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## EE C245 - ME C218 Introduction to MEMS Design Fall 2011

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Lecture Module 2: Benefits of Scaling

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### Micro-Scale Oven-Control Advantages

**Macro-Scale**

Atomic Cell @ 80°C  
 Macro-Oven (containing heater and T sensor)  
 Insulation  
 Laser  
 Thermally Isolating Feet

$R_{th} = 56 \text{ K/W}$   
 $C_{th} = 26 \text{ J/K}$

$P(@ 80^\circ\text{C}) = 1 \text{ W}$   
 Warm Up,  $\tau = 24 \text{ min.}$

**Micro-Scale**

300x300x300  $\mu\text{m}^3$  Atomic Cell @ 80°C  
 Heater  
 Laser  
 T Sensor (underneath)  
 Long, Thin Polysilicon Tethers

$R_{th} = 83,000 \text{ K/W}$   
 $C_{th} = 6.3 \times 10^{-6} \text{ J/K}$

$P(@ 80^\circ\text{C}) = 2.6 \text{ mW}$   
 Warm Up,  $\tau = 0.1 \text{ s}$

$T = P \times R_{th}$

$R_{th} \sim \frac{\text{support length}}{\text{X-section area}}$

$C_{th} \sim \text{volume}$

**308x lower power**    **18,000x faster warm up**

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### Physics Package Power Diss. < 10 mW

- Achieved via MEMS-based thermal isolation

Cesium cell  
 VCSEL / Photodiode  
 Heater/Sensor Suspension  
 Frame Spacer  
 VCSEL Suspension  
 Symmetricom / Draper Physics Package Assembly

Only ~5 mW heating power needed to achieve 80°C cell temperature

Power [mW]

Temperature [°C]

◆ Measured  
 — Model

7 mm  
 20 pin LCC

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## Micro Gas Analyzers (MGA)

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### Micro Gas Analyzers

**Objective:** enable remote detection of chemical agents via tiny, ultra-low power, fast, chip-scale gas analyzers that greatly reduce the incidence of false positives

**Approach:** use micromachining technologies to implement separation-based analyzers (e.g., gas chromatographs, mass spectrometers) at the micro-scale to enhance gas selectivity

**Conventional Sensor**

Capacitor Plates, Gas Sensitive Polymer, Species A, Species B,  $\Delta C \sim \text{gas conc.}$

**Problem:** polymer has finite sensitivity to both A & B

**Separation Analyzer**

Species A, Species B

**Result:** species A & B now separated  $\Rightarrow$  can identify and analyze individually

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### Advantages of Miniaturization

**Portable Gas Chromatograph**

19", Depth = 10", 13"

**Chip-Scale Gas Chromatograph**

Preconcentrator, Detector Array, 5 mm, 1-2 cm, Separation Column, Micropump

Reduction Factors

Size	40,500 cm <sup>3</sup>	20,000X	Size	2 cm <sup>3</sup>
Sensitivity	1 ppb	1,000X	Sensitivity	1 ppt
Analysis Time	15 min.	225X	Analysis Time	4 sec
Energy Per Analysis	10,000 J	10,000X	Energy Per Analysis	1 J