Natural Gas Pipeline Sensors

PAC Technical Meeting

10/24/2014

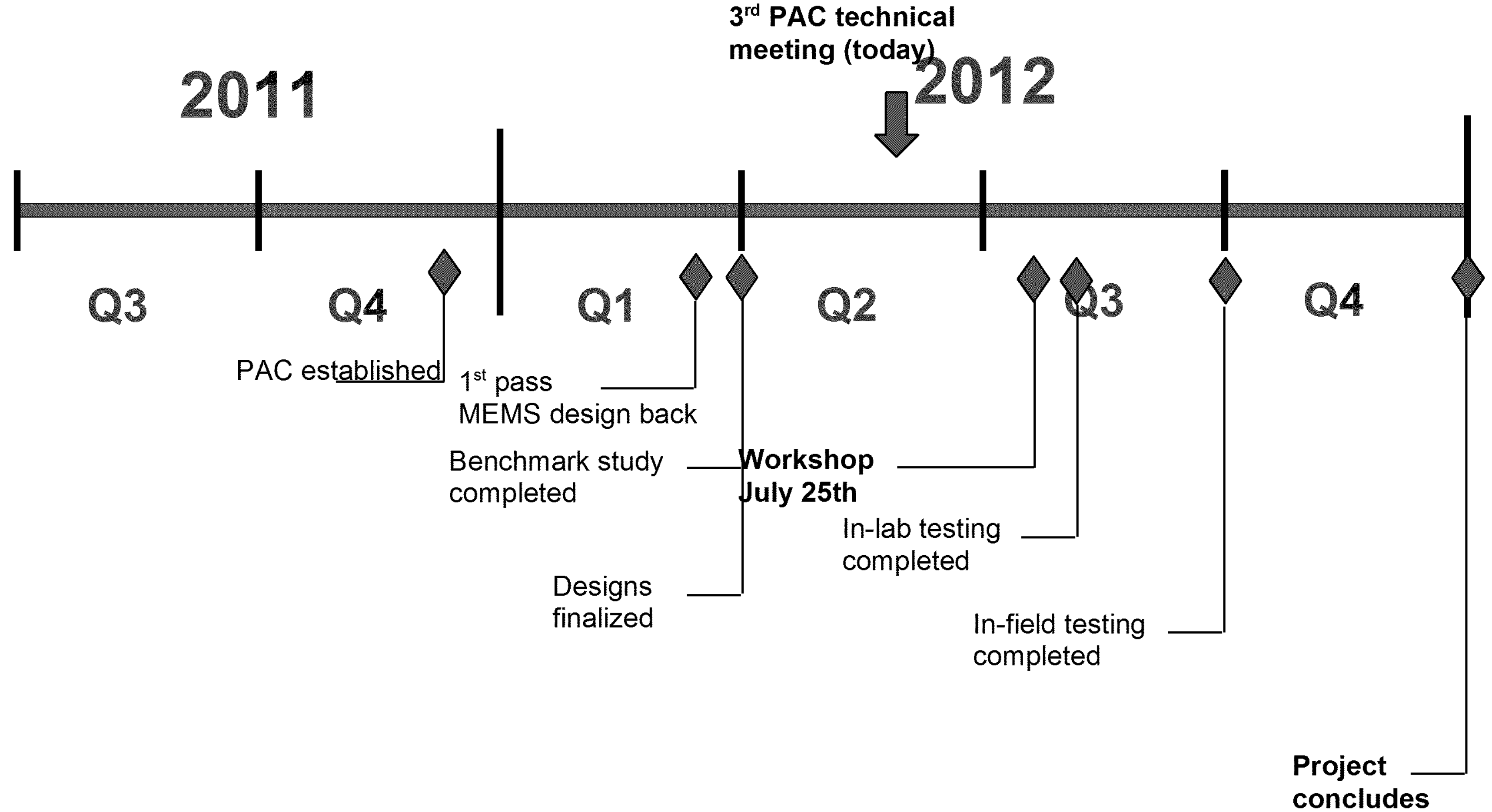
Prof. Paul Wright (ME/CITRIS)
Gaymond Yee (CIEE)
Fabien Chimrai (EECS/BSAC)
Prof. Dick White (EECS/BSAC)
Yiping Zhu (EECS/BSAC)
Prof. Kris Pister (EECS/BSAC)
Dr. Igor Paprotny (EECS/BSAC)
Adam Tornheim (MSME)

Agenda

- Timeline
- Progress/Status:
  - Wireless Sensor Modules
  - Laser Ultrasonic Testing (LUT)

Project Timeline

UC Berkeley - Natural Gas Sensors



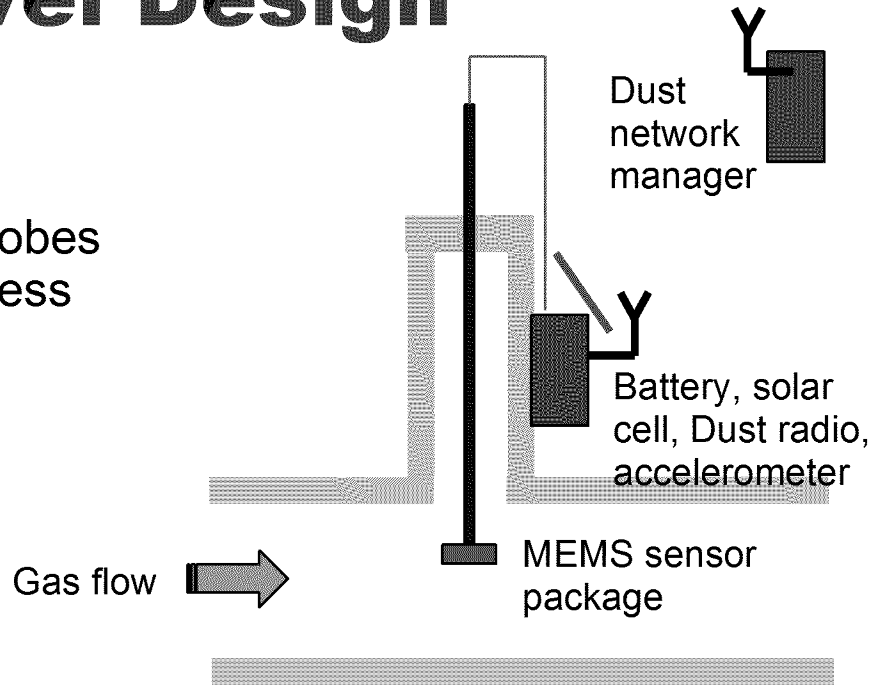
Sensing System Design

- Online sensors that would be useful
  - Pressure sensors (MEMS/low cost) ← Design 2nd
  - Flow sensors (MEMS/low cost) ← Design
  - Vibrations sensors (distributed/low cost) ← Off the shelf
  - Moisture sensors (MEMS/low cost) ← Pr. Designs
  - Odorant level sensors (low cost) ← Pr. Designs
  - Methane detector (low cost) ← Pr. Designs
  - Laser Ultrasonic's (Weld/Corrosion detection) ← Designs / Collaboration

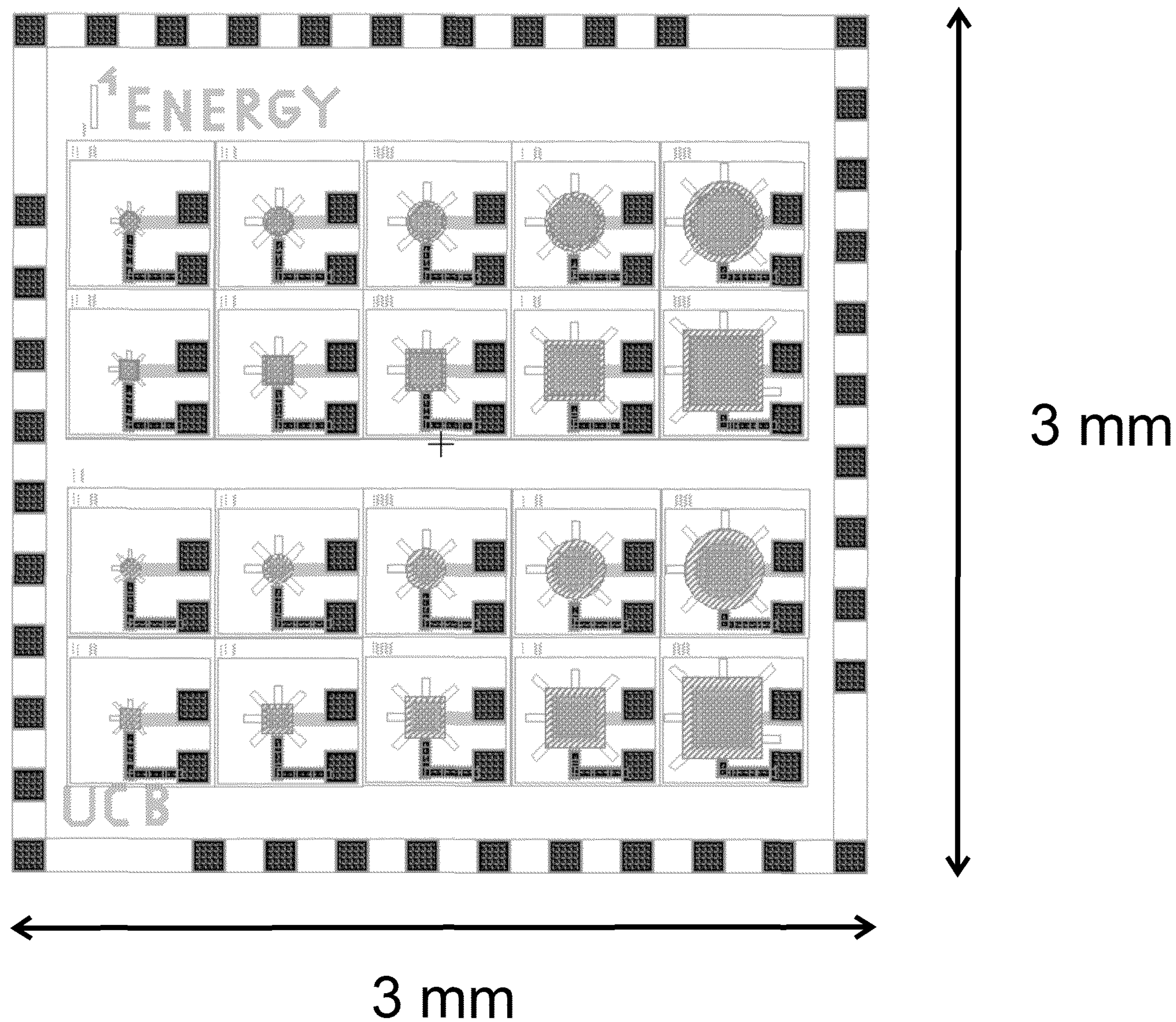
May fall back on off-the shelf sensors for initial pilot testing

System-Level Design

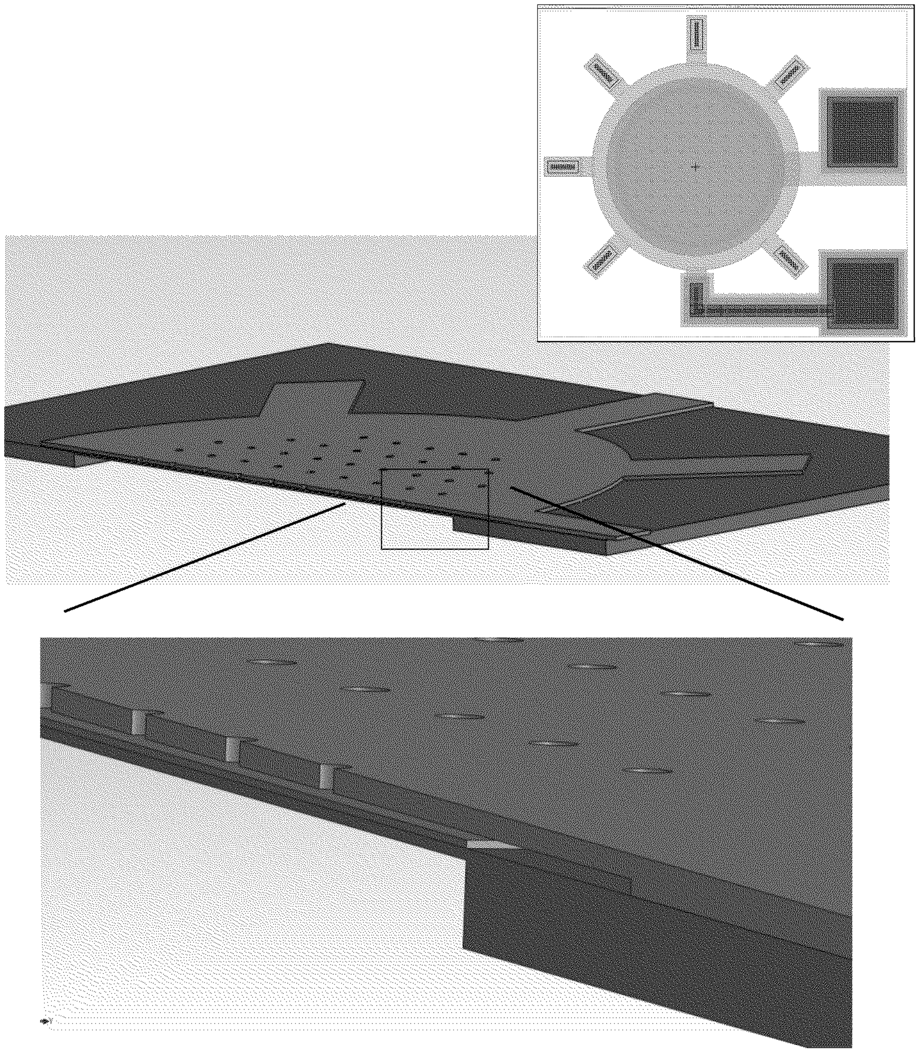
- Baseline design
  - Sensors deployed as retractable probes into the gas flow via the ¾ inch access port.
- Sensor suite
  - Pressure
  - Flow
  - Accelerometer (external)
- Radio
  - Dust Networks (~70 μW standby)
- Power
  - Battery/Solar (>10 year lifetime)

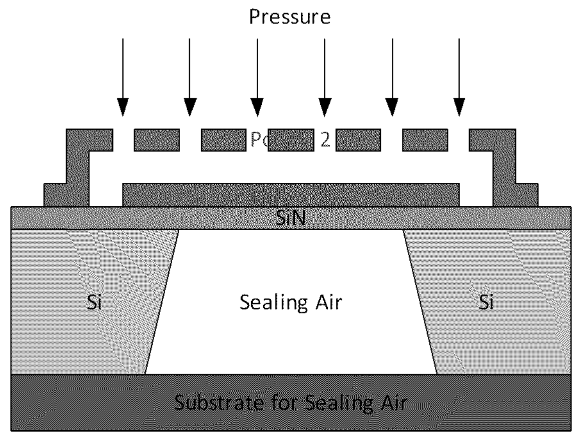


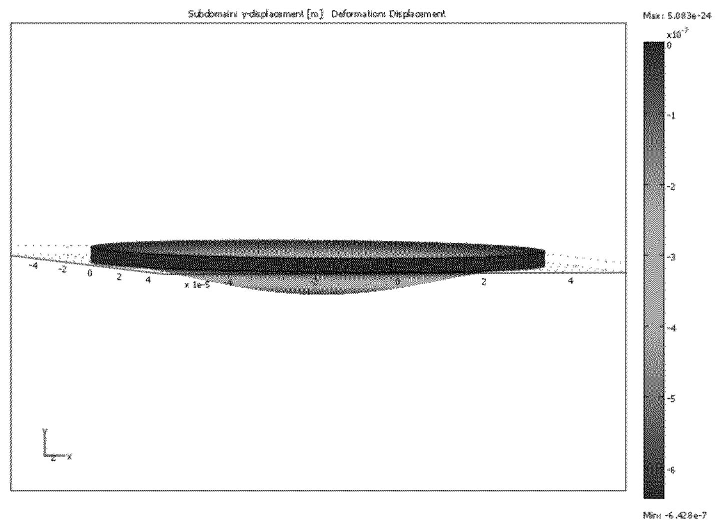
Diaphragm Based MEMS Sensors



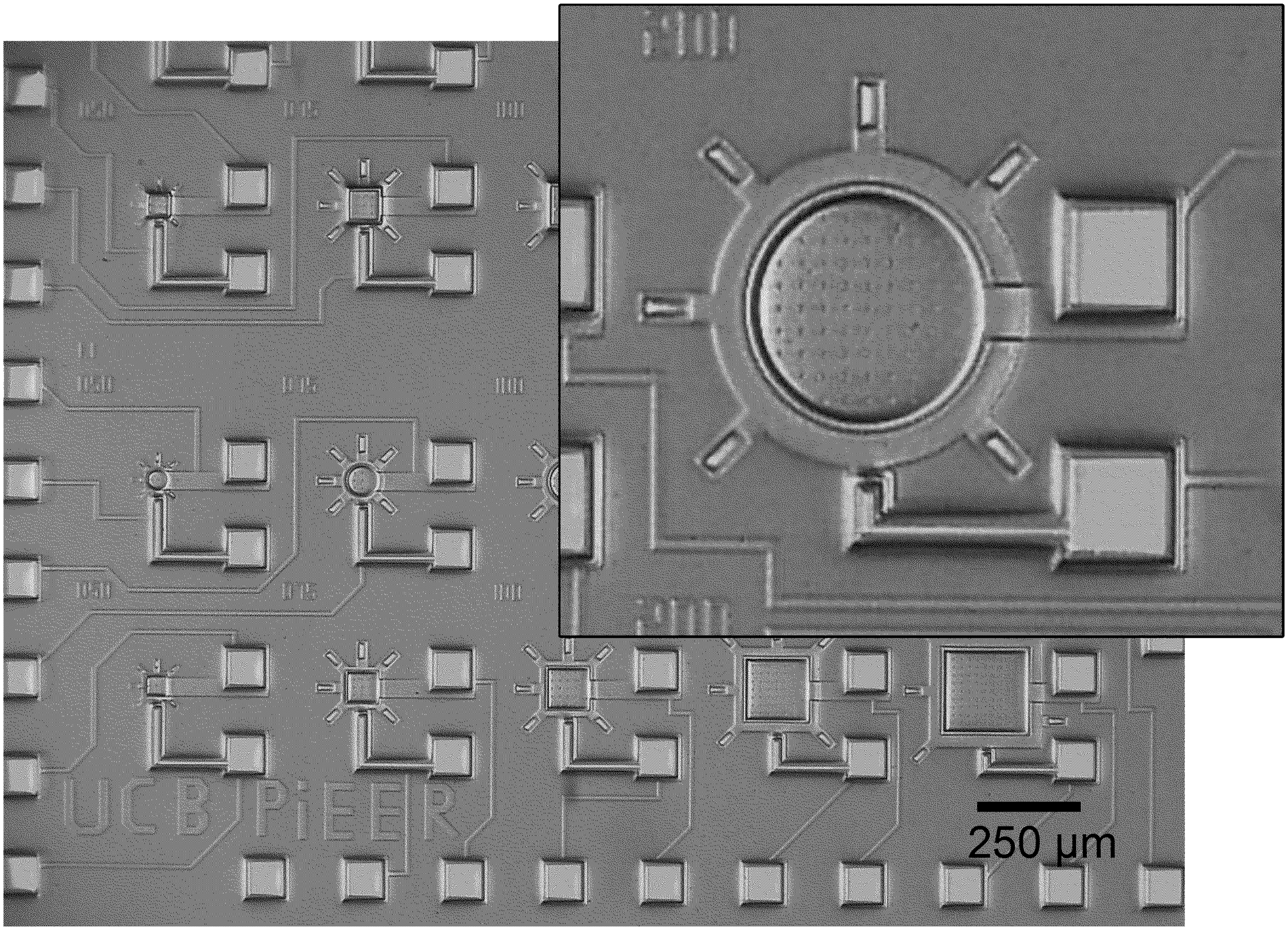
Diaphragm Based MEMS Sensors (2)





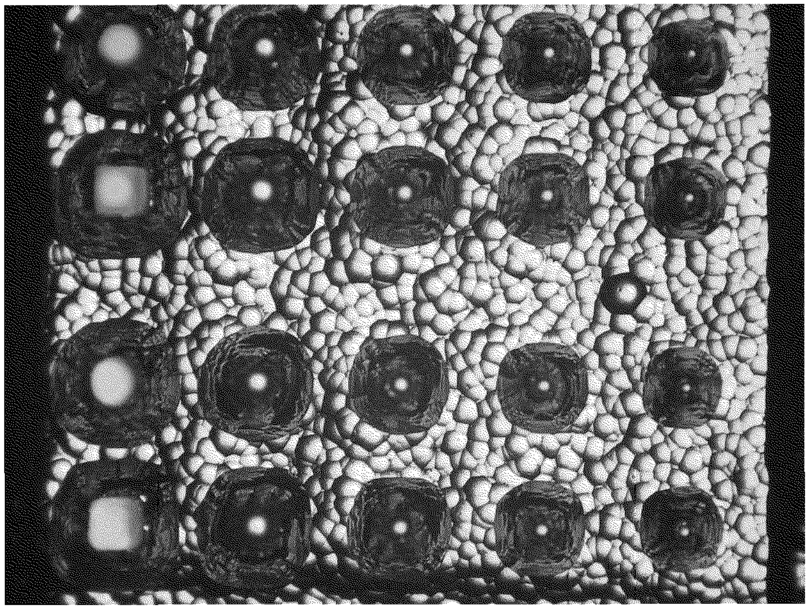


Diaphragm Based MEMS Sensors (3)

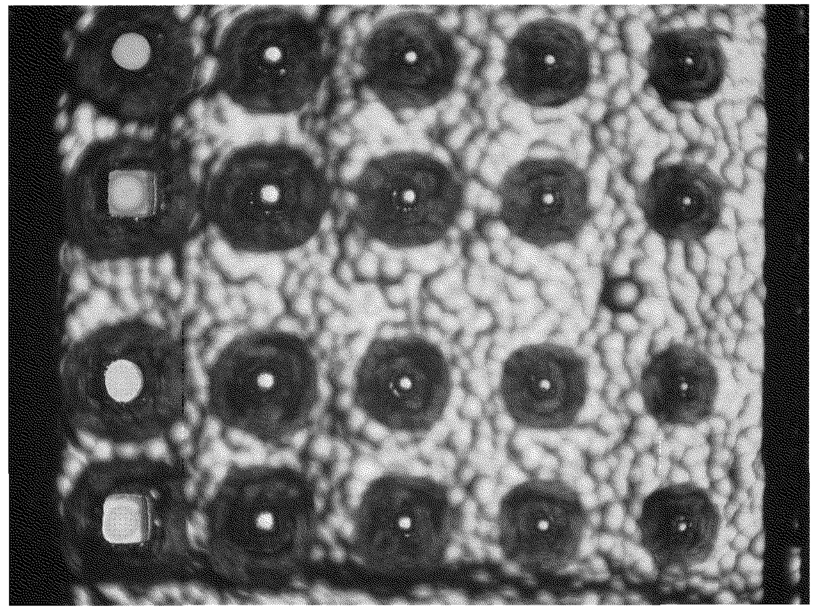


Diaphragm Based MEMS Sensors (4)

Backside 1



Backside 2

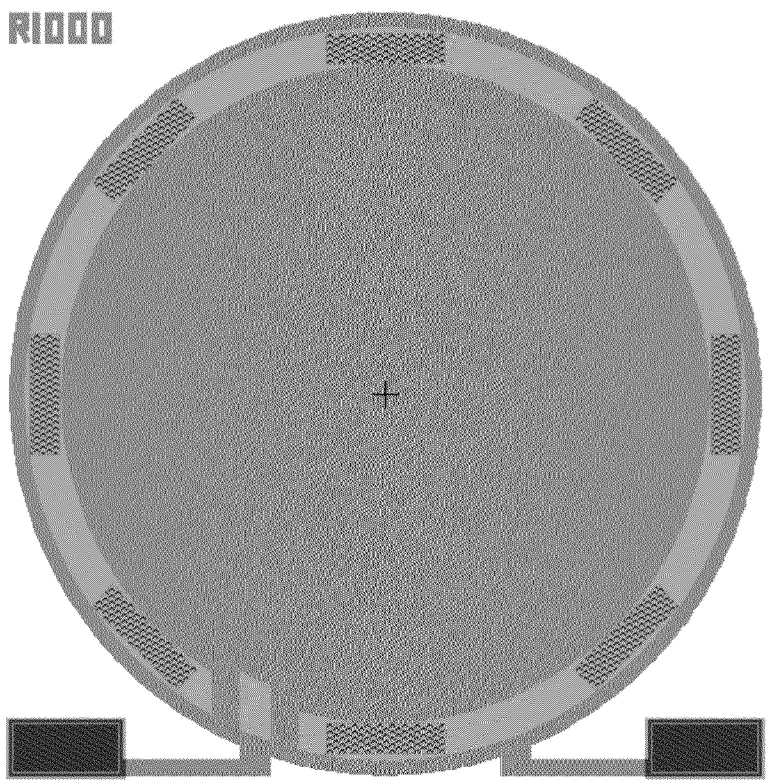


Etching problems

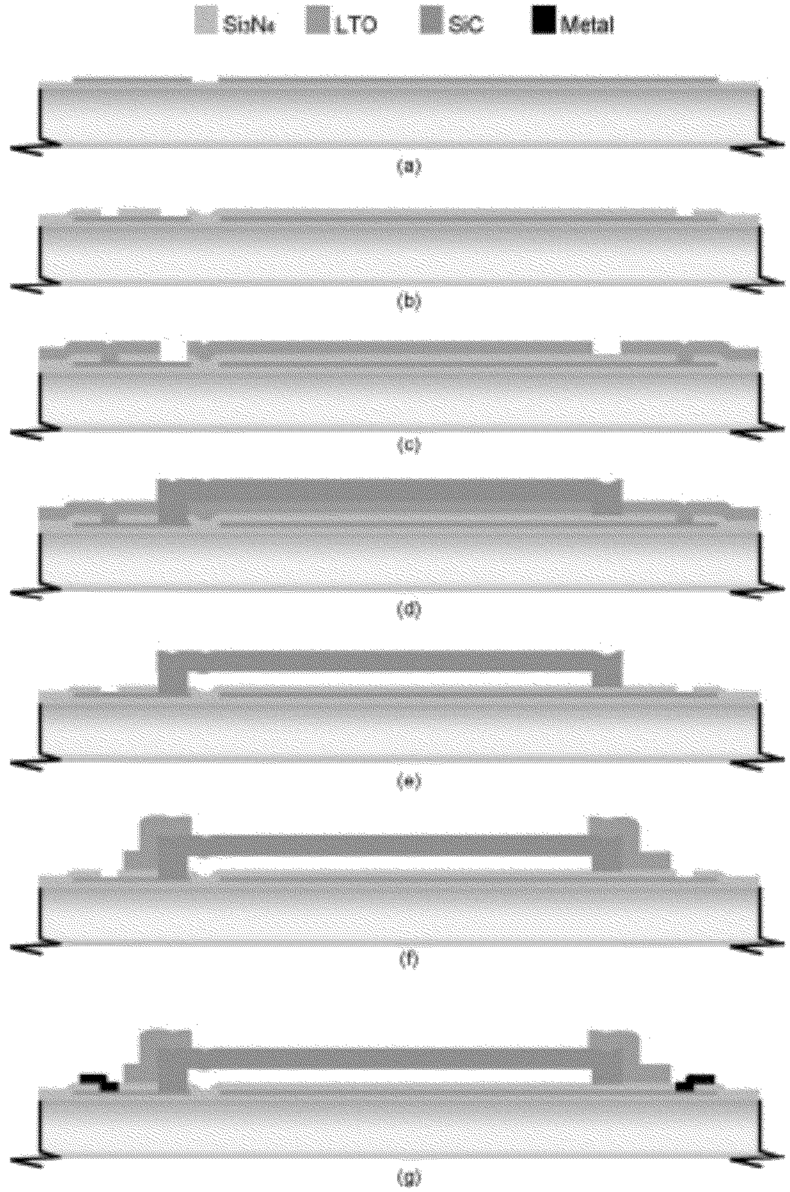
1. SiO2 and PR masks are not thick enough to prevent through Si wafer etching.
2. Backside silicon surface became rough and hard to be sealed.
3. SiN layer cannot self-stop the deep silicon etching.

SB_GT&S_0503213

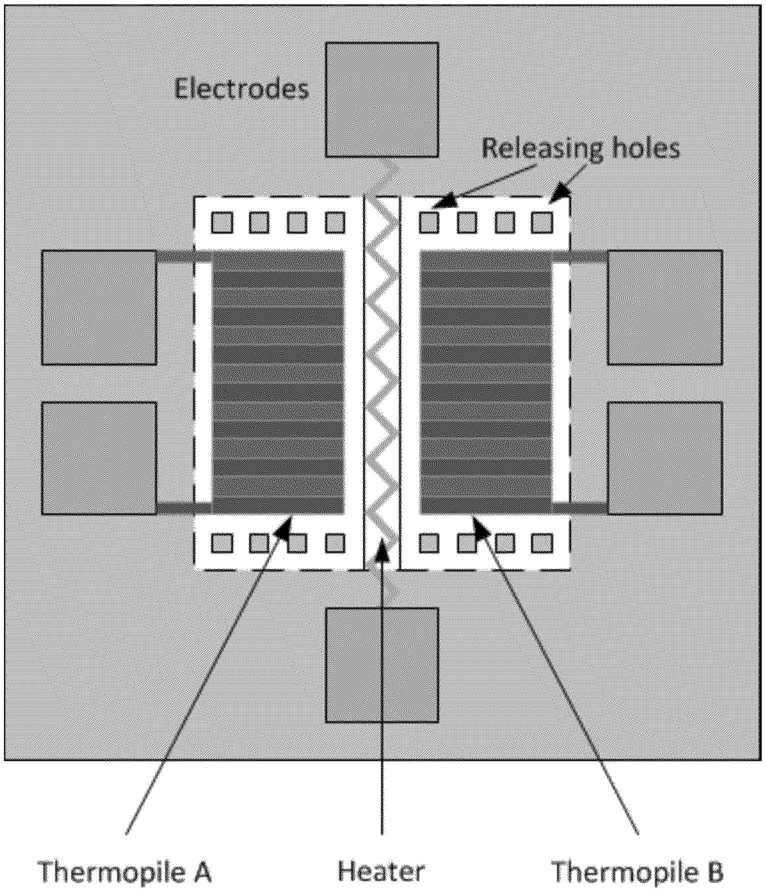
Diaphragm Based MEMS Sensors (5)

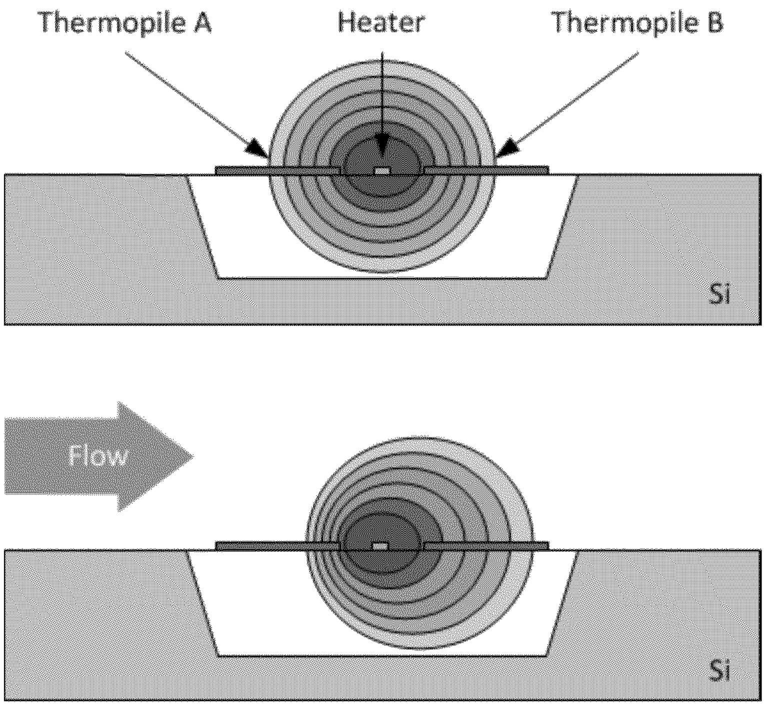


New pressure sensor design



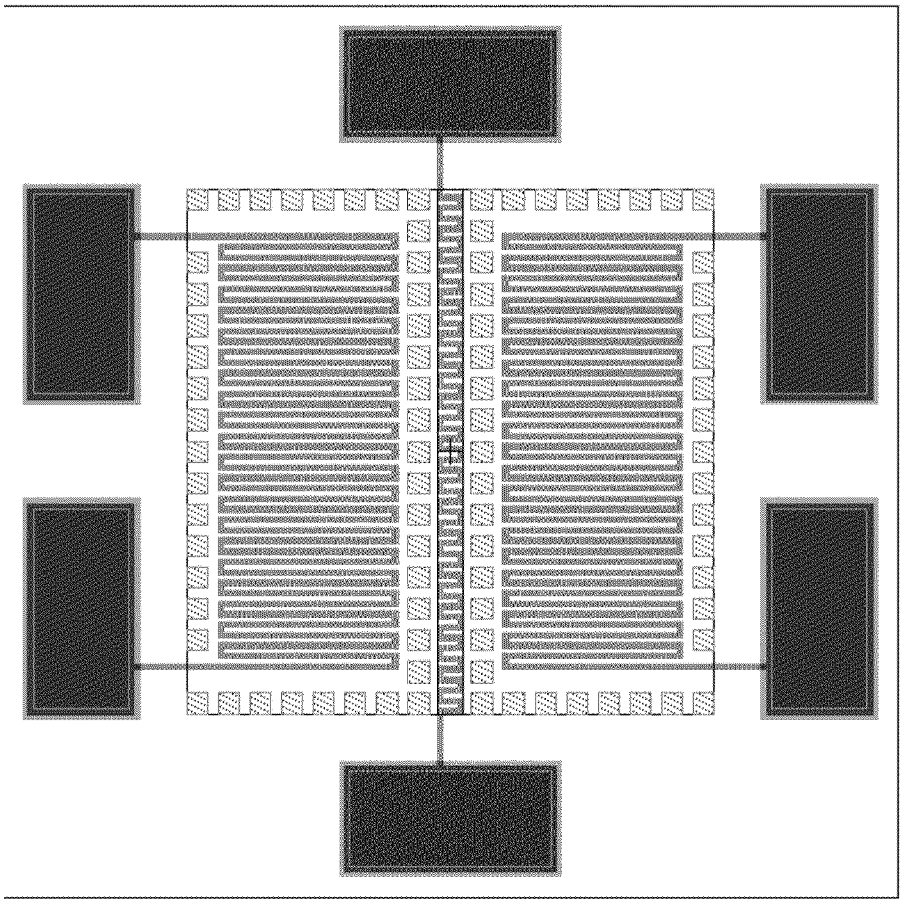
MEMS Flow Sensors

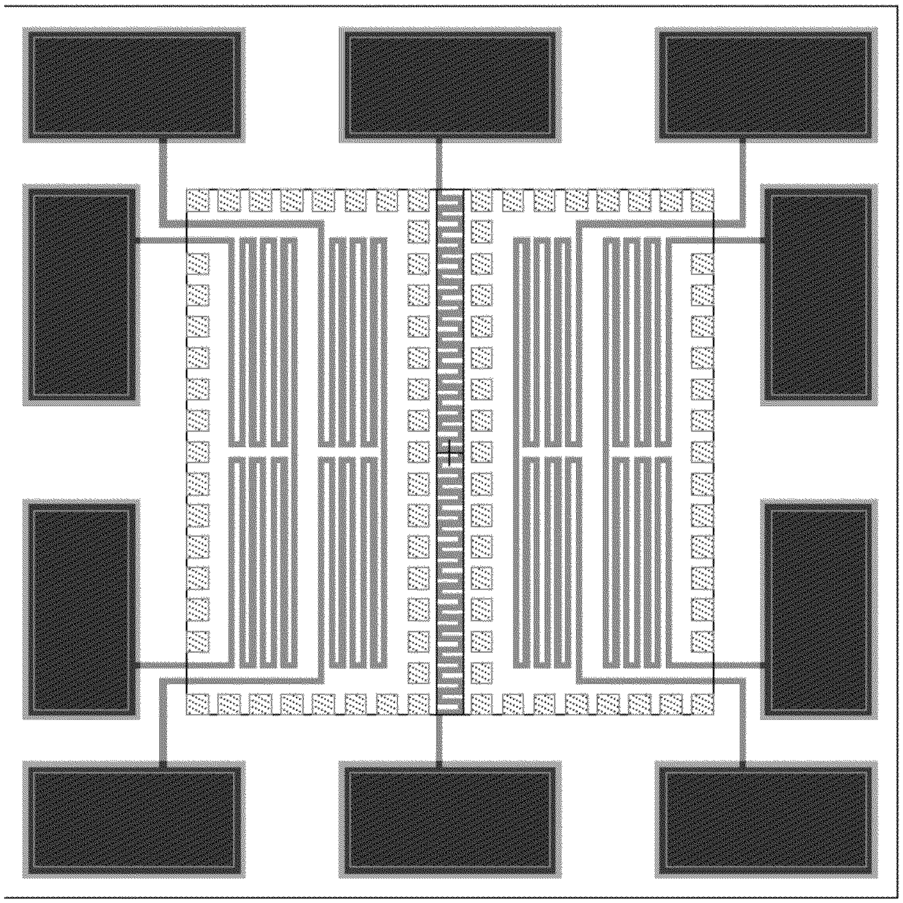




SB_GT&S_0503215

Heater MEMS Flow Sensors

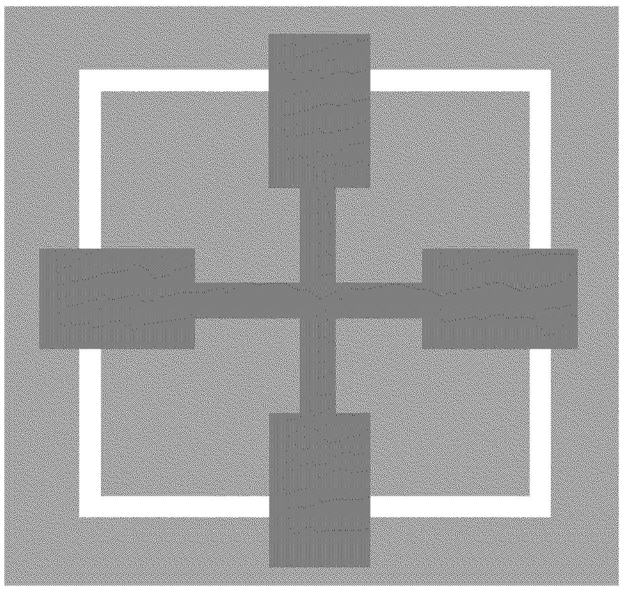


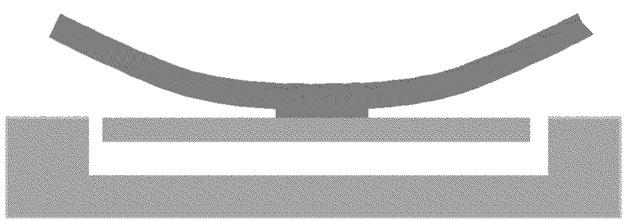


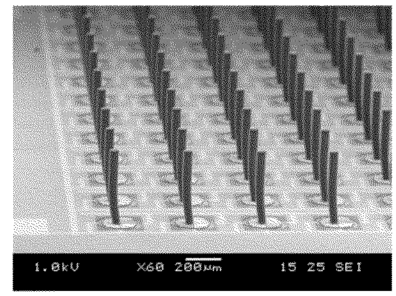
Masks Layout Design

Non-heated MEMS design

- Dynamic pressure sensing:
  - Paddle or whiskers







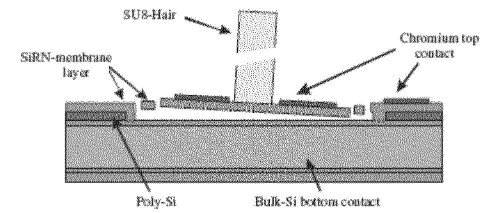
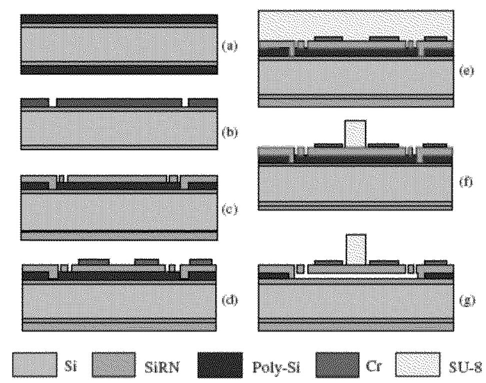


Figure 2. Sensor structure with SU-8 hair.

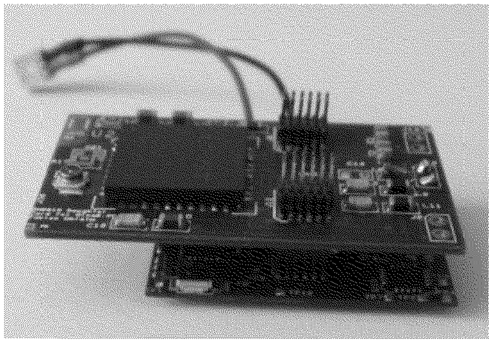


Krijnen et al, 2006

WirelessHART Interface Module (WHIM)

- Chevron-Richmond: 80% WirelessHART coverage on the refinery grounds => virtually any sensor can join and start reporting

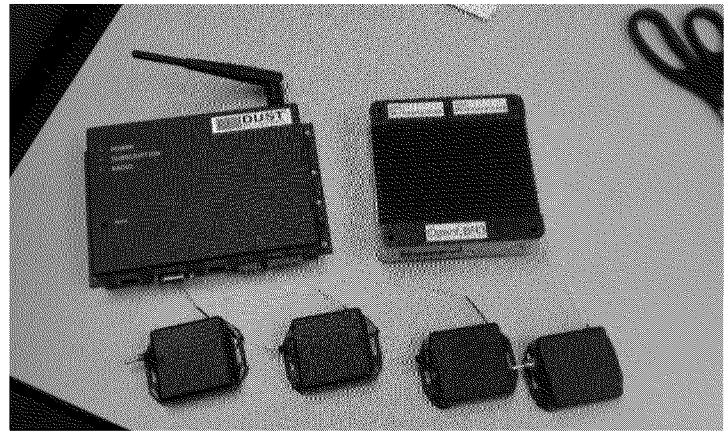
Component	Part Number	Specs
microcontroller	TI MSP430F2618	16-bit, 16MHz, 116kB flash, 8kB RAM
radio	DUST Networks DN2510	2.4GHz, WHART compliant
3-axis accelerometer (sensitive)	STMicroelectronics LIS344ALHTR	+/-2 Gs or +/-6 Gs, 1.8 kHz, 660 mV/G, 50 uG/rtHz
3-axis accelerometer (large range)	Kionix KXSD9-1026	+/-8 Gs, 2 kHz
3-axis gyroscope	Invensense ITG3200	2000 degs/s
3-axis magnetometer	Honeywell HMC5843	compass
temperature sensor	TI TMP20AIDRLT	+/-2.5 C, -55 C to 130 C



- Expandable
- In sleep mode ~70uA => extended battery life (years)
- Time Synchronized Channel Hopping network => efficient end-to-end communication with few retransmissions

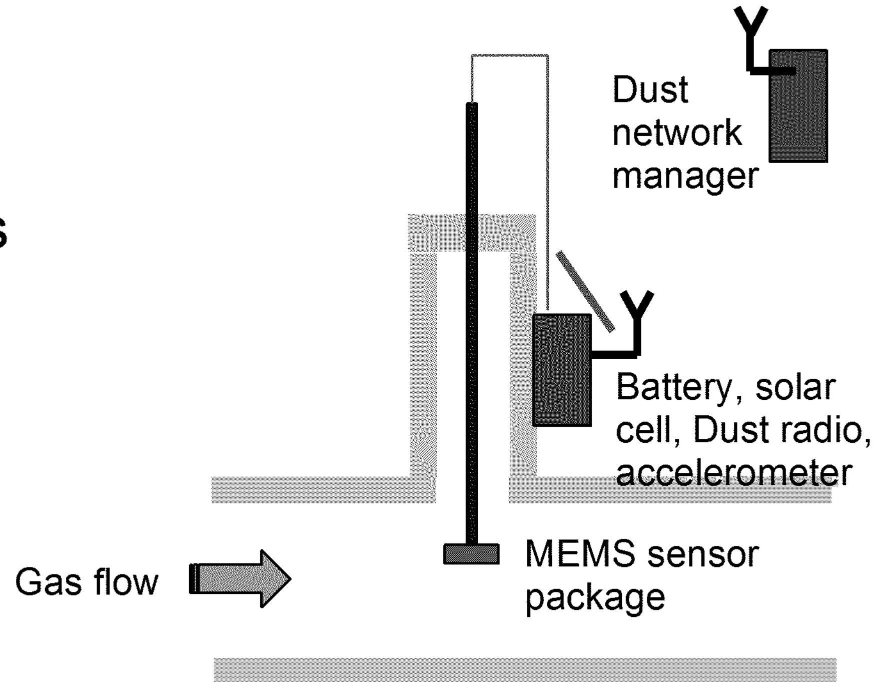
Pilot Deployment - Chevron

- 6 weeks long (November/December)
- No false positives
- 100% detection
- Box withstood rain, strong winds and sunlight exposure (IP65)



Questions/Concerns for the PAC Distributed Sensors

- Question about heated filament
- Insertion probe:
  - Manufacture/type
  - Feed-through
  - Installation, dimensions
- Testing locations



Center for Information Technology Research in the Interest of Society

BSAC

Laser Ultrasonic Testing