“MICROSENSOR DEVELOPMENT”

Joseph R. Stetter

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CPAC SUMMER INSTITUTUTE – 21-23 JULY 2009

“Safety, Security, Surveillance Sensors for the 21st Century”

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www.kwjengineering.com www.transducertech.com
KWJ ENGINEERING INCORPORATED

Advanced Products for Today and Technology for Tomorrow!

KWJ ENGINEERING is a rapidly growing high-tech business with the mission to revolutionize the capability for detection and situational-awareness for the purpose of improving health, safety, and security for mankind and the environment.

- Sensor Platforms – MEMS, p-MEMS
- Nanotechnology Enabled Sensors
- Instrumentation, Metrology
- Low power, small, light-weight, low cost


8440 Central Avenue, Newark, CA 94560
(877) 794 4296
www.kwjengineering.com
www.transducertech.com
www.ecosensors.com
www.detectcarbonmonoxide.com
KWJ’s Environment For Innovation!

FACILITIES

500 ft² Clean Room; 3000 ft² Bldg; Instruments & Systems Design Center; R&D Lab; Manufacturing Area.

Multidisciplinary

CHEMISTRY/BIOCHEMISTRY, PHYSICS, PROCESS ENG., ELECTRICAL ENGINEERING, MATERIALS SCIENCE, INSTRUMENT DESIGN AND MANUFACTURE

Experienced Staff

Kenneth W Johnson, Dr. Joseph R. Stetter, Edward Stetter, Mel Findlay, Larry Johnson, Oliver Seth, Vinay Patel, David Abouav, Robert Cheney, & support staff with > 150 years combined gas detection, instrument, and sensor experience.

Advanced Product Design, Fabless MEMS Manufacture

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KWJ Partners With Customers/Clients

- **Strategic Partnerships**
  - Design
  - Manufacture
  - License
- **Distributed Products**
  - Rep-Network
- **OEM Products**
  - In-House Clients
- **Custom products**
  - Special Need
KWJ CREDENTIALS

• Founded 1991 - OEM & Custom Gas Detection Instruments

• > 150 years senior engineer experience in gas detection.

• Technology Status
  • *New IP in sensors, instruments, MEMS, ...*
  • > 20 years of reliable fielded instrumentation, ...
  • Tens of thousands of products/systems in use worldwide.

• Private ownership. Funded by product sales, no VC yet.

• Strategic Partnerships:
  University
  Industrial
  Government/National Laboratories/Not-For-Profit

• World-class capability: Fabless MEMS, R&D, Analytical Science, Integration
Technology Platforms Provide Our Unique Analytical Systems Capability and Experience:

- Optical, Thermal, Catalytic, MOX, Electrochemical, Mechanical, Ion Technologies.
- MEMS Platforms – Microfabricated, Ultra Low Power.
- Thermal Sensors – TCD, Catalytic, HMOx; CH₄, CO₂.
- Electronic Sensors – MeS, VOCs, Hydrazines.
- Impedance-Based Biosensors - Bacteria.
- Ion Mobility Spectrometry [IMS – Agents, Explosives]
KWJ - Markets Served

Applications:

- Medical, In-line O2, ...
- Energy – Purity, Safety,
- Industrial – Process, Safety, ...
- Health - Protection
- Consumer – Pilots, Scuba, ...
- First Responder – Fire, Police, Arson...
- Sensors – HVAC, IAQ, Industry
- R&D – New Products
  - Custom products
  - New Capability
  - MEMS microsensors

Wearable protection from KWJ’s Pocket CO
KWJ Gas Detection Products

*Instruments and Sensors: Cost-effective / High Performance*

- In-Line CO – Medical and industrial breathing air
  - A222 packaged for CO and CO₂ breathing air purity [MedCon]
  - A5700 alarm and monitor [3M, MST, ...]
  - A310/316 – Medical CO monitor

- CO₂ flow monitor/alarm; 0-20% in CH₄

- A333 low pressure cylinder alarm

- Pragmatics®: Pipeline/arson calibration-free leak detectors for >15 yrs.
KWJ Gas Detection Products (continued)

*Instruments and Sensors: Low Cost / High Performance*

- 0-100% CH₄ analyzer
- Vapor recovery stack gas combustibles monitoring
- Flare gas monitor for CH₄-mix to stack [20-40% CH₄]
- Remote, fixed-site and portable H₂S and toxics monitor
  - Sample draw detector assembly for CH₄, O₂, CO or H₂S
- Mobile Combustible Gas Detection system for tank farms
  - Monitor and alarm during repairs, cleaning, painting operations
- Wearable/portable “POCKET” gas detector/monitor/dosimeters
  - Fire, police, first responder, building inspector, pilots, scuba, …
  - SATA under hood CO detection, …
- Complete line of OZONE in air and OZONE in water monitors
- R&D for military, government and industrial clients.
Metrology - Expertise

[Comprehensive characterization of sensors/instruments]

• Applications
  – Characterization
  – Validation
  – Benchmarking
  – Calibration
  – Tiered testing

• Capability
  • Facilities
    • Clean room
    • SSTUF
    • Sensor production/cal
    • Instrument design/cal
      • CSA, UL, CE, ...
  • Expertise
    • Analytical chemistry
    • Engineering
    • Sensor science
  • Equipment
    • P’stat, spectrometers
    • Collaboration-ICSSE...

Shared Sensor Testing User Facility
SSTUF - Test and Evaluation

[Sensor validation - tools + \textit{what to do + how to do it!}]
KWJ Engineering Incorporated

- Chemical-/Bio-/Gas-Sensors
- Instruments – In-line or Wearable
- Applications engineering [fast-to-market]
  - Demonstrated Systems
  - Superior Performance
  - 100x Lower Power/Cost/Size
- Nano-Materials Research/Development
- Micro-Fabrication/Micro-Fluidics
- Advancing Detection Capabilities
- Sensor Characterization/Metrology with Sensors

What Can We
• Design • Build • Measure for You?
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Advanced Products for Today
and Technology for Tomorrow!

APPENDIX – RECENT PROJECTS

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MICROSENSORS FOR PROCESS AND ENVIRONMENTAL APPLICATIONS

[KWJ nanoTCD for binary gas mixtures, fast GC, gas-purity, leaks, ...]

Channel 1 records voltage, and channel 2 records current

Sensor Resistance calculated from:
\[ R(t) = \frac{(V1(t) \cdot Rf)}{V2(t)} - Rf \]

Temperature vs. resistance calibrated in separate experiment.

Sensor in box purged with pure gas.
KWJ MEMS TCD sensor - Mar 09

[<100ns response time; Power 0.6 nW/reading
Detection of He, N2, air, CO2]

Response:
1] Nano seconds;
2] slope over 1st 40 nano sec is unique for gases;
[may offer Selectivity];
3] Stability for this design has achieved the equivalent of 22 billion readings without the need for calibration.
Response over 40 nano-seconds

Slopes are different for different gases:
K = a C_v s (mw)^{-1/2}

Carbon Dioxide: \( y = 16122x + 1182.9 \)
Nitrogen: \( y = 12803x + 1286.8 \)
Air: \( y = 16465x + 1126.1 \)
Helium: \( y = 12766x + 1196.6 \)
MEMS Sensor Features

- NeSSI compatible
- RELIABLE
- Versatile
- Reliable
- “Selective”
- Sensitive
- Ultra-fast!

Steady-State Response to ~1 vol% H2
(Note: Method used to mix 1% H2 by hand will result in some test-to-test variation)
APPLICATIONS OF KWJ MEMS nanoTCD

Separation in sub-seconds!

Ultrafast Gas Chromatography on Single-Wall Carbon Nanotube Stationary Phases in Microfabricated Channels

Michael Stadermann, Adam D. McBrady, Brian Dick, Vanessa R. Reid, Aleksandr Noy, Robert E. Synovec, and Olgica Bakajin


PE: VOCs in 35 sec vs 35 min
IAQ Sensors

Distributed Control Ventilation:

- Comfort – T, RH, CO2
- Productivity
- Security - hazards
  - Agents
  - Pollutants, O3
  - Explosives

KWJ CO2 MEMS SENSOR
MEMS CO2 Measurement Data

Sensor Output Vs CO2

Output (mV) vs. CO2 (%)

-900 -800 -700 -600 -500 -400 -300 -200 -100 0

1 2 3 4 5 6 7

2009
Response of MEMS Sensor to CH4 in Hydrogen

5% CH4 in H2

Non-linearity at low Concentration likely due to leaks in system

- 2.5% CH4
- 1% CH4
- 0.5%
- 100% H2
Refinery Hydrocarbon Leak Detection example

- $3000/node for sensor; $5000 nema 4 instr.
- $200/node for sensor; $1000/pt instr.
- $50/node for sensor/wireless/pt

[240 USA/800 world refineries; $10/pt; 5 yr life]

Flanges per refinery = 240,000;
Valves per refinery = 40,000;
Total points per refinery = 280,000;
Total points world = 291,760,000; $3B
Opportunity/Mkt= $300M; $30M replacement
H2 Sensor Infrastructure

Social Infrastructure
- Vehicles
- Power sources
- Pipelines
- Dispensers
- Compressed gas
- Valves, flanges, ...

Business differentiators:
1] technical
2] cost
3] service

Infrastructure Apps-Cube
- manufacture
- transport
- store
- Dispense/use
- Safety
  - LEL, asphyxiation
  - Leak detector
  - Area monitor
- Purity/amount
- Area monitor
- Leaks-pipe/truck
- Process monitor

Fixed site
- mobile
MEMS Methane & H2 Measurement Data

MEMS Bridge Sensor Output vs. H2 Concentration

Sensor Output Vs CH4
HPA – HYDROGEN PURITY ANALYZER

• Process analyzer for detection of impurities in H2 stream.
• Monitors purity of end-product for Hydrogen generating stations of the future!
• EC Hydrogen sensor incorporates unique CO filter for strong selectivity.

• Integrated into KWJ’s “Pocket” detector that weighs < 1 ounce, and runs for months on a watch battery!
On-line Measurement of Dissolved Ozone with EC Sensors

Wineries, food processing, laundry, cruise ships and hotel rooms, casino, restaurants, waste water, drinking water, aquariums, air cleaning, ...

In-line Dissolved Ozone Measurement

Other Dissolved Gases Too!

Portable Dissolved Ozone Measurement (DO3)
Dissolved Ozone Measurement

Sensor Output cal at 0.41 ppm hach reading

ECH Sensor Output

These spikes occur because for time being there were no water in flow block (since we are change the connection manually) at time to switch back connection from ozone water to clean water.

7/8/2009 Hach Reading 0.43
7/9/2009 Hach Reading 0.51
7/10/2009 Hach Reading 0.55
7/13/2009 Hach Reading 0.47
7/14/2009 Hach Reading 0.54
KWJ’s “Pocket” Family of Gas Detectors / Dosimeters

- Low cost, low power, and long battery life (replaceable).
- EC sensor gives accurate, reliable measurements.
- Loud alarms, vibrator, LED. Digital display with backlight.
- Weighs less than 1 ounce!
- Dosimetry and data / event logging.

Hydrogen, H2S, Carbon Monoxide, Ozone
Tiny Sensors and “Pocket” Detectors For...

- NO – asthma, breath analysis [15 M patients in US]
- CH₄ – safety [55M meters NA]; process;
- CO, CO₂, O₂, flow rate/volume – safety; metabolism
- Isoprene – cholesterol [11 M tests annually]
- H₂/CO – neonatal jaundice, intestinal distress
- Isoprostane/CO – cystic fibrosis/bronchitis
- H₂S – periodontal disease; petrochemical safety
- Pollutants, ethanol, ozone, NOₓ, pH, …; industry
- Vital signs monitoring; first responders, EMTs,…
- CO - pilots, divers, home inspectors, police, fire, first responders, boats, homes, auto, …
- H₂ – hydrogen energy, safety, …
- PROCESS CONTROL SENSORS
- Indoor Air Quality – CO₂, T, RH
- BETA H₂S and CH₄ personal monitors

Awareness – smart sensors
Personalized safety, health, surveillance
Home, affordable, capable, low cost
Presymptomatic, diagnostic, compliant
Robots are fascinating because they mimic humans and our behavior!

Challenge: Sensing And Artificial Senses
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- Instruments – In-line or Wearable
- Applications engineering [fast-to-market]
  - Demonstrated Systems
  - Superior Performance
  - 100x Lower Power/Cost/Size
- Nano-Materials Research/Development
- Micro-Fabrication/Micro-Fluidics
- Advancing Detection Capabilities
- Sensor Characterization/Metrology with Sensors

What Can We
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- Build
- Measure for You?

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