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EE C245 - ME C218 Introduction to MEMS Design Fall 2010

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Lecture Module 2: Benefits of Scaling

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Lecture Outline

- Reading: Senturia, Chapter 1
- Lecture Topics:
 - ↳ Benefits of Miniaturization
 - ↳ Examples
 - ↳ GHz micromechanical resonators
 - ↳ Chip-scale atomic clock
 - ↳ Micro gas chromatograph

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Benefits of Size Reduction: MEMS

- Benefits of size reduction clear for IC's in elect. domain
 - ↳ size reduction \Rightarrow speed, low power, complexity, economy
- MEMS: enables a similar concept, but ...
 - MEMS extends the benefits of size reduction beyond the electrical domain**

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Performance enhancements for application domains beyond those satisfied by electronics in the same general categories

- Speed \Rightarrow Frequency \uparrow , Thermal Time Const. \downarrow
- Power Consumption \Rightarrow Actuation Energy \downarrow , Heating Power \downarrow
- Complexity \Rightarrow Integration Density \uparrow , Functionality \uparrow
- Economy \Rightarrow Batch Fab. Pot. \uparrow (esp. for packaging)
- Robustness \Rightarrow g-Force Resilience \uparrow

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Vibrating RF MEMS

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Basic Concept: Scaling Guitar Strings

Guitar String

Vib. Amplitude

Low Q

High Q

110 Hz Freq.

Vibrating "A" String (110 Hz)

Stiffness

Freq. Equation:

$$f_o = \frac{1}{2\pi} \sqrt{\frac{k_r}{m_r}}$$

Freq. Mass

μMechanical Resonator

Metallized Electrode

Anchor

Polysilicon Clamped-Clamped Beam

h_r

[Bannon 1996]

Performance:

- $L_r = 40.8 \mu\text{m}$
- $m_r \sim 10^{-13} \text{ kg}$
- $W_r = 8 \mu\text{m}, h = 2 \mu\text{m}$
- $d = 1000 \text{ \AA}, V_p = 5 \text{ V}$
- Press. = 70 mTorr

$f_o = 8.5 \text{ MHz}$

$Q_{vac} = 8,000$

$Q_{air} \sim 50$

Transmission [dB]

Frequency [MHz]

3CC 3λ/4 Bridged μMechanical Filter

Performance:

- $f_o = 9 \text{ MHz}, BW = 20 \text{ kHz}, PBW = 0.2\%$
- I.L. = 2.79 dB, Stop. Rej. = 51 dB
- 20 dB S.F. = 1.95, 40 dB S.F. = 6.45

$P_{in} = -20 \text{ dBm}$

Transmission [dB]

Frequency [MHz]

Sharper roll-off

Loss Pole

[S.-S. Li, Nguyen, FCS'05]

[Li, et al., UFFCS'04]

In

Out

Design:

- $L_r = 40 \mu\text{m}$
- $W_r = 6.5 \mu\text{m}$
- $h_r = 2 \mu\text{m}$
- $L_c = 3.5 \mu\text{m}$
- $L_b = 1.6 \mu\text{m}$
- $V_p = 10.47 \text{ V}$
- $P = -5 \text{ dBm}$
- $R_{Qr} = R_{Qo} = 12 \text{ k}\Omega$

[S.-S. Li, Nguyen, FCS'05]

[Li, et al., UFFCS'04]