Ground Testing of the JPL Electronic Nose: Mechanisms of Response in Conductometric Polymer-Carbon Composite Sensors

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AIR QUALITY MONITORING REQUIREMENTS

Monitor cabin environment with time stamped measurements and rates of change

- Major constituents - "near-continuous" monitoring
  - H₂, O₂, CO₂, H₂O
  - H₂, CH₄, CO
- Trace contaminants - less frequent monitoring required
  - 40 organic compounds
- Event Monitoring - rapid response time
  - pyrolysis markers - CO, HCN, HCl
  - marker compounds for electronics overheating
  - monitoring for sudden release from fluid systems, experiments, EVA, waste
  - follow progress of decontamination after an event

AIR QUALITY MONITORING

JPL ELECTRONIC NOSE

FUNCTIONS
- Incident monitor for targeted contaminants exceeding Spacecraft Max Allowable Concentration (SMAC). Identify and quantify target compounds at SMAC level.
- Monitor for presence of compounds associated with fires or overheating electronics
- Monitor clean-up process

CHARACTERISTICS
- Low mass, low power device
  - First Generation: 1.5 kg; < 1 L; 1.5 W avg, 3 W peak
  - Second Generation: < 1 kg; < 1 L; 1.5 W avg, 3 W peak
- Requires little crew time for maintenance and calibration

WHAT IS AN ELECTRONIC NOSE?

An array of non-specific chemical sensors, controlled and analyzed electronically, which have overlapping responses to compounds. Compounds are identified and quantified by recognition of patterns of response.

1. Etch a measure background resistance in each sensor and establishes R₀ (baseline).

2. Contaminant comes in contact with and surfs into sensors.

3. The sensors, polymer films loaded with a conductive medium such as carbon black, change resistance by swelling or shrinking as air composition changes.
WHAT IS AN ELECTRONIC NOSE?

4. Resistance is recorded, the change in resistance is computed, and the distributed response pattern ("fingerprint") of the sensor array is used to identify gases and mixtures of gases. The magnitude of response is used to quantify the identified compound.

5. Responses of the sensor array are analyzed and quantified using software developed for the task.

CONDUCTION IN POLYMER-CARBON COMPOSITES

1. Tunneling
   - Carbon to carbon through polymer matrix
   - Resistance is controlled by electric field between adjacent particles

2. Percolation Controlled
   - Carbon-to-carbon through particle contact
   - Resistance is controlled by contact resistance between particles and by gaps too large for tunneling
Resistance Change: Response to l-propanol
dip in response magnitude at increased humidity shown in calculated
swelling behavior

Resistance Change: Response to Hydrazine
sessions at 50°C, more at 34°C, delivery by air R12 1 ppm

AIR / ANALYTE DELIVERY SYSTEM
A computer-controlled gas delivery system bubbles air through solvents
and mixes them with humidified air. Temperature is controlled in the gas
delivery system using heaters.

- concentrations are verified using a Rosemount Hydrocarbon Analyzer calibrated
to standard gases (methane, methene, toluene, aniline). Humidity is verified
using calibrated sensors.
- Background gases can be cleared air or bottled gas. Humidity is added by
bubbling through water and mixing humidified air with dry air.
100 LITER TEST CHAMBER

DEVICE OPERATION AND TESTING

Test Chamber

- 100 L test chamber
- Temperature controlled using a water jacket
- Pressure controlled by evacuating and backfilling with clean, humidified air
- Test analytes are delivered using a syringe for rapid injection (to simulate a spill) or a syringe pump (to simulate a leak).
- Solid analytes (insects) are delivered by placing a measured quantity in a feedthrough. Gaseous analytes (burning insulation) is delivered through a tube.
- Chamber air can be circulated within the chamber or directed through a filter to simulate the Air Revitalization System.
- Testing will begin after a complete training set has been taken.

Data analysis is automated to find events and identify them.

100 LITER TEST CHAMBER

DATA ANALYSIS

Functional Group Classification

Three primary alcohols (methanol, ethanol, 1-propanol) can be distinguished by their response patterns. A sub-pattern made up of five sensors has been identified as being indicative of primary alcohols. This technique can be used to identify compounds by functional group.
DATA ANALYSIS

Functional Group Classification

Classify Unknowns in Mixtures and/or With More Than One Functional Group

preliminary software was for single unknowns, with a single functional group. Focus was on alcohols and aromatics.

developed software routine for choosing best subsets of sensors for functional group classification based on fingerprint group distance calculation. Software will find a subset of sensors that has a minimum value of the distance between one particular group divided by the distance between the rest of the target analytes. Each different functional group has a different optimal subset of sensors, and so different combinations of functional groups. This sensor selection software is a very useful tool and may be applicable to other general sensor selection evaluation needs.

Also devised a two-step data analysis approach in which the result of the first (main) step will be given preference in the second (functional group analysis) step. For example, if the first step results in "methanol" plus "Freon" with an unacceptably large residual (r), then the software will assume it could be one of some unknown analytes.

Analyses for 2nd Generation ENoSE

| Substance | SW/SMAC | UV/SMAC | IR | IR Path
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