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ROBOTIC CONTROL FOR REPRODUCIBLE NANOPARTICLE ASSEMBLED FILMS

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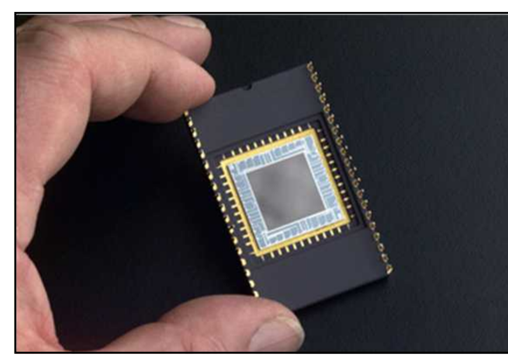
Abstract

Having the ability to sense harmful gases has come to the forefront of nanotechnology. Due to their interesting properties nanoparticle films have emerged as useful platforms for miniaturized chemical sensing. For nanoparticle sensors to become practical in real world applications, a reproducible method of assembly has to be implemented. This project focuses on robotic assembly techniques that deposit nanoparticle films on various substrates. We have developed a process to iteratively assemble and electronically characterize nanoparticle films using a custom robotic preparation system. The robot's design uses commercially available pneumatic and electronic actuators, valves and regulators to manage precision movements. Control of the robot is obtained by a custom Labview program which uses a TTL and GPIB interface to control relays, power supplies, and measurement circuitry.

Miniaturization of Sensor Technology

Sensor technology is an important tool in our nations homeland security and defense programs. They aid in the detection of chemical and biological agents. The Micro Analytical Systems team is working on miniaturizing sensor and detection applications from large desktop size to handheld and finally embedded micro and nano scale devices. The goal is to detect smaller and smaller quantities of analytes and make sensors that are portable, low power and reliable.



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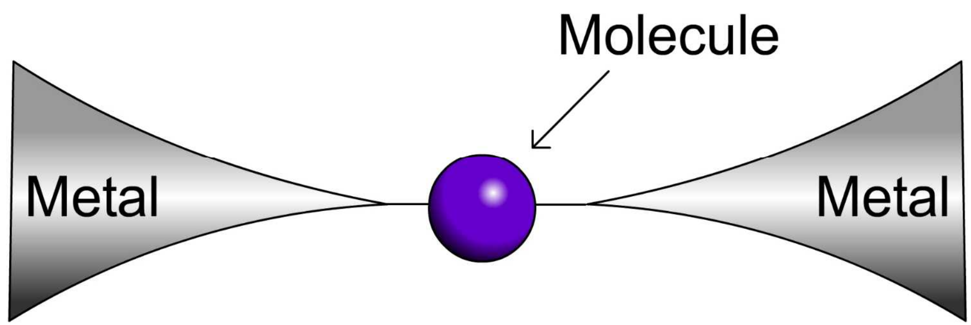
The Ideal Experiment

In the ideal experiment, we would suspend a single detecting molecule across two electrodes. Because we would be dealing with a single molecule, any change to the molecules properties would be directly related to the binding of an analyte. By measuring electronic changes we could detect the presence of an analyte.



Impracticality of the Ideal Experiment

In practice, it is very difficult using today's technology to suspend a single molecule between two electrodes due to:

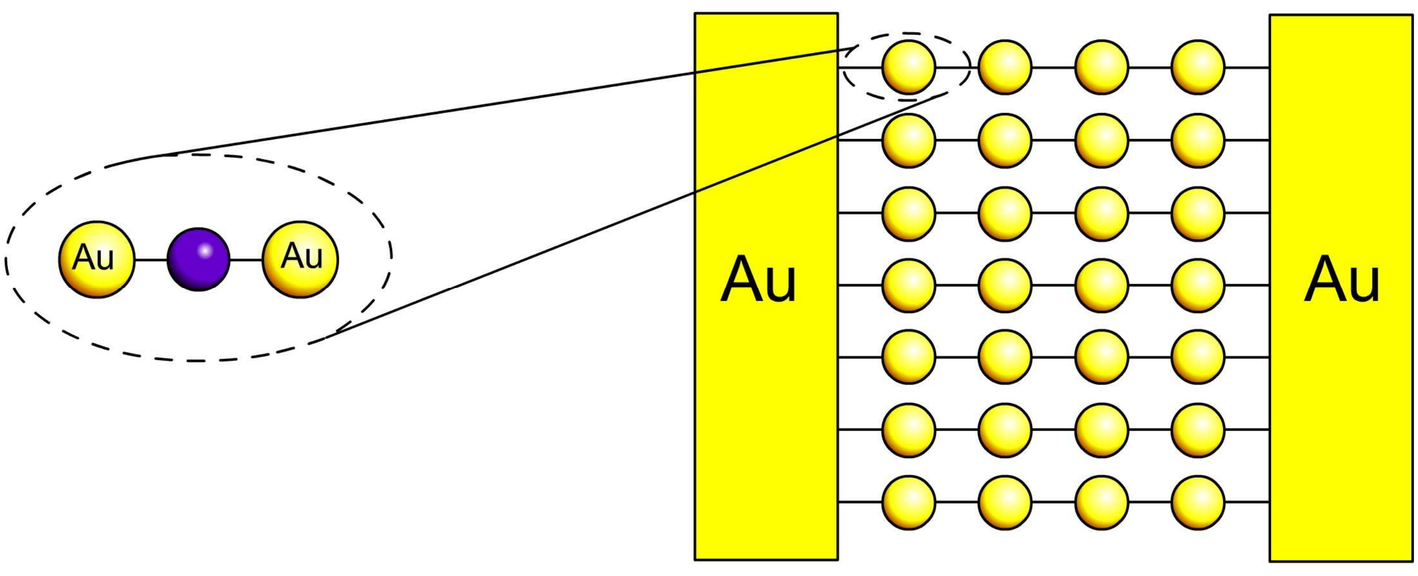
- Difficulty in controlling and maintaining a nanometer size gap due to thermal expansion and vibration.
- Difficulty to mass manufacture 3-D nanoelectrodes.
- Nanoelectrodes are not robust.
- Difficulty in controlling the binding of the molecule to the nanogap.

The ideal experiment is routinely carried out in laboratory environments (controlled vibrations & temperature):

- Scanning Tunneling Microscopy
- Break junctions.

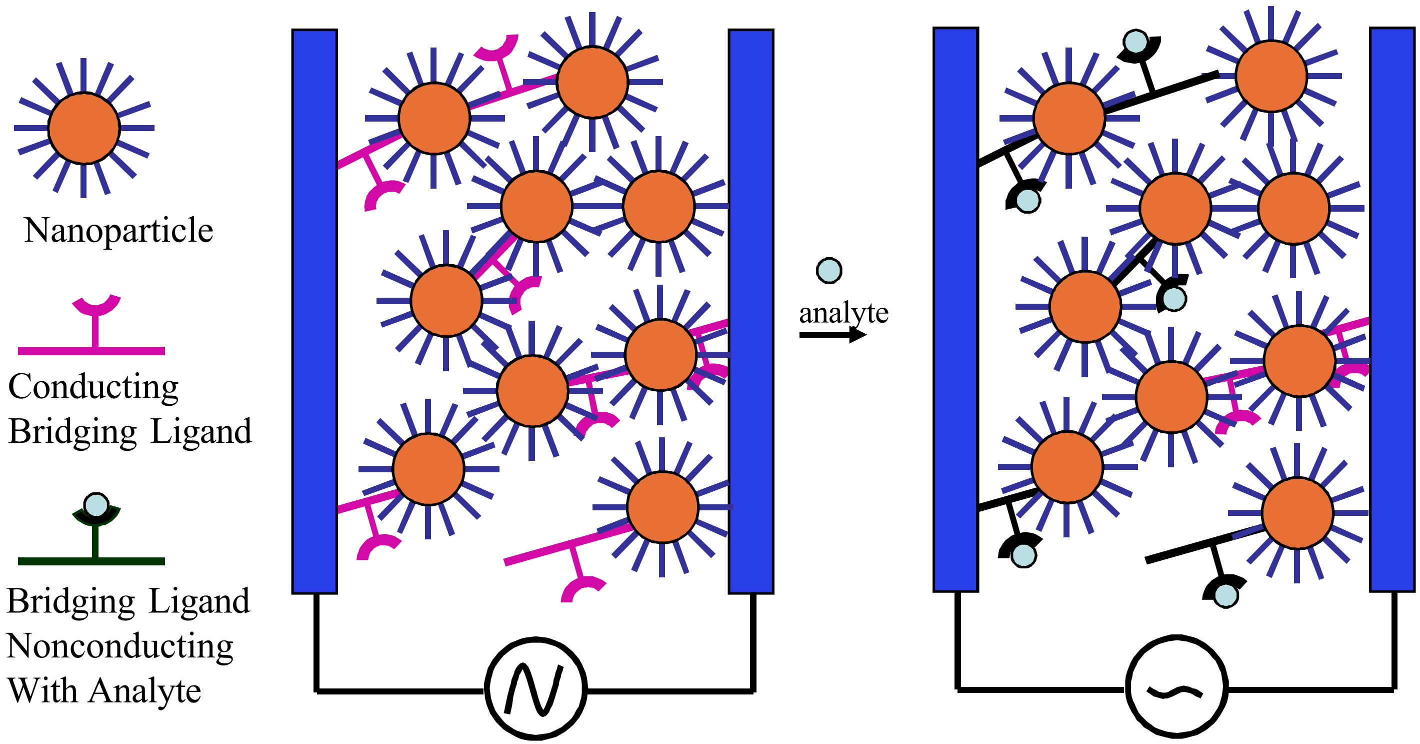
An Ensemble Structure

By using nanoparticles we can approximate the ideal experiment in the field. We connect multiple single molecular structures creating an ensemble of the ideal experiment. The nanoparticles serve two jobs, they represent mini electrodes as well as a pathway for electrons to travel across.



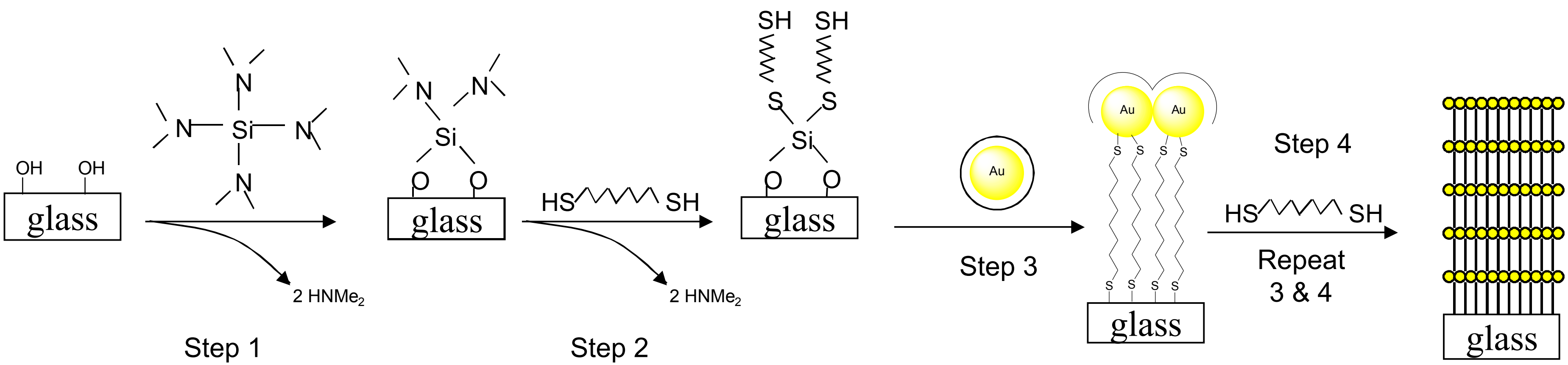
Sensing and Detecting

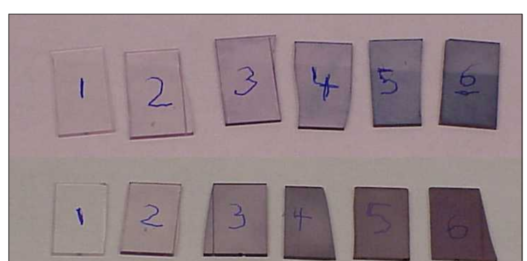
When specific molecules bind with the ligand layers the HOMO LUMO gap is changed thereby changing the conductivity, by measuring this resistance we will can detect and characterize the analyte.



Metallic Nanoparticle Ligand Assembly

The glass is treated with Piranha which hydrates the surface. It is then treated with tetrakisdimethylamino silane and then reacted with a Dithiol. At this point the surface is ready for nanoparticle attachment. The nanoparticles create a framework for the sensing molecules. Each applied layer increases the number of electron pathways which causes a decrease in resistance.





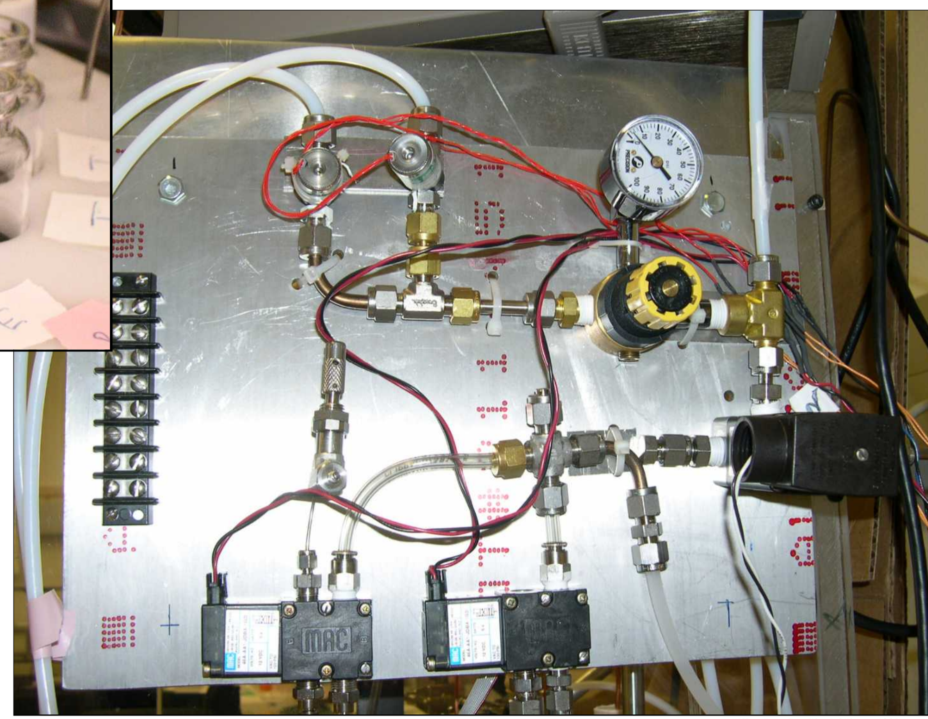
Advantages and Steps of Automation

- Advantages of Automation
  - Film thickness reproducibility for consistent reliable resistance readings.
  - Film surface uniformity.
  - Ease of construction.
  - Convenient measurement techniques.
  - A step towards producing a commercial sensor.
- Stages of Assembly
  - Dip into nanoparticle solution.
  - Rinse (Toluene)
  - Wash (Toluene, Toluene, Ethanol)
  - Dip into ligand solution.
  - Rinse (Toluene)
  - Wash (Toluene, Toluene, Ethanol)
  - Dry (Nitrogen)
  - Take IV measurement.

Robotic Assembly

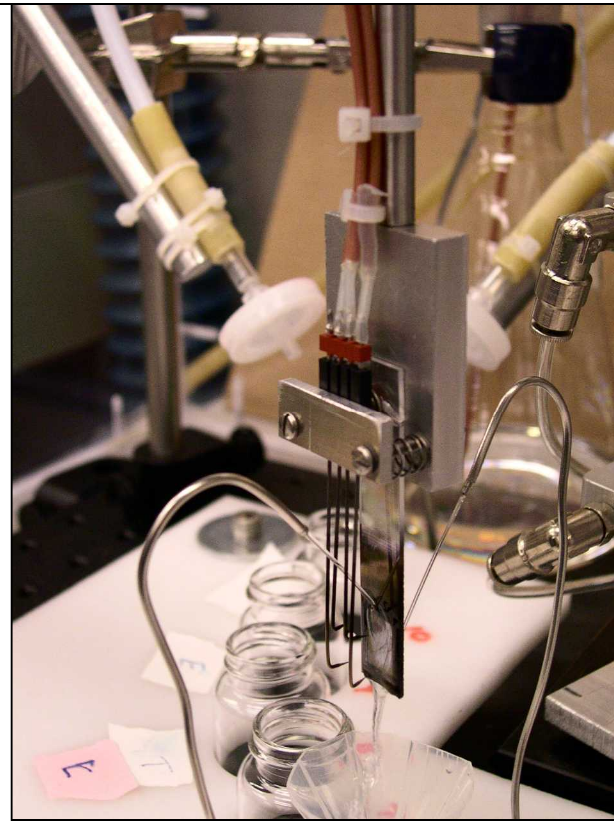
Through a series of steps the robot iteratively assembles nanoparticle – ligand layers creating a conducting film.

Pneumatic parts and a drying mechanism are controlled by regulators and mechanical and electronic valves.



Robotic Assembly

•The substrate is dipped into the nanoparticle solution.

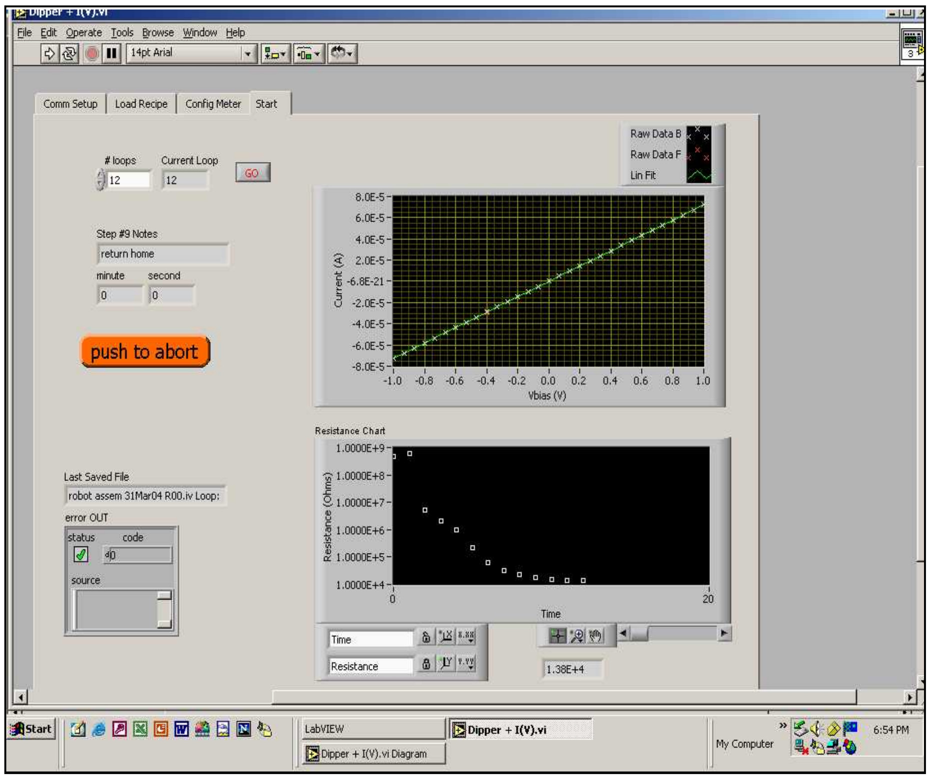


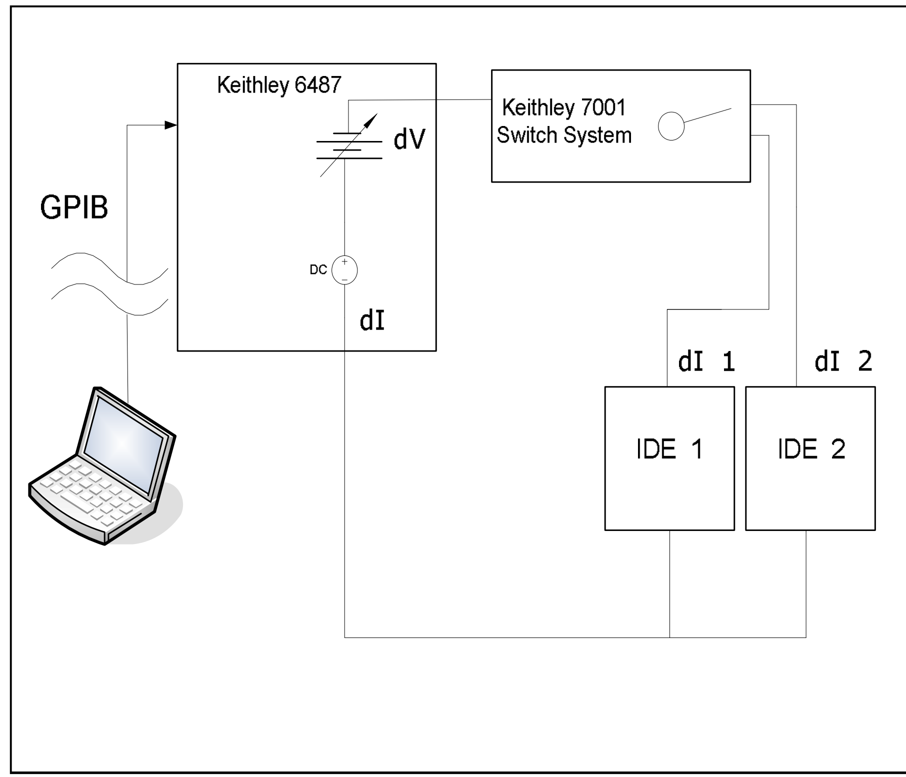
•A rinse stage removes excess nanoparticles and ligands.

•The substrate is dried before a resistance measurement is taken.

Software Interface

A custom developed Labview program interacts with the robot through both GPIB and TTL interfaces. We can plot the resistance measurements of the film after each applied layer. As the nanoparticle – ligand structure builds the resistance drops.





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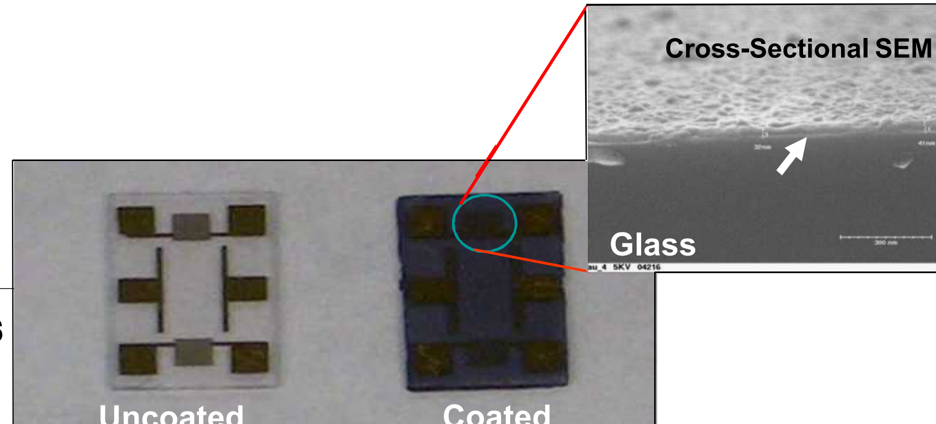
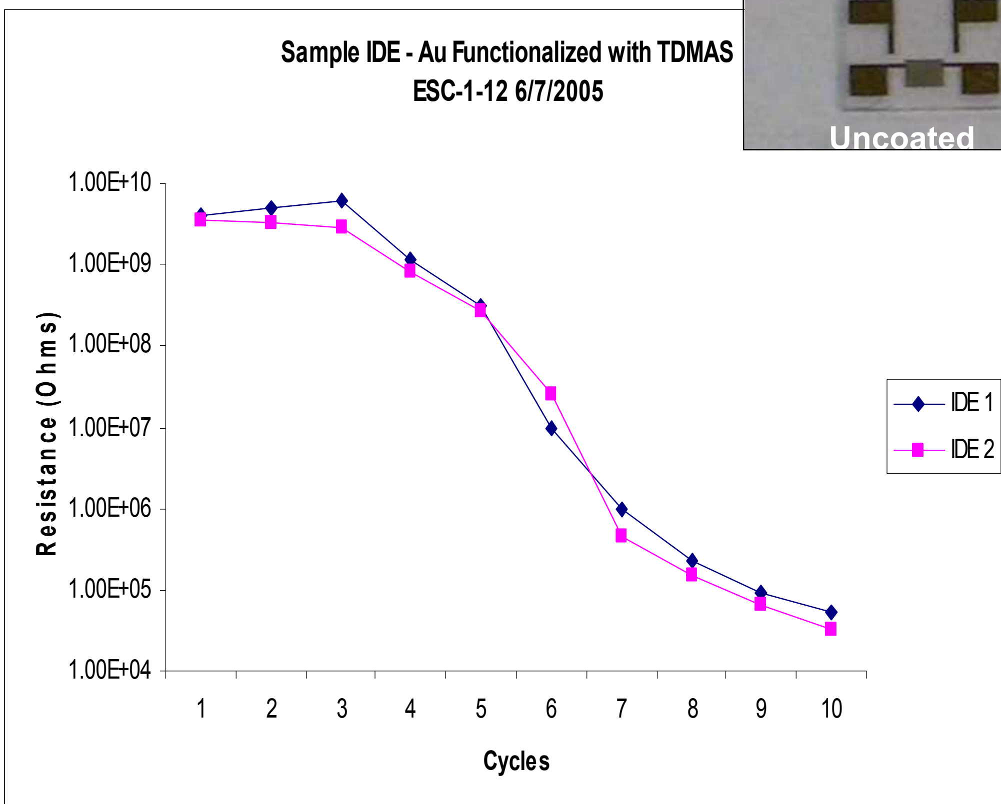
Gold Nanoparticles and Octanedithiol Ligand





We coated two substrates with 10 layers of gold nanoparticles bonded with ODT. The resistance dropped as the layers were applied. By automating we ensure that the measurements are consistent among both interdigitated electrodes.

Conclusion

Sensors are an important technology in our nations homeland security and defense programs. Exploring nanotechology could open the door to very small portable, reliable, selective and low power sensors. Nanoparticle sensors have the potential to detect very small quantities of chemical and biological agents. Automating sensor construction allows consistency, uniformity and reproducibility in sensor research which advances the technological development towards portable commercial applications.

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