Smart Sensor Technology for Environmental Monitoring Applications

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• INTRODUCTION

• SENSOR PLATFORMS AND SMART SENSOR SYSTEMS
  ➢ “LICK AND STICK” HARDWARE
  ➢ WIRELESS SENSOR AND NODES

• ENVIRONMENTAL MONITORING
  ➢ FIRE/ENVIRONMENTAL MONITORING
  ➢ WATER MONITORING

• SUMMARY AND CONCLUSION
BASE PLATFORM SENSOR TECHNOLOGY
Integration of Micro Sensor Combinations into Small, Rugged Sensor Suites
Example Applications: AEROSPACE VEHICLE FIRE, FUEL LEAKS, EMISSIONS, ENVIRONMENTAL MONITORING, CREW HEALTH, SECURITY

- Multi Species Fire Sensors for Aircraft Cargo Bays and Space Applications
- Environmental monitoring (ISS Whitesand Testing)
- “Lick and Stick” Space Launch Vehicle Leak Sensors with Power and Telemetry
- Aircraft Propulsion Exhaust High Temperature Electronic Nose
- Breath Sensor System Including Mouthpiece, PDA Interface, And Mini Sampling Pump
- Hydrazine EVA Sensors (ppb Level Detection)

- Oxygen Sensor
- SiC Hydrocarbon Sensor
- H2 Sensor
- Nanocrystalline Tin Oxide NOx and CO Sensor
BASE PLATFORM SENSOR TECHNOLOGY

• SENSOR DEVELOPMENT RESULTING FROM:
  - MICROFABRICATION AND MICROMACHINING TECHNOLOGY
  - NANOMATERIALS
  - SiC-BASED SEMICONDUCTOR TECHNOLOGY

• TECHNOLOGY DEVELOPS PLATFORMS FOR A VARIETY OF MEASUREMENTS
  - SCHOTTKY DIODE
  - RESISTANCE BASED
  - ELECTROCHEMICAL

• MODIFY PLATFORMS AND MATERIALS TO MEET NEEDS OF THE APPLICATION

• SELECTIVE DETECTION OF TARGETED SPECIES

Meet the Needs of a Range of Applications Based On Platform Technology

- High Temp O2 Detection
- High Temp CO2 Detection
- Room Temp O2 Detection
- Glucose sensor
- Ca++ Detection

Electrochemical Cell Platform formed by Microprocessing

BASIC APPROACH

Vary Substrate and Sensor Materials Depending on Application
CHEMICAL SENSOR “FAMILY TREE”

SENSING PRINCIPLE

Schottky Diode
- SiC
- SiC Diode with Pd Alloy Gate
- Pd Alloy SiO2 Diode
- Pd Alloy Diode

Resistor
- Nanocrystalline SnO2
- Doping

Solid State Electrochemical Cell
- ZrO2
- Amperometric
- With varying cell voltage

Calorimetric
- NASICON
- Amperometric
- Catalytic Coating

HC
- H2
- CO
- NO
- NOx
- CO
- O2
- H2O
- CO2
- H2
- HC

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Core Microsystems Technology

Microsystems Approach: Stand-alone, Complete Miniaturized Systems Including Sensors, Power, Communication, Signal Processing, And Actuation to Enable a Smart Sensor System

“Lick and Stick” Smart Leak Sensor System

“Lick and Stick” Leak Detection Electronics and Three Sensors

System Configured with Different Wireless Antennae

Wirelessly Transmitted 3 Sensor Data

Basic Approach: Meet the Needs of Multiple Applications Building from a Core Set of Smart Microsensor Technology
EXAMPLE APPLICATION: FIRE/ENVIRONMENTAL MONITORING

COMBINE CHEMICAL SPECIES/PARTICULATE DETECTION IN SMART SYSTEM

- DECREASE FALSE ALARM RATE IN BOTH AERONAUTICS AND SPACE APPLICATIONS
- INTEGRATED FIRE AND ENVIRONMENTAL MONITORING SYSTEM
  - SINGLE SYSTEM COVERING BOTH FIRE AND ENVIRONMENTAL APPLICATIONS
  - COMPLEMENTARY SENSOR TECHNOLOGIES: CROSS-CORRELATION BETWEEN SENSOR ELEMENTS IMPROVES OVERALL SYSTEM MEASUREMENT
  - DEVELOPING MOBILE UNITS FOR FIRE FIGHTERS (HOMELAND SECURITY)
  - DATA STORAGE AND PROCESSING, BUILT-IN SELF CHECK; WIRELESS COMM OPTION

Testing at FAA with Combined Particulate and Chemical Species System: Advanced Detection of Fires with No False Alarms

Combine Particulate And Chemical Species Detection

Basic Approach: Transition Hardware Into Core “Lick And Stick” Hardware Platform; Multiple Configurations Available

COMBINED FIRE/ENVIRONMENTAL MONITORING: STATIONARY AND HAND HELD UNITS (CHEMICAL SPECIES)

WIRLESS SENSOR AND NODE
WATER QUALITY MONITORING APPROACH

• COMPLEMENT WATER BASED DETECTION WITH ATMOSPHERIC ENVIRONMENTAL MONITORING
  - WHOLE FIELD APPROACH
  - MULTIPLE SITES FOR REGIONAL COVERAGE
  - CORRELATE WITH OTHER MEASUREMENTS E.G. REMOTE MONITORING

• SENSORS TAILORED TO MEASURE TARGETED SPECIES AND PARTICULATES. EXAMPLE:
  - THREE ELECTRODE ELECTROCHEMICAL CELL: OPERATION IN BOTH AIR AND AQUEOUS ENVIRONMENTS
  - CAPABILITY TO BE TAILORED FOR DETECTION OF SPECIFIC SPECIES

• DEMONSTRATED AQUEOUS BASED CHEMICAL SPECIES MEASUREMENTS (INCLUDES MEASUREMENTS IN DIVERSE MEDIA, E.G., BLOOD):
  - BIOLOGICAL OXYGEN DEMAND (BOD)
  - pH
  - HEAVY METAL IONS

• PARTICULATE FLUID MONITORING DEMONSTRATED
  - SPACE ACT AGREEMENT ACTIVITY RELATED TO LIQUID-BASED PROCESS PARTICLE MONITORING
  - TECHNIQUE CAN BE TAILORED FOR SPECIFIC PARTICLE MORPHOLOGIES

Three Electrode Electrochemical Sensor Configuration: Modify for Selective Monitoring of Targeted Constituents
WATER QUALITY/ATMOSPHERE MONITORING APPROACH

ESTABLISH MULTIPARAMETER SMART SENSOR CAPABILITIES

• COMBINE CHEMICAL SPECIES AND PARTICULATE DETECTION APPROACHES TO TARGET WATER TOXINS AND POLLUTANTS
  ➢ BASELINE: BOD, PH, HEAVY METAL IONS
  ➢ EXPAND ARRAY TO SPECIFIC TOXINS E.G., ARSENIC, FLUORIDE AND CHLORINE
  ➢ TARGET MORPHOLOGIES OF BIOLOGICAL SPECIES

• DETECTION OF OTHER TARGETS OF INTEREST, FOR EXAMPLE, MICROCYSTIN-LR
  ➢ BIND ANTIBODY TO SENSOR ELECTRODE STRUCTURE
  ➢ CHANGES IN ELECTRICAL SIGNAL DUE TO CHANGES IN ANTIBODY
  ➢ CAN BE INCLUDED IN WATER MONITORING ARRAY

• PROVIDE SMART SENSOR SYSTEM TECHNOLOGY TO MONITOR BOTH ATMOSPHERE/WATER
  ➢ COUPLED WITH SMART HARDWARE FOR DATA PROCESSING AND STORAGE
  ➢ ESTABLISH MONITORING STATIONS OVER A REGION (BOTH WATER BASED AND ATMOSPHERIC)
  ➢ WIRELESS NODES TO FORM BROAD REGIONAL NETWORK
  ➢ CORRELATION OF MEASURED PROPERTIES TO:
    • SEASONAL PATTERNS (E.G. FARM RUNOFF) AND POLLUTION
    • OCCURRENCE OF DISRUPTIVE EVENTS (E.G., ALGAE BLOOMS)
    • INDICATIONS OF CHANGE IN LOCAL PROPERTIES

CORE POINT: IN ORDER TO UNDERSTAND WATER QUALITY, A MULTIPARAMETER, REGIONAL APPROACH NEEDED TO IDENTIFY CAUSATION AND CHANGES
SUMMARY AND LONG-TERM VISION

• SMART SENSOR SYSTEM TECHNOLOGY DEVELOPED USING BASE PLATFORM TECHNOLOGY AND MICROSYSMS
  ➢ MULTIPARAMETER, SELECTIVE MICROSENSOR APPROACH
  ➢ INTEGRATION INTO SMART SENSOR SYSTEMS WITH A MICROPROCESSOR, DATA STORAGE, AND COMMUNICATION CAPABILITIES
  ➢ SYSTEMS FOR TARGETED APPLICATIONS DEMONSTRATED

• WATER QUALITY MONITORING: WHOLE FIELD APPROACH: BOTH WATER AND AIR MONITORING IN PARALLEL

• ADOPT SMART SENSOR SYSTEM APPROACH
  ➢ SELECTIVE, MULTIPARAMETER SENSOR TECHNOLOGY
  ➢ INTEGRATED WITH SMART SYSTEM HARDWARE
  ➢ REGIONAL MONITORING WITH WIRELESS NODES

• CORE TECHNOLOGIES EXIST; TARGETED DEVELOPMENT NEEDED FOR THIS APPLICATION
  ➢ SPECIFIC TOXINS AND BIOLOGICAL PARAMETER
  ➢ IMPLEMENTATION OF SYSTEMS
  ➢ CORRELATION OF RESULTS

• THE WATER SYSTEM IS A CONNECTED SYSTEM: MONITORING WATER QUALITY NEEDS A WHOLE FIELD APPROACH
  ➢ SMART SENSOR SYSTEMS CAN BE USED TO PROVIDE BASIC IN-SITU INFORMATION FOR MODELS AND CORRELATION OF EVENTS
Back-Up Slides
HYDROGEN LEAK SENSOR TECHNOLOGY

- MICROFABRICATED USING MEMS-BASED TECHNOLOGY FOR MINIMAL SIZE, WEIGHT AND POWER CONSUMPTION

- DESIGNED TO OPERATE WITHOUT OXYGEN AND IN VACUUM ENVIRONMENTS

- HIGHLY SENSITIVE IN INERT OR OXYGEN-BEARING ENVIRONMENTS, WIDE CONCENTRATION RANGE DETECTION

- TWO SENSOR SYSTEM FOR FULL RANGE DETECTION: FROM PPM LEVEL TO 100%
A WIDE RANGE OF SYSTEM DEMONSTRATIONS AND APPLICATIONS
“LICK AND STICK” CORE HARDWARE

Jet Engines Emissions

Aircraft Fire Detection

Breath Monitoring

NASA Helios Fuel Cells

International Space Station Safety System

Rocket Engine Teststands

Environmental Monitoring