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Ultra low power electro-mechanical pull-in trigger for environmental acoustic emission monitoring

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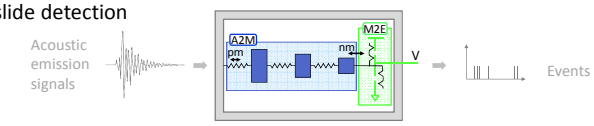
Motivation

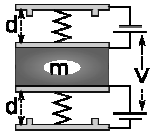
Objective: MEMS ultra-low power acoustic emission trigger for rock slide detection



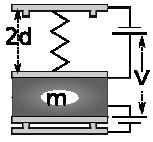
A coupled mass-spring system (A2M) enables
- Purely mechanical **amplification** of incoming vibrations
- **Frequency selectivity**
- at **zero power** expense

Threshold-detection by an electro-mechanical trigger (M2E) features
- **Static threshold control**, no power intensive sampling
- High on-off ratios
- Reduced computational load

Concept

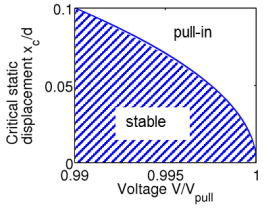


Pull-in



Coulomb forces cause pull-in upon threshold crossing in displacement and velocity

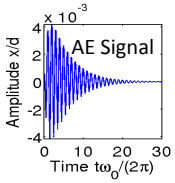
Threshold depends on V/V_{pull} and airgap d

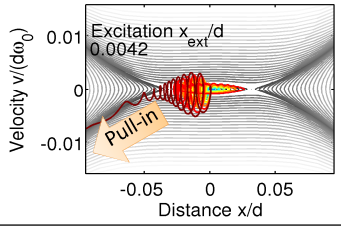


$$\frac{x_c}{d} = \sqrt{1 - \frac{V}{V_{pull}}}$$

$$V_{pull} = \sqrt{\left(\frac{kd^3}{2\varepsilon A}\right)}$$

V=0.999 V_{pull}

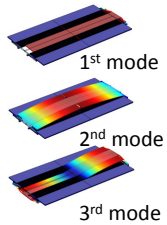




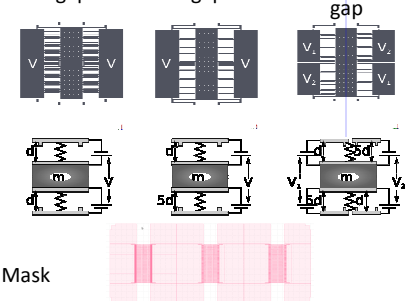
At 240 nm gap: Pull-in when exposed to AE signal with >1 nm peak amplitude

Design

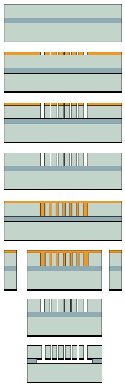
Comsol simulation of 3-D Eigenmodes



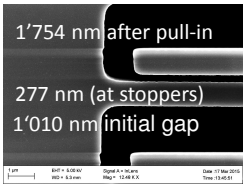
3 different actuation schemes:

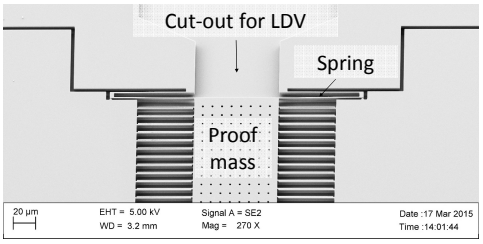


Fabrication



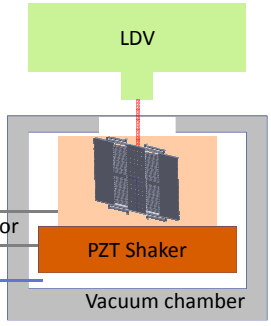
1. SOI wafer 5 μm device layer 2 μm BOX
2. Photolithography
3. ICP dry etch
4. resist strip
5. Protective photoresist
6. Dicing
7. Resist strip
8. Vapor HF Release

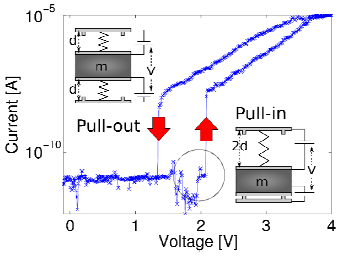




Experimental

Measurement set-up allows simultaneous optical and electrical characterization in controlled pressure environment





- < 3V pull-in voltage for battery operation
- Natural frequency 15kHz
- On-off ratio $\mathcal{O}(10\text{^}3)$

Conclusion

- Simulations show potential of pull-in mechanism for low power detection of Acoustic Emission signals
- A set-up for simultaneous optical and electrical characterization of pull-in devices under controlled pressure has been developed
- Initial measurements show low pull-in voltages <3 V for battery operation and on-off ratios $\mathcal{O}(10\text{^}3)$

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