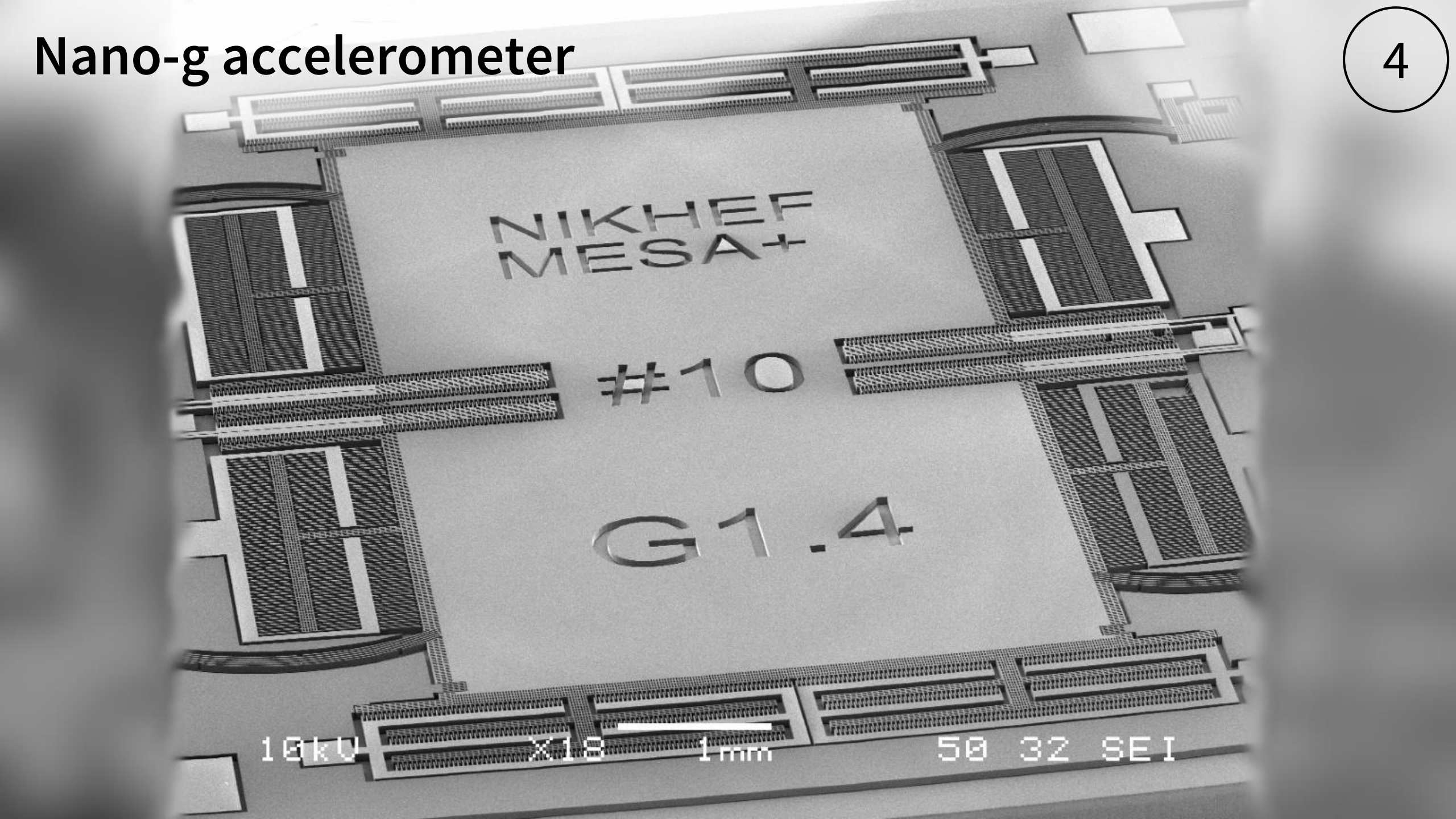


Four exotic MEMS devices

ordered in decreasing testability



Nano-g accelerometer



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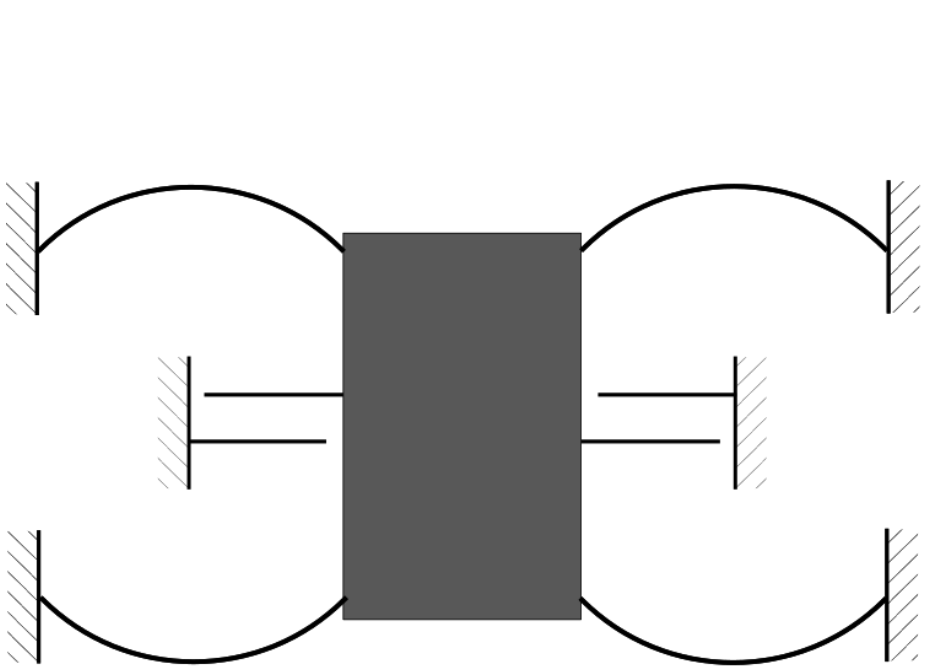
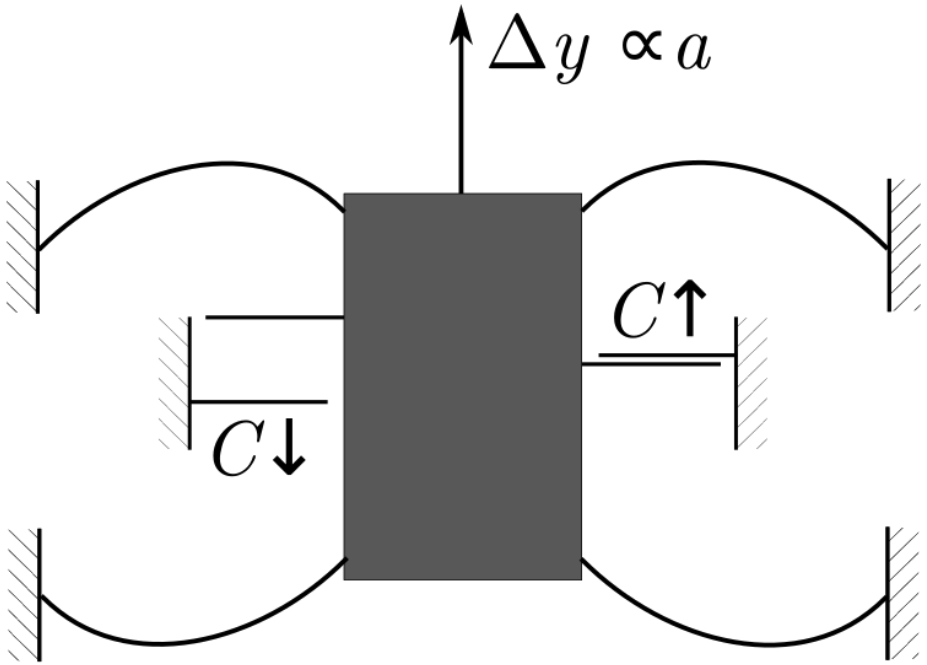
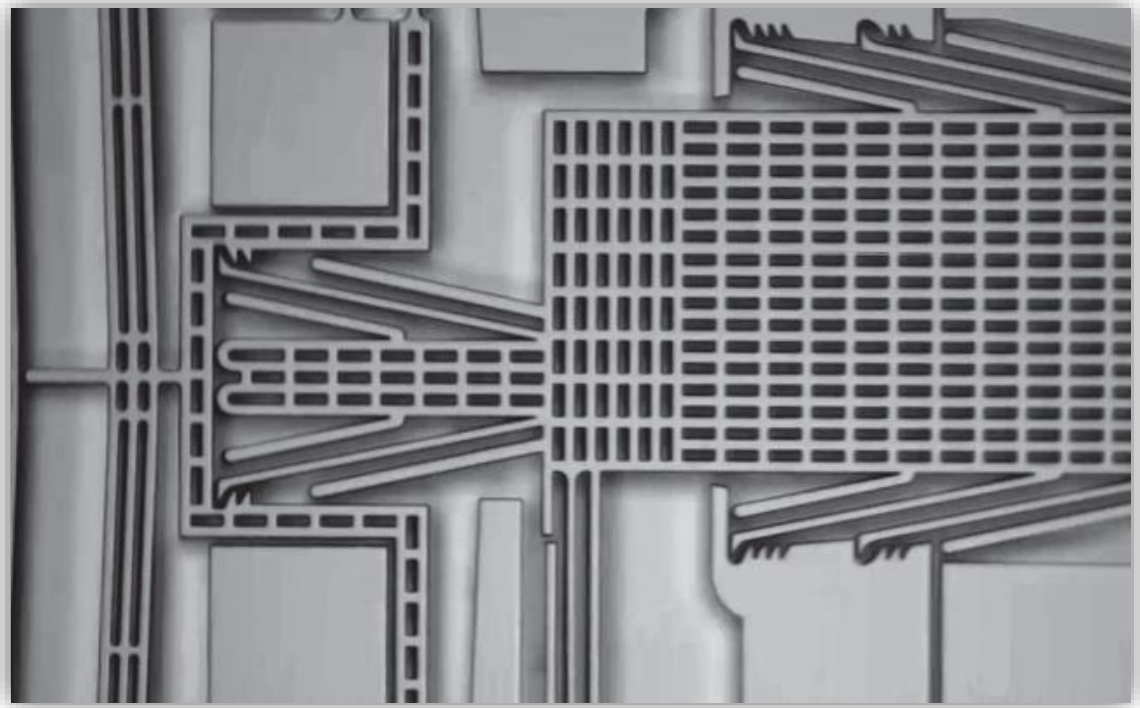
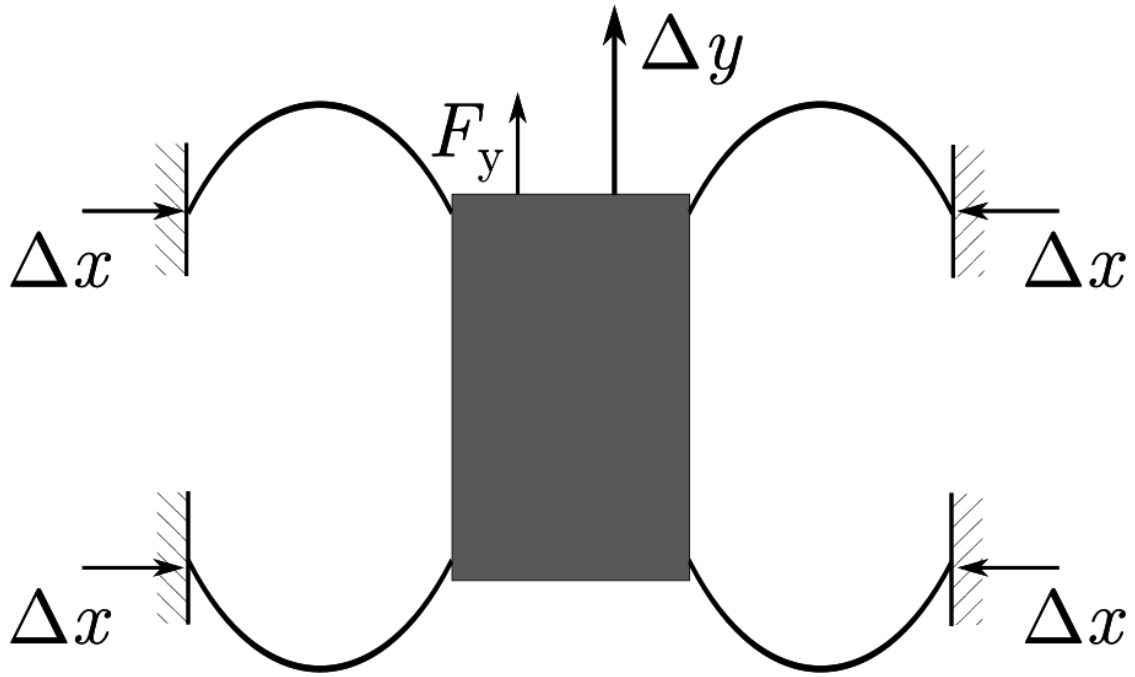




🕮 B. A. Boom et al., *Nano-G accelerometer using geometric anti-springs,* IEEE MEMS, 2017.
🕮 P. Kamp, *Towards an Ultra Sensitive Seismic Accelerometer, MSc thesis, 2015.*

Nano-g accelerometer





📖 B. A. Boom et al., *Nano-G accelerometer using geometric anti-springs,* IEEE MEMS, 2017.
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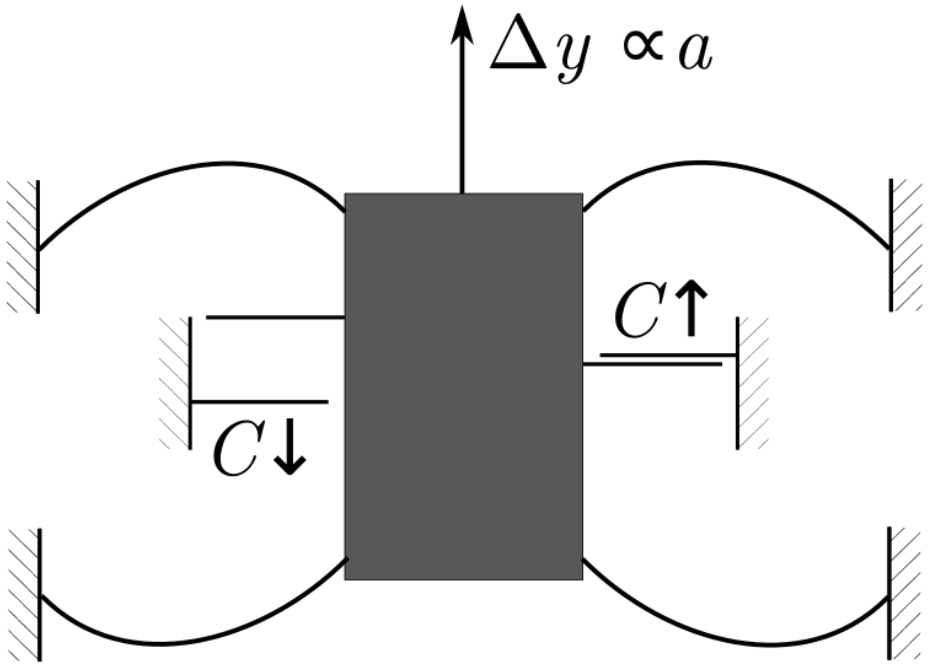
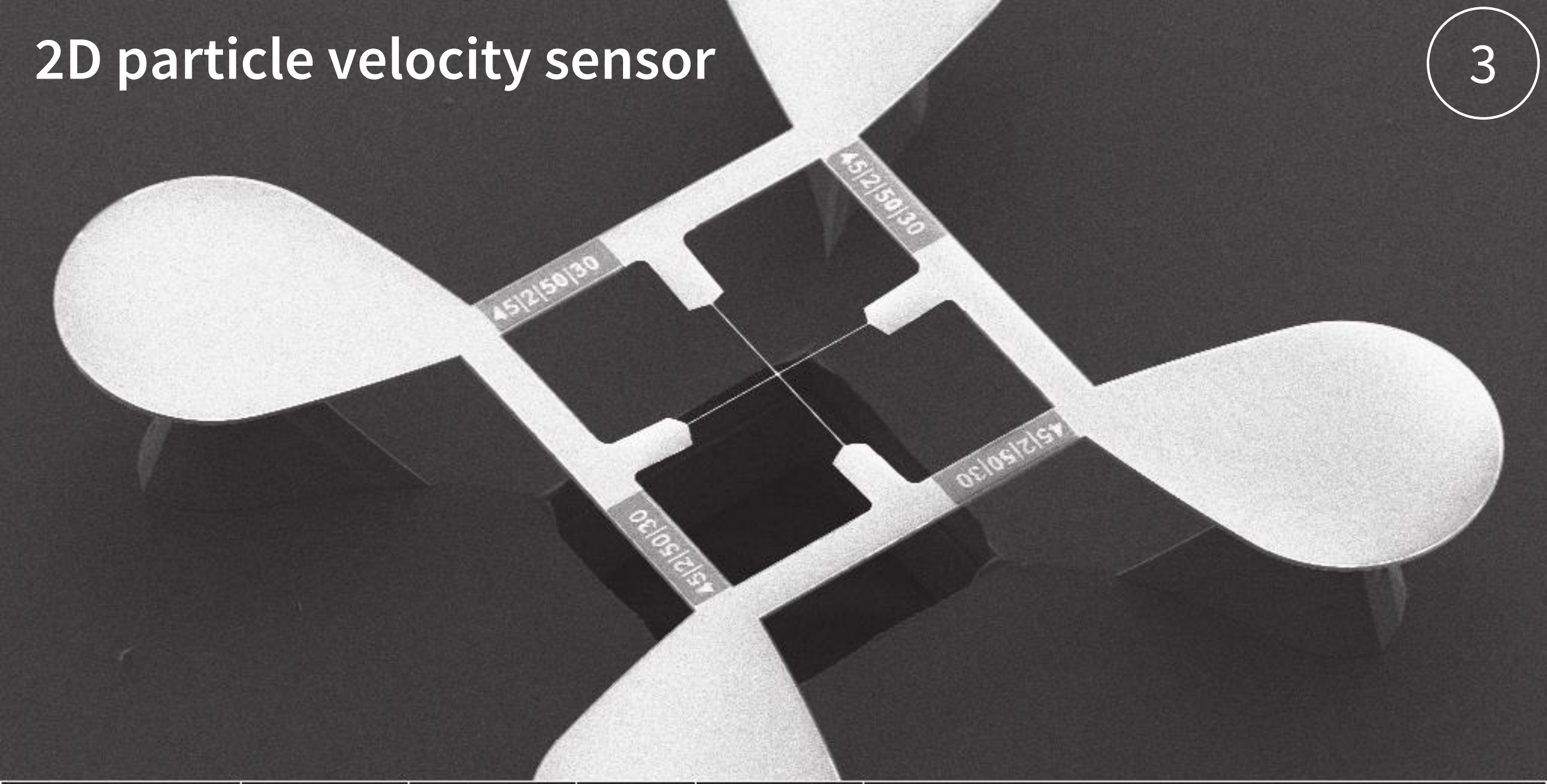
2D particle velocity sensor



Stimulus: acceleration of 1 ng.	o
Readout: capacitance.	–
Testability	**–**

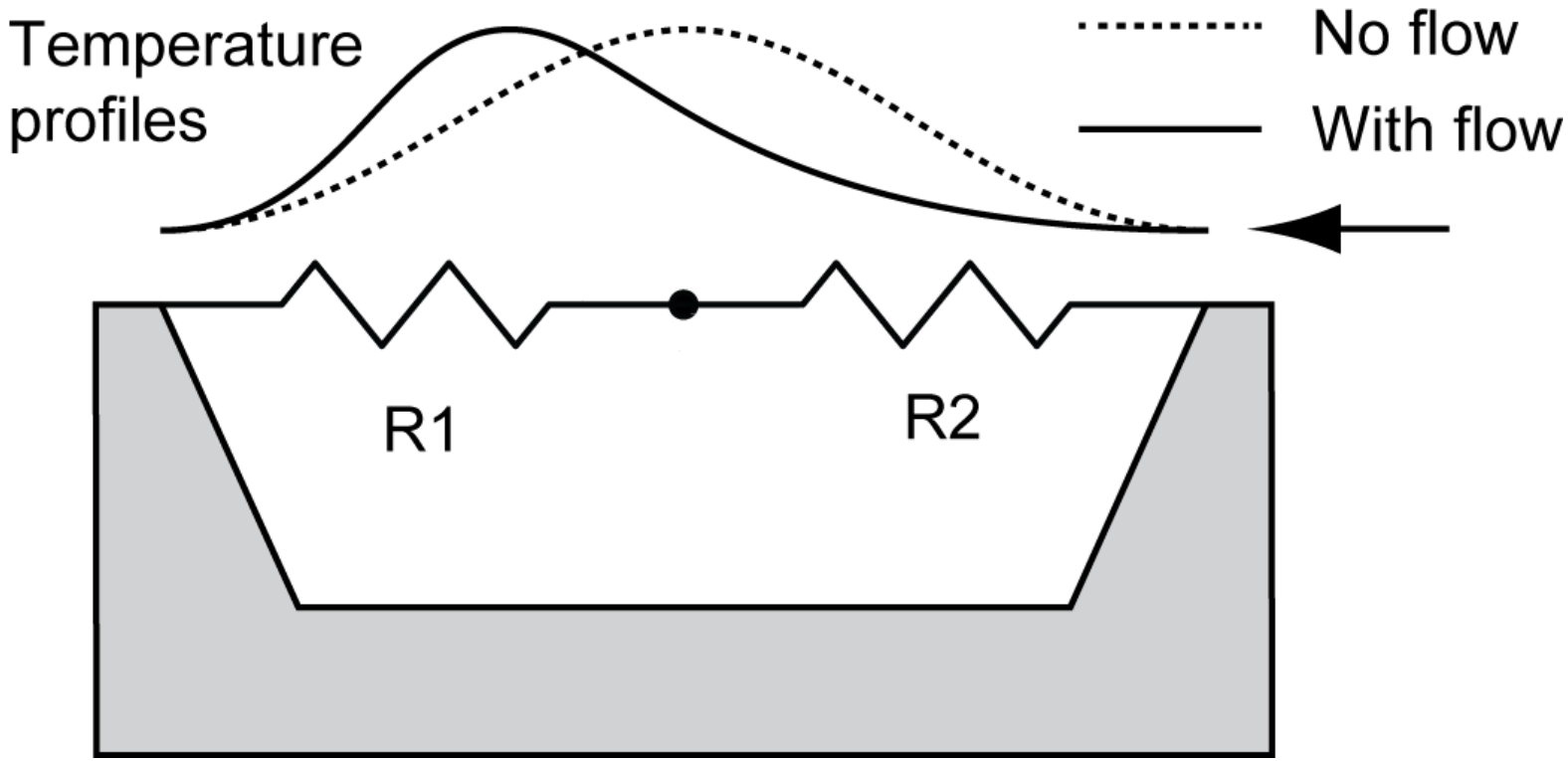
📖 B. A. Boom et al., *Nano-G accelerometer using geometric anti-springs,* IEEE MEMS, 2017.
📖 P. Kamp, *Towards an Ultra Sensitive Seismic Accelerometer, MSc thesis, 2015.*

2D particle velocity sensor



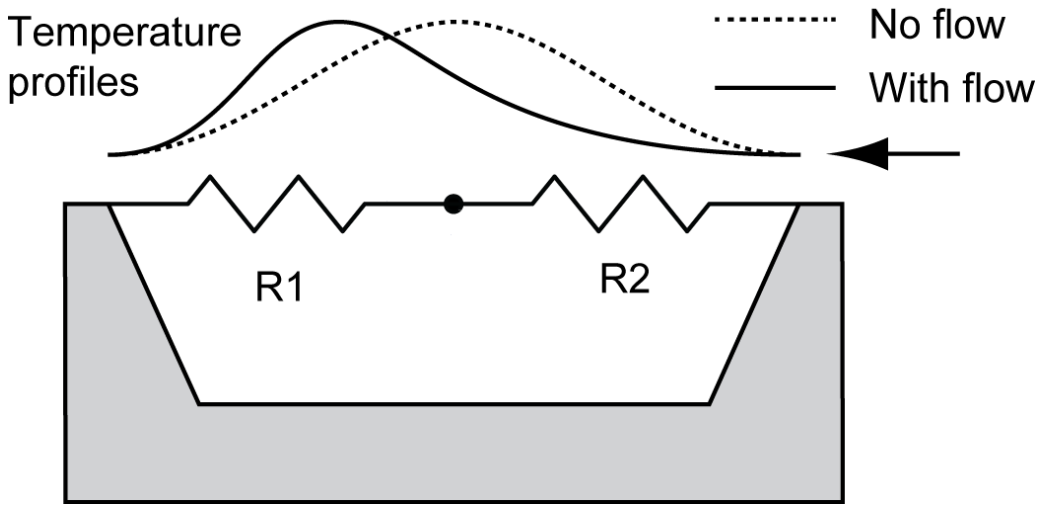
11/30/2014	HV	HFW	curr	WD	500 µm
11:24:08 PM	15.00 kV	1.73 mm	19 pA	31.7 mm	

2D particle velocity sensor



📖 O. Pjetri et al., *A crossed-wire 2-dimensional acoustic particle velocity sensor*, IEEE SENSORS, 2013.

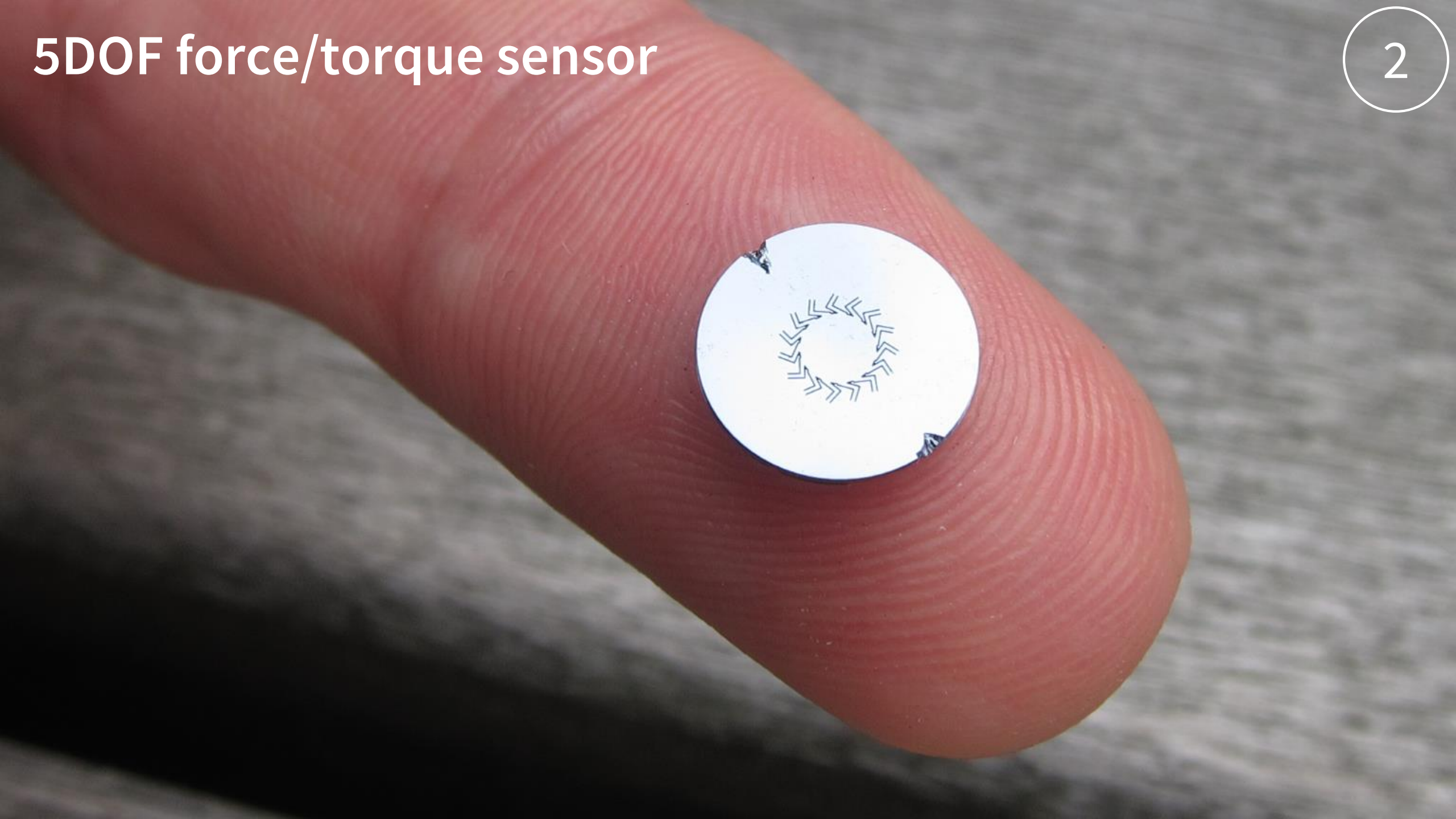
2D particle velocity sensor



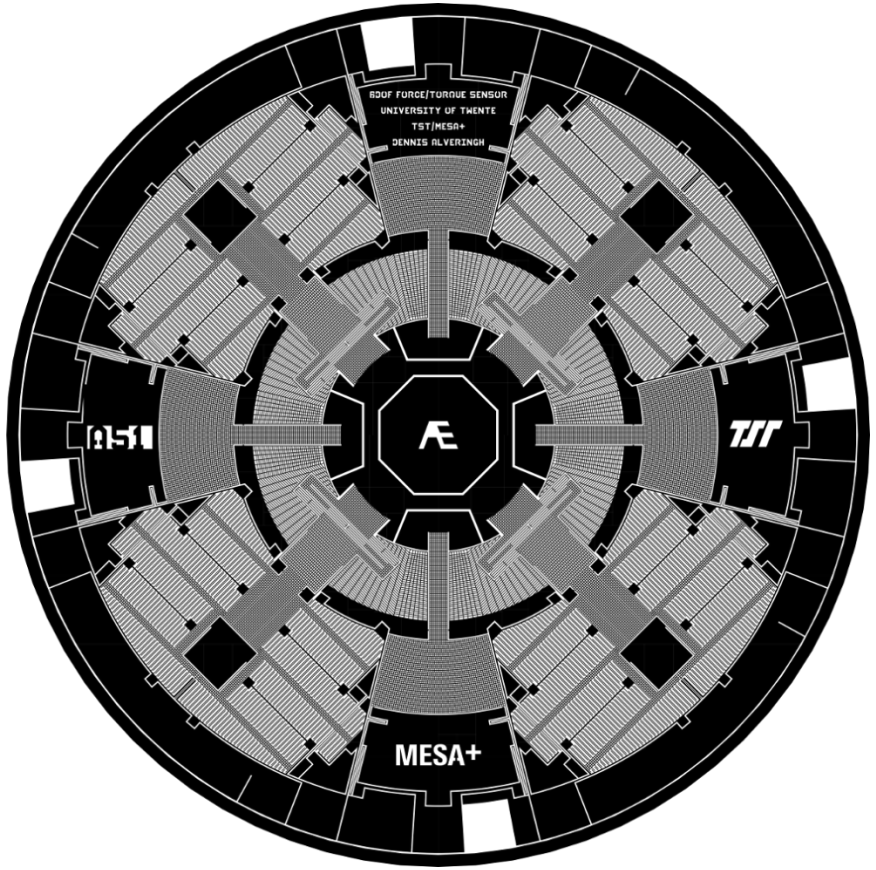
Stimulus: 2D audio.	––
Readout: Wheatstone bridge.	+
Testability	**–**

📖 O. Pjetri et al., *A crossed-wire 2-dimensional acoustic particle velocity sensor*, IEEE SENSORS, 2013.

5DOF force/torque sensor

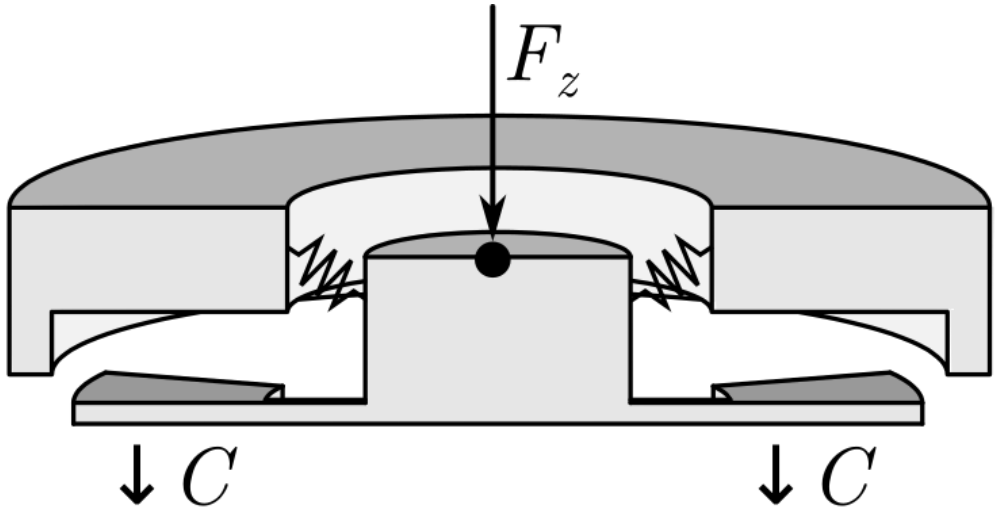


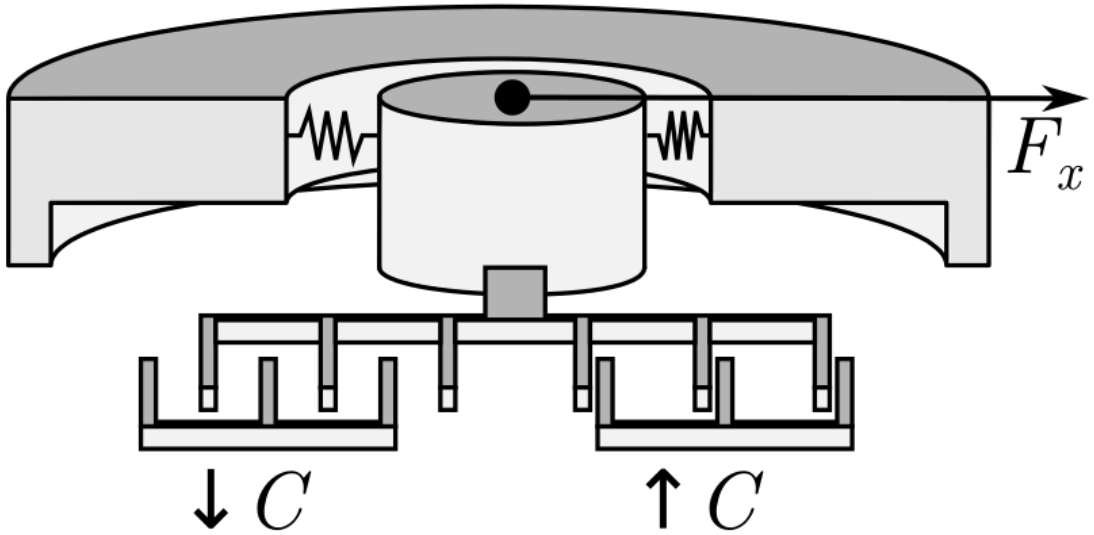
5DOF force/torque sensor



📖 D. Alveringh et al., *A large range multi-axis capacitive force/torque sensor realized in a single SOI wafer,* IEEE MEMS, 2014.

5DOF force/torque sensor

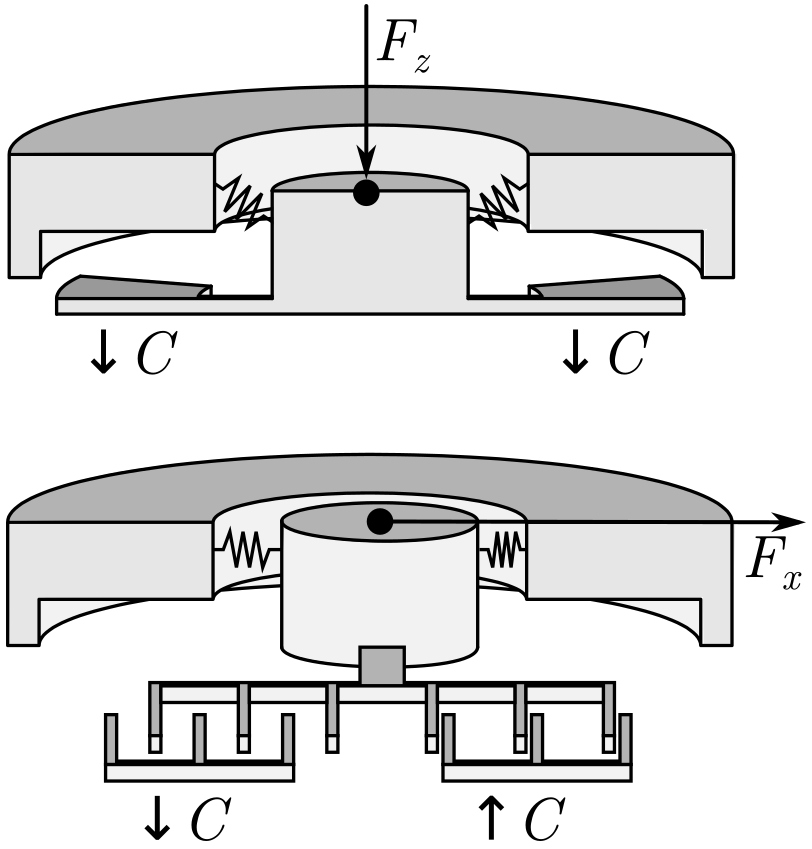




📖 D. Alveringh et al., *A large range multi-axis capacitive force/torque sensor realized in a single SOI wafer,* IEEE MEMS, 2014.

Fabrication

5DOF force/torque sensor

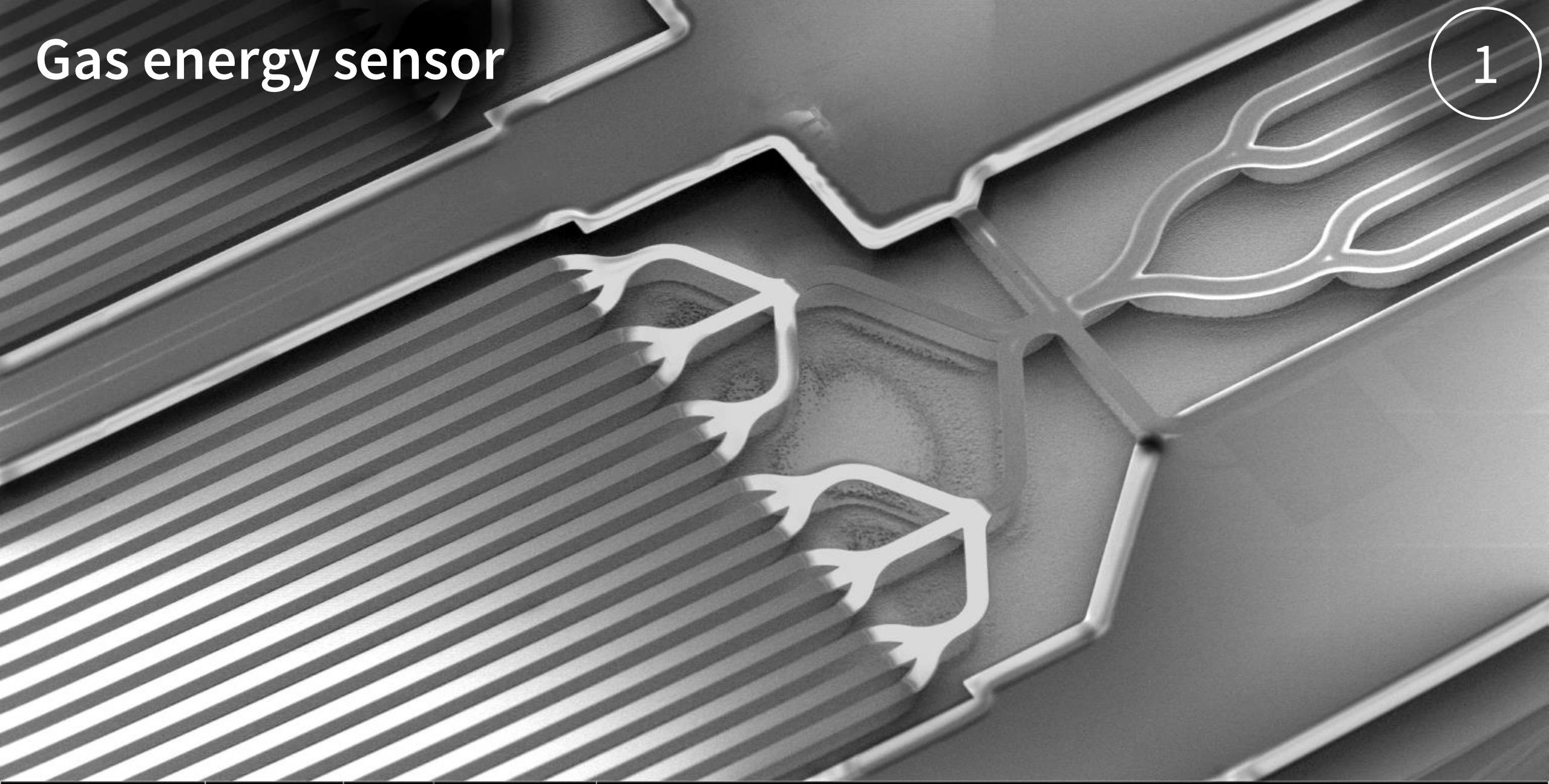


Stimulus: contact force.	––
Readout: capacitance.	–
Testability	**––**

🕮 D. Alveringh et al., *A large range multi-axis capacitive force/torque sensor realized in a single SOI wafer,* IEEE MEMS, 2014.

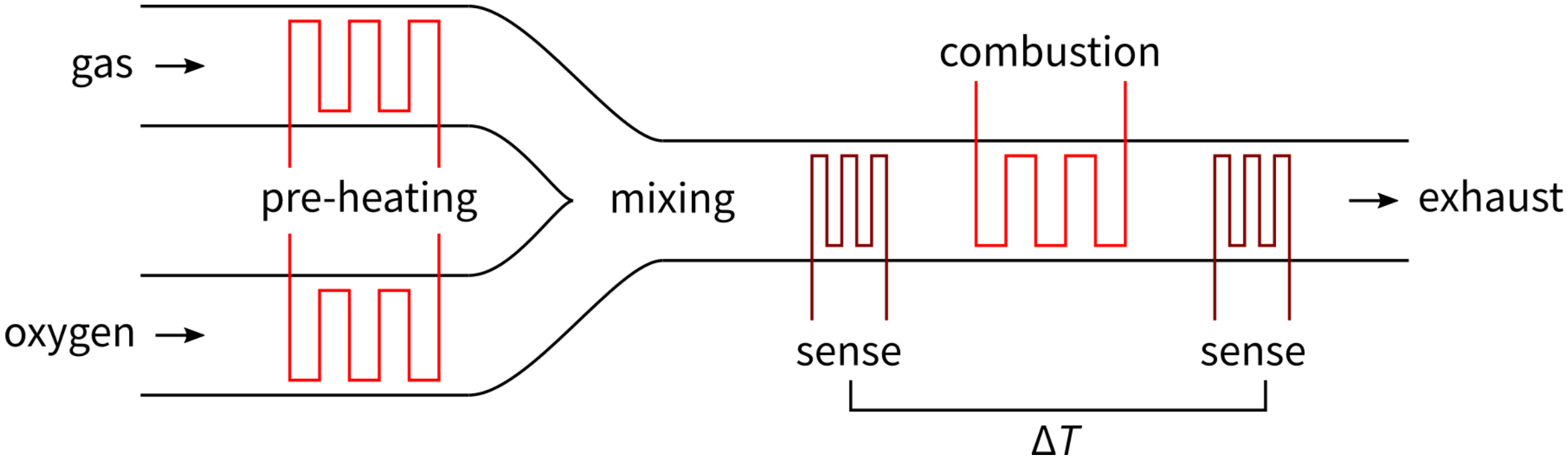
Gas energy sensor

1



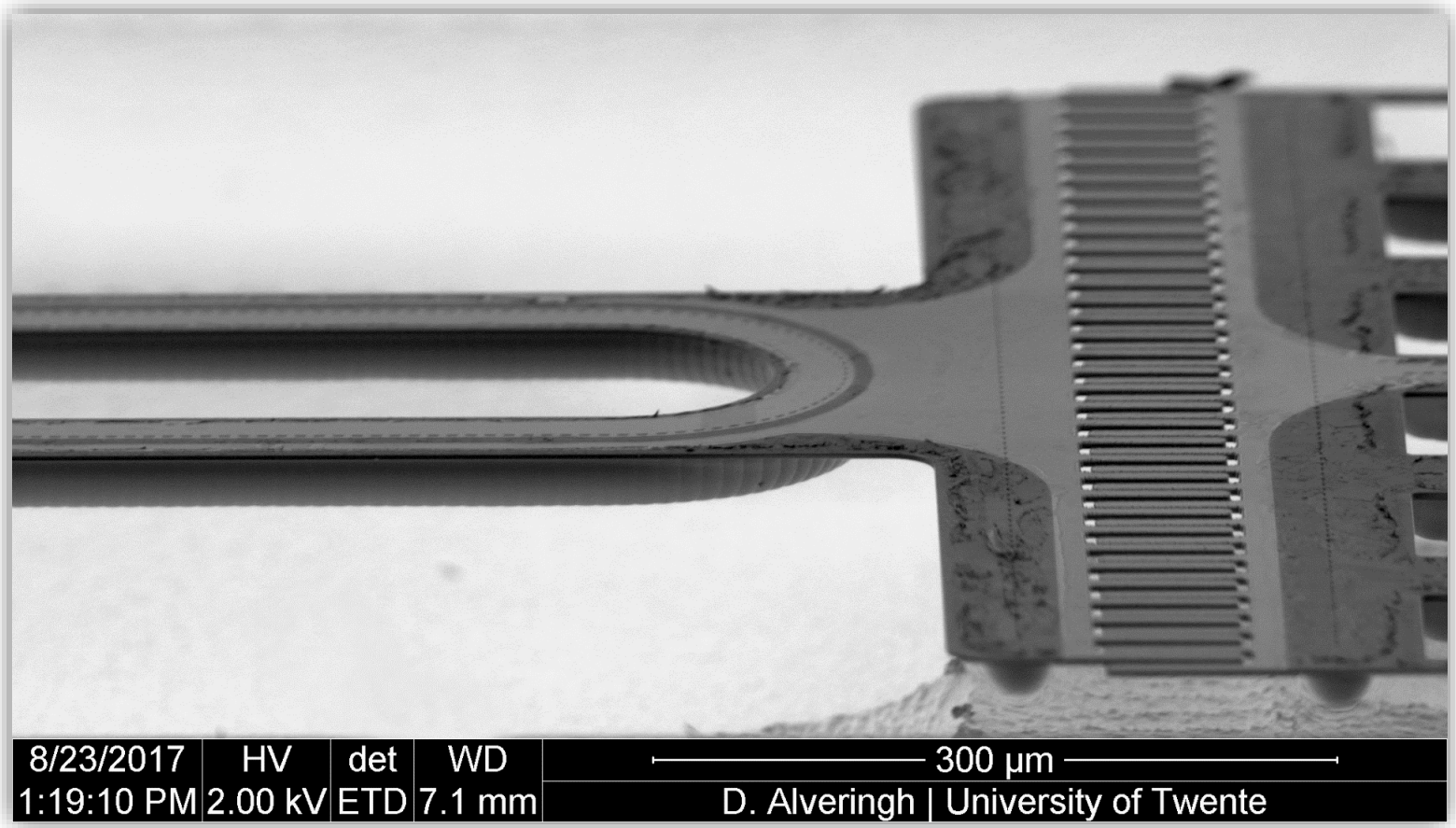
7/14/2015	HV	det	WD	3 mm
2:11:46 PM	5.00 kV	ETD	30.8 mm	D. Alveringh | University of Twente

Gas energy sensor



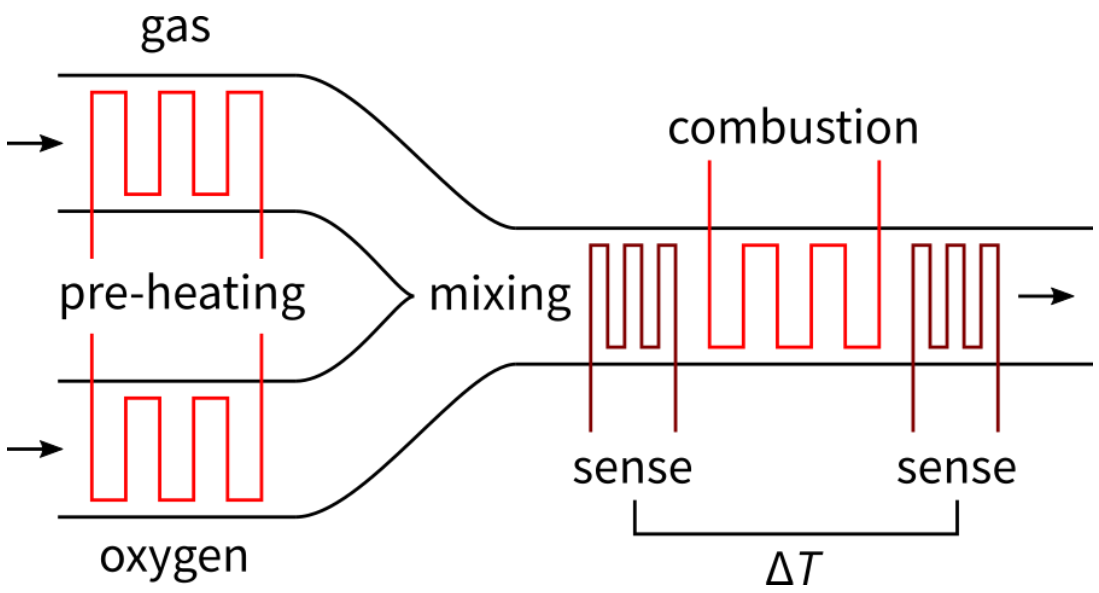
📖 E. Mekenkamp, *Microburner for Wobbe Index measurements*. MSc thesis, 2015.

Fabrication



silicon silicon oxide silicon nitride gold

Gas energy sensor



Actuation: Joule-heating to 600 °C.	–
Stimulus: gas flows of flammable gases.	–––––
Readout: resistive.	++
Testability	**––––**

📖 E. Mekenkamp, *Microburner for Wobbe Index measurements*. MSc thesis, 2015.

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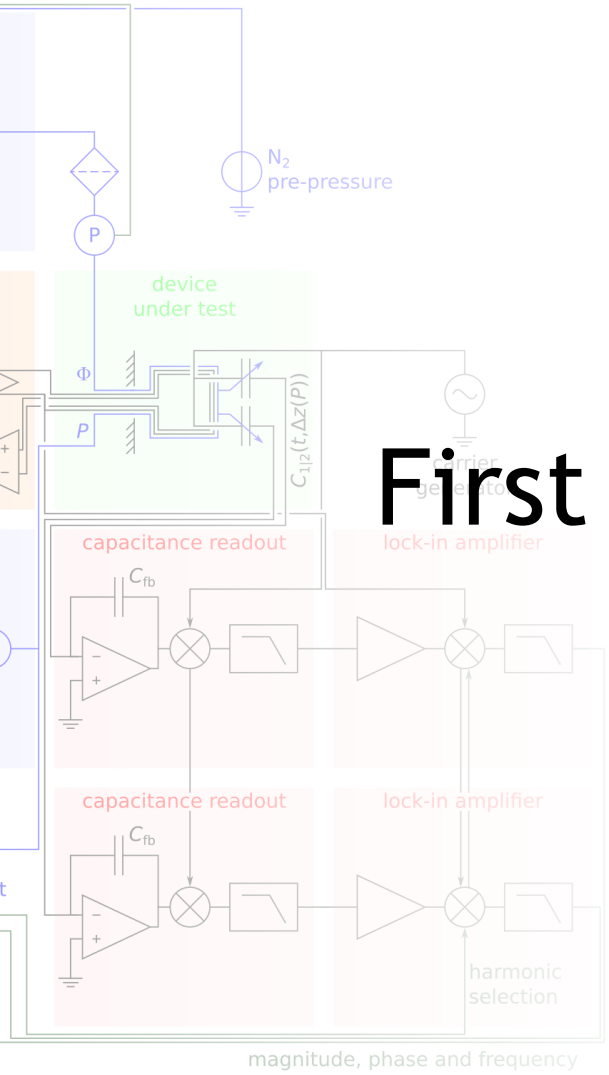
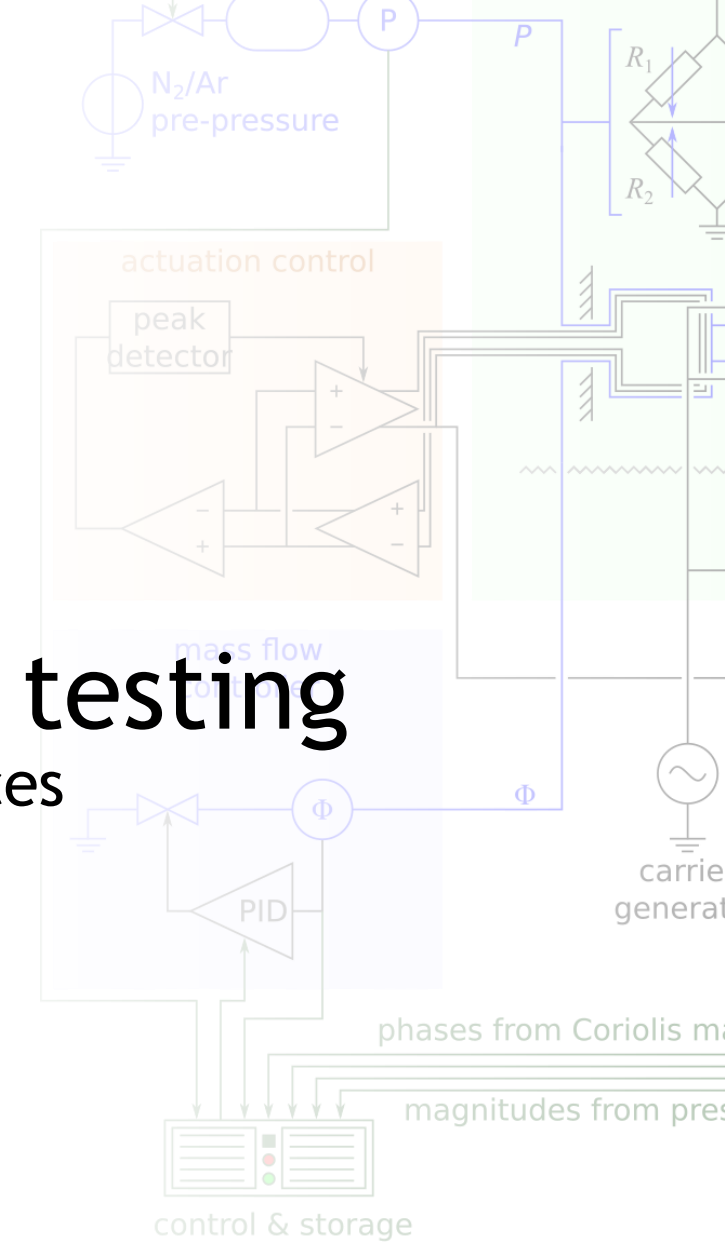


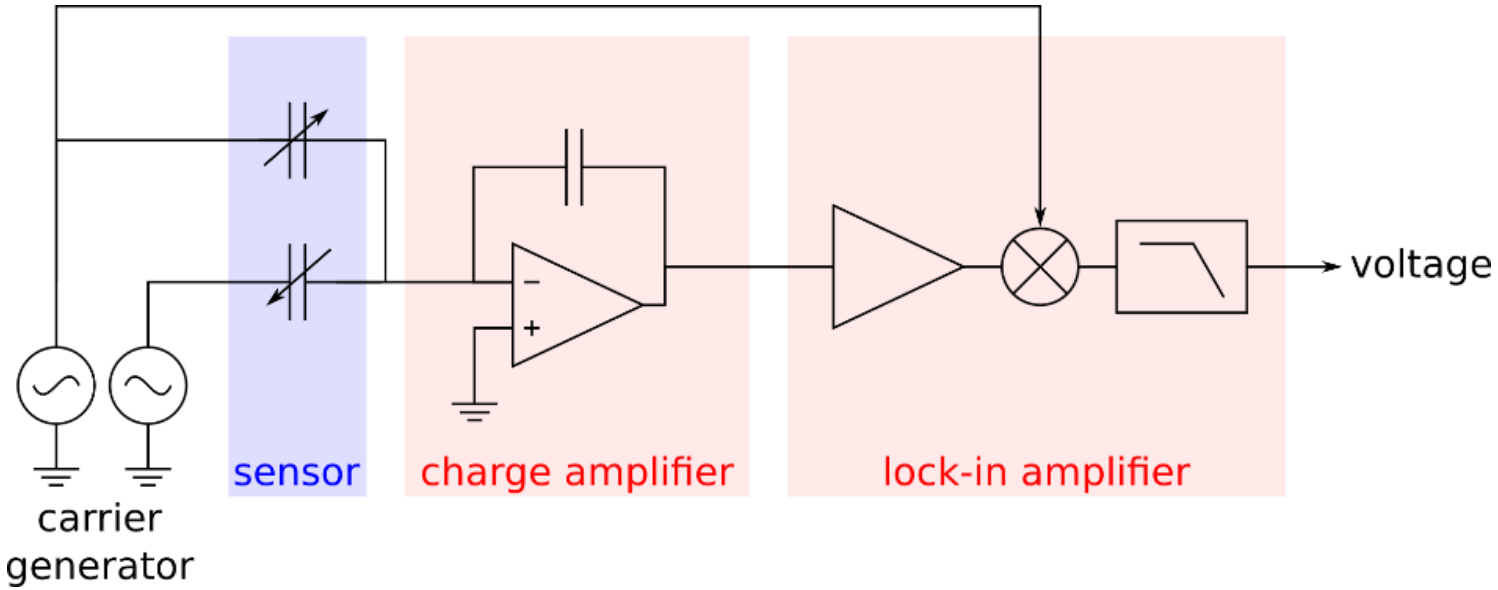
First steps in large scale MEMS testing

what we learned from exotic MEMS devices



Capacitive readout electronics

The needed instrument for many MEMS devices

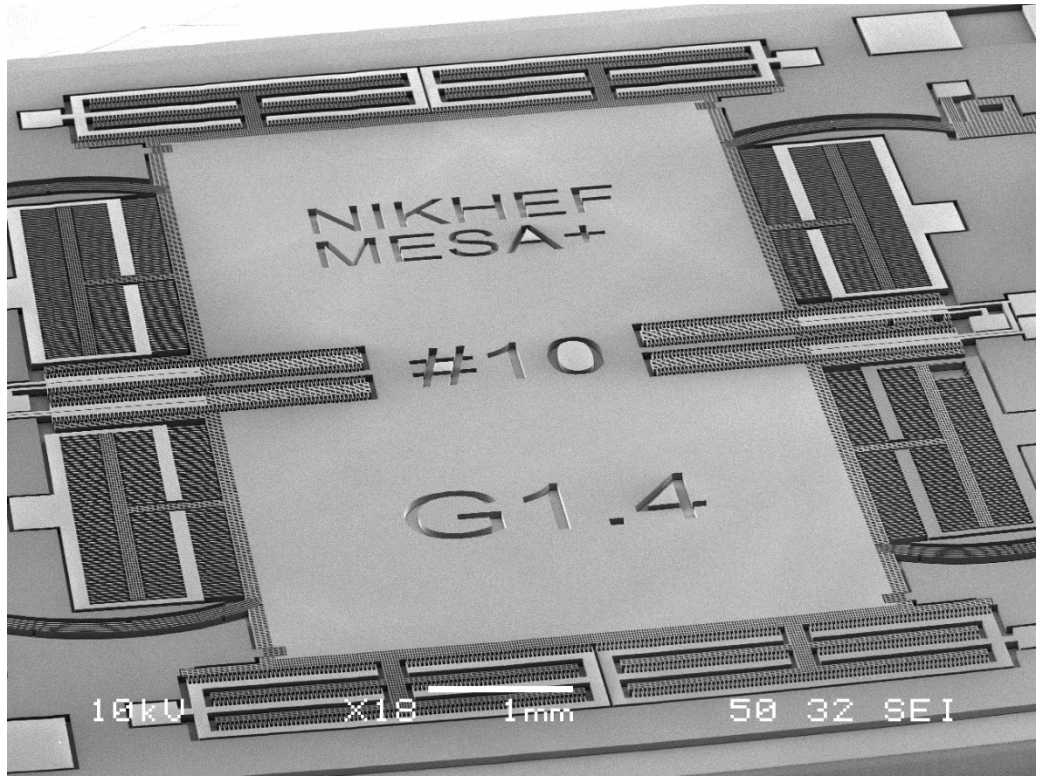


- Towards aF-resolution.
- First stage needs to be close to the DUT.
- Shielding against crosstalk.

📖 D. Alveringh, *Integrated throughflow mechanical microfluidic sensors,* PhD dissertation, 2018.

Electrical stimulation

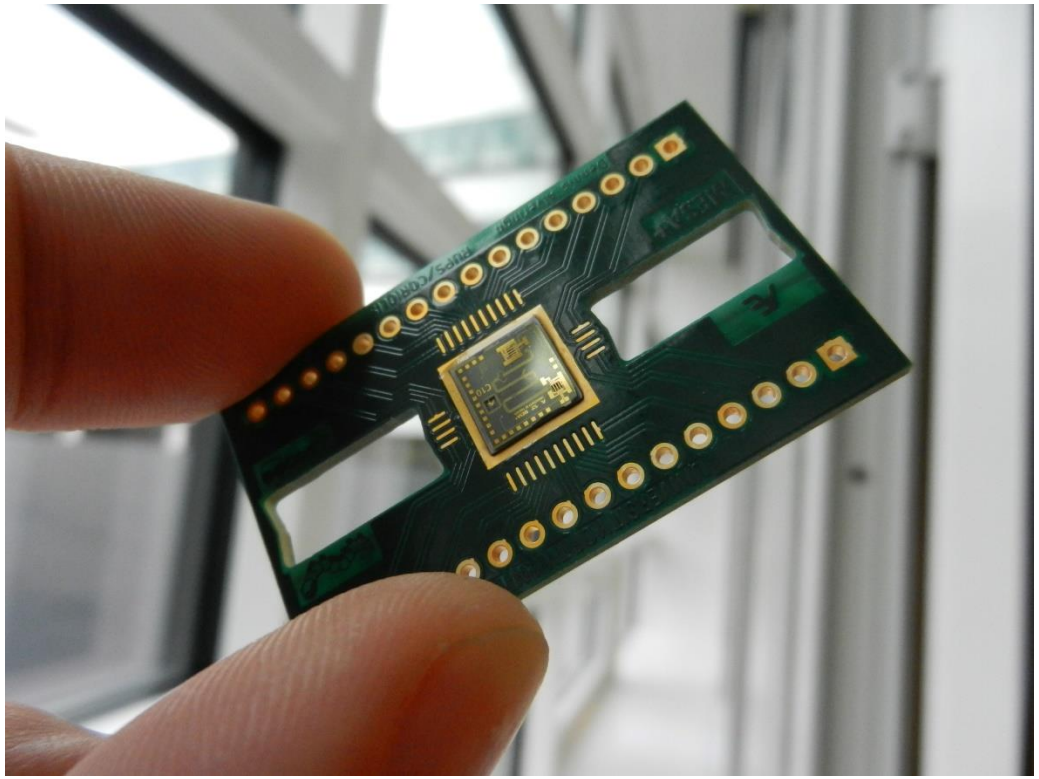
Built-in self-test (BIST) for MEMS devices



- Electrostatically pull the proof mass.
- Measure the capacitance of the readout structures.
- Check the results with an electromechanical model.

Interfacing of microfluidic sensors

Don’t underestimate the future of microfluidics

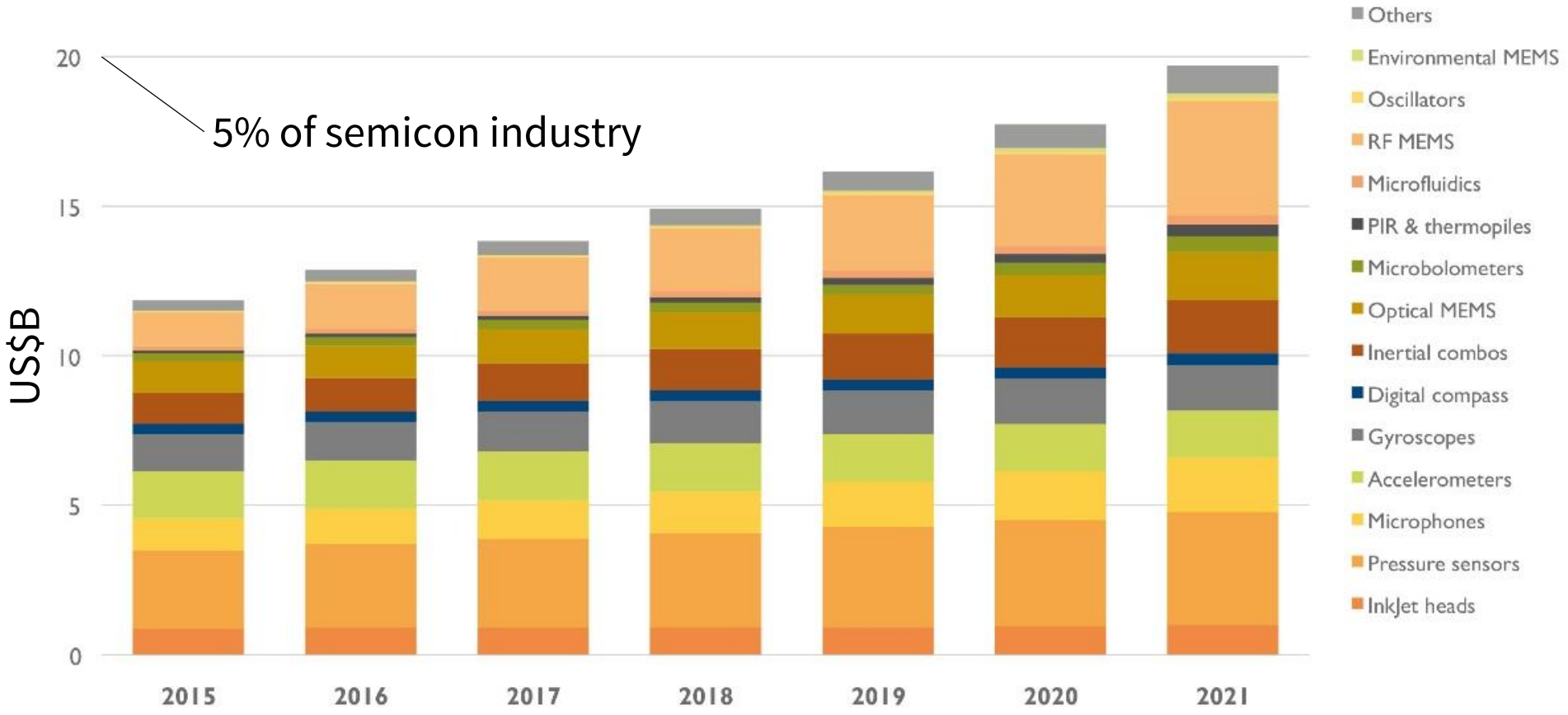


- Lab-on-a-chip devices.
- Many medical applications.
- Large scale production.

- Straight-forward electrical test.
- But fluidic interfacing is challenging.

Is it worth the struggle?

MEMS development in US$B



📖 Yole Développement, *Status of the MEMS Industry report*, 2016.

Conclusions

- The diversity in MEMS devices is significant, especially concerning stimulus and readout.
- The need for accurate capacitance measurement instrument is the common denominator among MEMS devices.
- The first steps in large scale MEMS testing involve electrical instead of physical stimulation.

Acknowledgements

- Salland Engineering.
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  I.e. Olti Pjetri, Boris Boom, Remco Wiegerink, Joost Lötters, Egbert Mekenkamp, Pieter Kamp, Remco Sanders, and Robert Brookhuis.

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