Gold Nanocluster Electronics and Sensors

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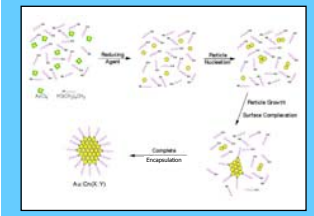
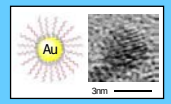
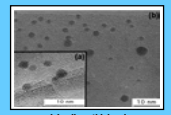
NRL Electronics, Chemistry and Bio-Molecular Sciences

Presenter: Dr. Mario Ancona, NRL Electronics Division

What are gold nanoclusters and how are they made?







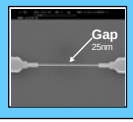
(a) alkanethiol and
(b) ethylene oxide clusters

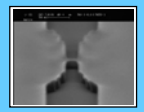
Why are gold nanoclusters interesting?

- Easily prepared (first in ancient times).
- Surface chemistry well-known and easy to work with:
  - Control over assembly on surfaces.
  - Control over sensitivity/selectivity to chemical vapors.
- Electrical properties potentially very useful:
  - Of "molecular" size yet act as simple metals.
  - Quantum mechanical tunneling.
  - Ultra-small capacitance => Coulomb blockade at 300K.

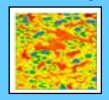
How are devices/sensors fabricated from gold nanoclusters?

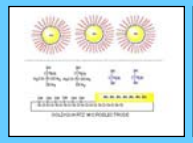
Pre-Patterned Si-SiO_2 Substrate





Self-Assembly Chemistry

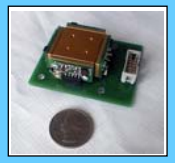




Why should the Navy/Marine Corps be interested?

Near-term: Ultra-small, ultra-sensitive, ultra-low-power chemical sensors.

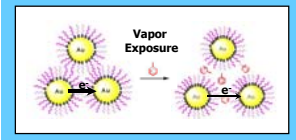
Long-term: Ultra-small, ultra-low-power electronics.

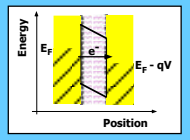


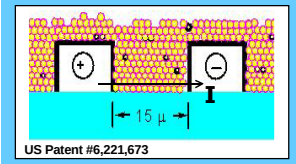
MSI, Inc. & NRL (for DTRA)

Gold Nanocluster Sensors

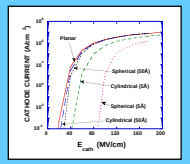
Basis of Operation: Tunneling



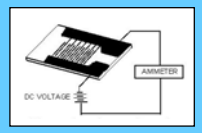


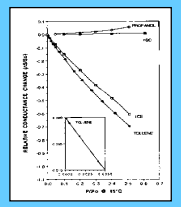


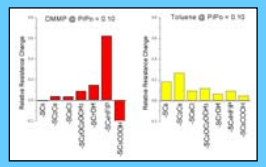
US Patent #6,221,673



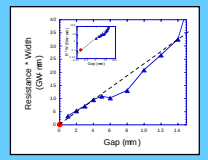
Sensor Characteristics

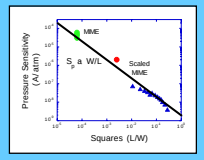


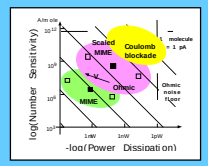


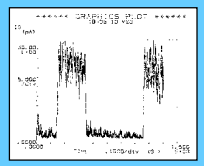


Chemiresistor Scaling









The Future

UAV CWA Detection
(Photo: USMC photo)

Residual Life Indicators
(Photo: MSI & NRL for DTRA)

UCB/MLB/Crossbow Mote
(Photo: UC Berkeley)

Biosensors
(Photo: NRL)

Gold Nanocluster Electronics

Basis of Operation: Coulomb Blockade

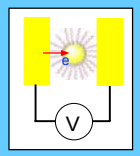
Ultra-small size of nanoclusters implies ultra-small capacitance:

- Room temperature operation.

  $k_BT << \frac{e^2}{2C}$ Æ T ~ 300K

- Strong nonlinearity at useful voltage.

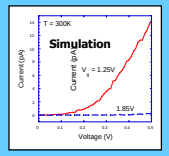
  $V < \frac{e}{C}$ Æ V ~ 1 volt



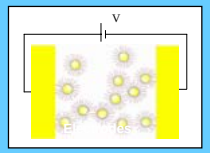
Nonlinearity allows:

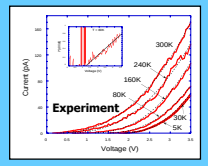
- Switching: Single-electron transistor.
- Electron control: Single-electron pump.

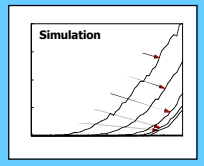
Potential for ultra-small-size and ultra-low-power electronics.



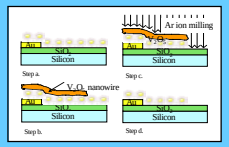
Electrical Characteristics

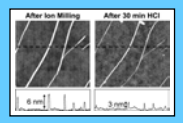


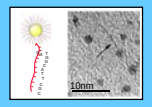


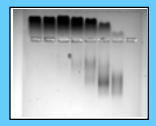


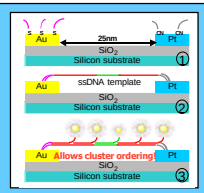
Novel Assembly Schemes



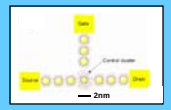




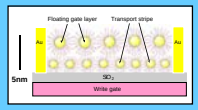




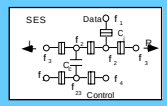
The Future



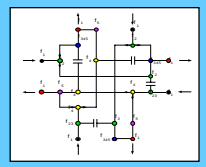
Cluster-based Transistor



Cluster-based Memory



Single-Electron Switch
US Patent #5,838,021



Single-Electron Digital Circuits