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# Intelligent Chemical Sensors and Modern Applications

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**Abstract:**

We live in a world that is producing ever evolving capabilities like “cloud” computing, “nanoBots,” and “nanosensors” wherein the sensors extend human perception, robots extend our muscle and reach, and the cloud extends our brains. These modern revolutions combine to enable a new level of situational awareness and are evolving new approaches to solve longstanding and complex problems. Adding chemical-sensors requires self-compensating sensors in packages that are ultra-low-cost, ultra-low-power, and tiny, printed amperometric and MEMS sensors are made for these new applications.

**Key words:** “cloud”, sensors, nanobots, wireless, MEMS sensors, amperometric, gas sensors

## Background

“Swarming” is used in several contexts and most generally is an approach to gathering “shards” of data autonomously and solving problems that involve “swarming” in a real or virtual sense. In the cloud, shards of data, people, and resources can be brought together from disparate places, times, and situations to solve an immediate problem, i.e., by using an “App.” One example would be where an elderly person wishes to live alone but requires support to remember medications, take care to set the home comfort and safety controls, and monitor vital signs or other health situations. Another example is in Search as Rescue operation after a disaster. Chemical sensors can and will be important to solve these problems. But successful chemical sensors will need advanced analytical capability as well as be ultra-low power, low cost, and small size.

Apple uses the “cloud” to store all of your personal data from your iTunes®, iPod®, and iPhone® in the “Apple cloud” so that whenever you want, wherever you are, with any one of the wireless devices you have, you can access, with an “app,” any of the needed data to provide for your entertainment request. In this way, your brain is extended by the stored information and the cell phone extends your senses and can be considered a mobile-bot. Adding chemical sensors extends this paradigm to be useful to provide increased levels of safety, comfort, and home health care for the elderly. In the concept of the “swarm,” many chemical sensors working on the edge of the cloud [i.e., a swarm, of mobile and/or stationary sensors] such that each can provide a data shard [the shard is defined as the data set needed to solve a problem or create a recorded piece of data] can be a powerful situational awareness tool. The application of swarm principles to robots is called “swarm robotics”, while 'swarm intelligence' refers to the more general set of algorithms used and 'swarm prediction' has been used in the context of forecasting problems [1].

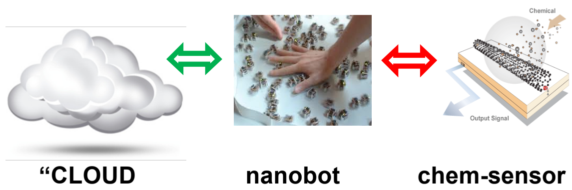


*Figure 1. The cloud will be coupled to swarms of nanobots with physical and chemical sensors, to increase the dimensionality of situational awareness in field applications like elderly care and Search and Rescue operations. Ultra-low power chemical sensors provide needed dimensionality!*

## Results

We have developed two new platforms for chemical sensing that are easily integrated into existing infrastructure and combined with communications and mobile robotic systems (Figure 2).

These sensors are tiny, ultra-low power and interfaced to circuits and algorithms that provide information, i.e. T/RH compensated selective signals for situational awareness.

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The amperometric sensor response has been characterized for detection of CO, H2S, Ozone, Cl2 and NH3 gases in this current project.


*Figure 2. New ultralow power sensors: (left) screen printed amperometric sensor the size of microSD card from cell phone and (right ) MEMS nano-watt TCD sensor*

Figure 3 shows the response of a printed sensor to NH3 using high surface area electrodes and a room temperature ionic liquid electrolyte. Additional gases are possible but these demonstrate that the small inexpensive sensors can have high performance. The LDL

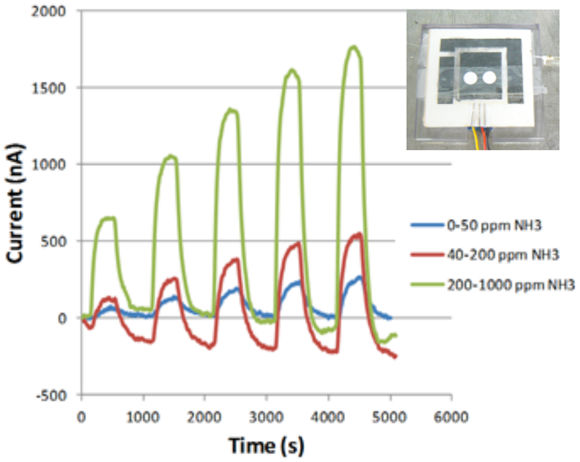



*Figure 3. Linearity of response for the HSA Pt + BMIM printed sensor. Three tests ranges are shown: 0-50 ppm, 40-200 ppm and 200-1000 ppm $NH_3$. Sensors operated at 0 mV bias.*

for CO is about 1 ppm while the LDL for Ozone is 50 ppb in air.

Figure 4 shows the response of a MEMS TCD to different concentrations of H2 over the range of 0.5% - 2.5% along with an SEM image of the MEMS structure. In Figure 5, we illustrate a compensated TCD signal for Hydrogen that is insensitive to changes in both temperature and RH. The algorithm to accomplish this task also includes a selectivity term and can uniquely ascribe the signal to hydrogen or an interfering gas like methane, helium, or other compound in the air making the output selective.

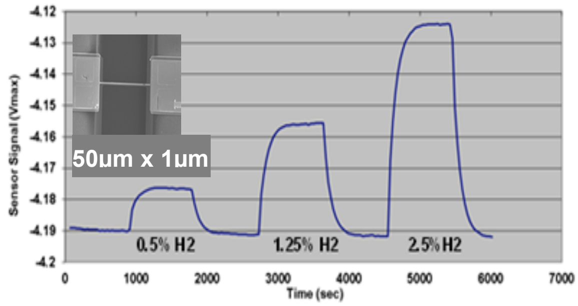
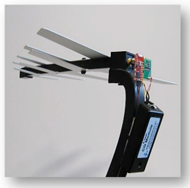



*Figure 4. KWJ MEMS Sensor Response to H2 in air*

The intelligent algorithm is important to prevent nuisance false positives and deadly false negatives in the sensor operation. In the development of these compensated sensors, we have always needed to be mindful of the low power and small size requirement of field devices for the elderly and for field operations of search and rescue. The sensors have been integrated into field electronic and communicating systems. The sensors are connected to an energy harvester [below] that scavenges energy from local TV stations. The harvester provides only 50 uW of power but this is totally sufficient to operate the new sensors in a "battery free" power mode forever.



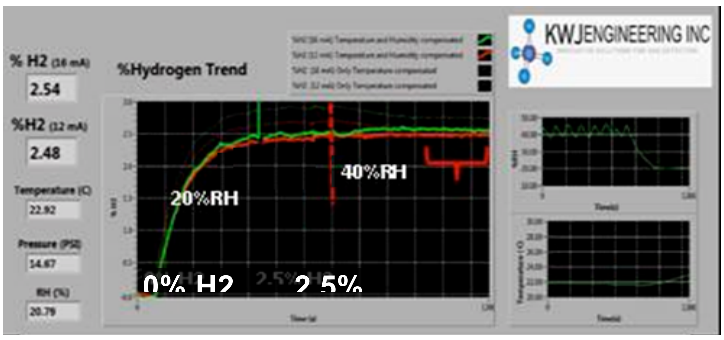



*Figure 5. Screenshot of response of self-compensating TCD to 2.5% H2 as the RH [40% to 20%] and T [20 to 25 deg. C] vary.*

## Conclusions

We are just beginning to explore the applications for this new integration of nano-sensors, power, communications and smart algorithms. We have defined the requirements for sensors that will enable fulfillment of this broad new opportunity for improving health, safety and personal monitoring: The chemical sensor must not only possess a sensor signal but the signal must be integrated into a model of response to provide compensation and selectivity such that the output can be used intelligently. The sensors must also be micro to nano-watt power and low cost so that the envisioned distributed field sensing is practical.

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Energy harvester courtesy of University of Washington, Prof. J.R. Smith.

## References

[1] Beni, G., Wang, J. Swarm Intelligence in Cellular Robotic Systems, Proceed. NATO Advanced Workshop on Robots and Biological Systems, Tuscany, Italy, June 26–30 (1989).

[2] http://www.hizook.com/blog/2009/08/29/i-swarm-micro-robots-realized-impressive-full-system-integration. Karlsruhe Inst. of Tech., KIT, Institute for Process Control and Robotics (IPR), Germany.

[3] US Patent 7,911,010 B2 Mar. 22, 2011, J. R. Stetter, Apparatus and method for microfabricated multi-dimensional sensors/sensing systems.