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Bimetallic Alloys for Surface Modification of Metal-Insulator-Semiconductor (MIS) Gas Sensors

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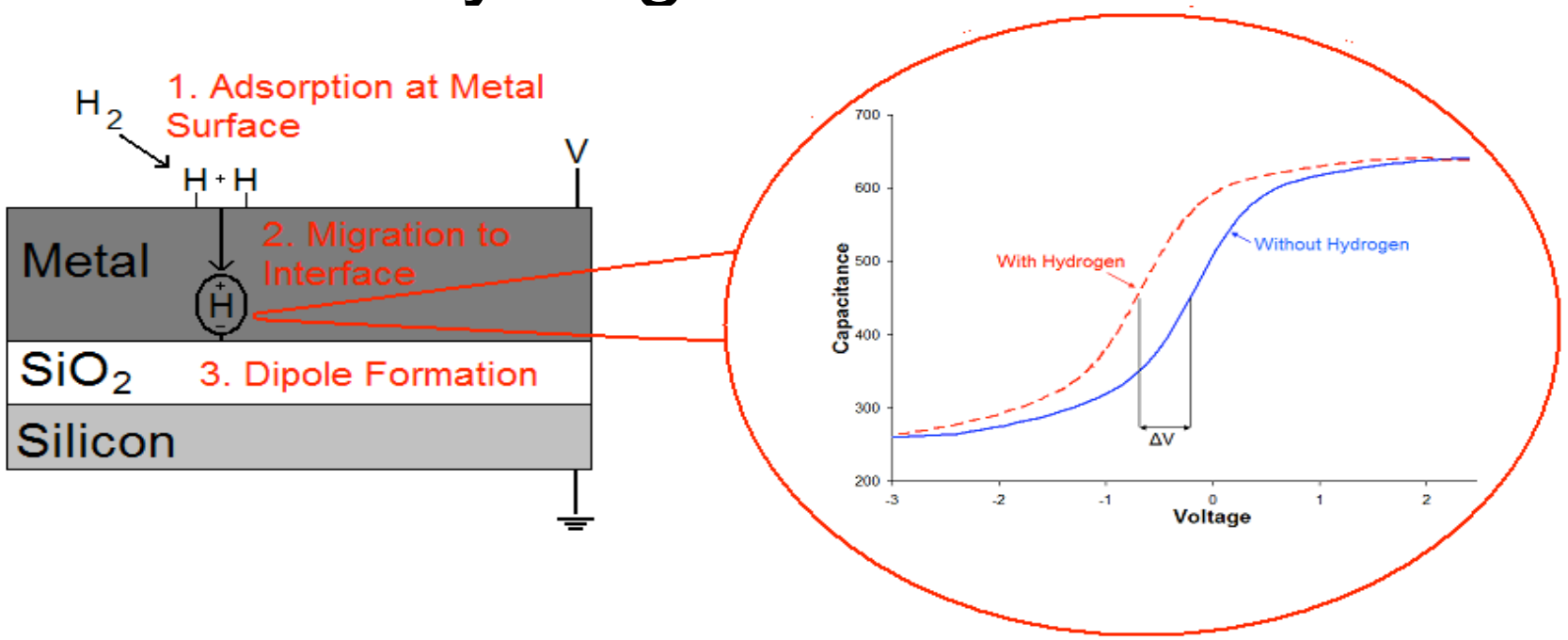
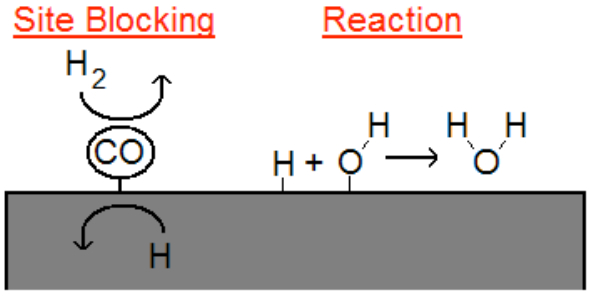
MIS Sensors are Highly Sensitive Hydrogen Detectors



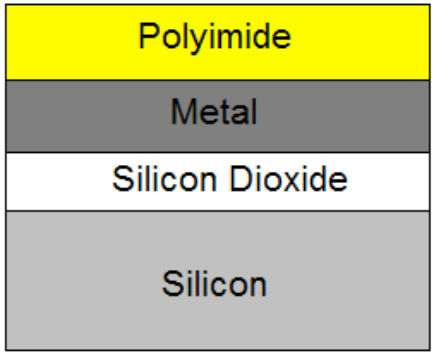


- MIS Sensors are sensitive to hydrogen for over 10 decades of hydrogen pressure[1]
- Numerous applications include gas sensing in transformers, fuel cells, and hydrogen plasmas
- However, limited selectivity has stalled industrial implementation

1. Johansson et al. *J Appl Phys*. *84*, **1998**, 44.

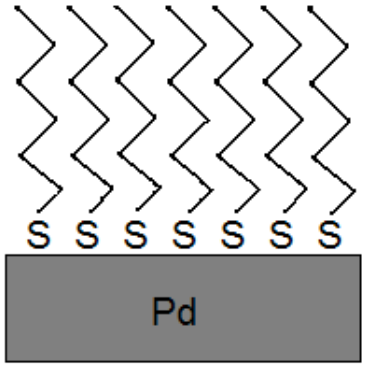
Coating Strategies for MIS Sensors

Polyimide Membranes



- Polyimide membranes exclude effects from hydrocarbons and carbon monoxide
- Effect is primarily diffusion based[1]

Self-Assembled Monolayers

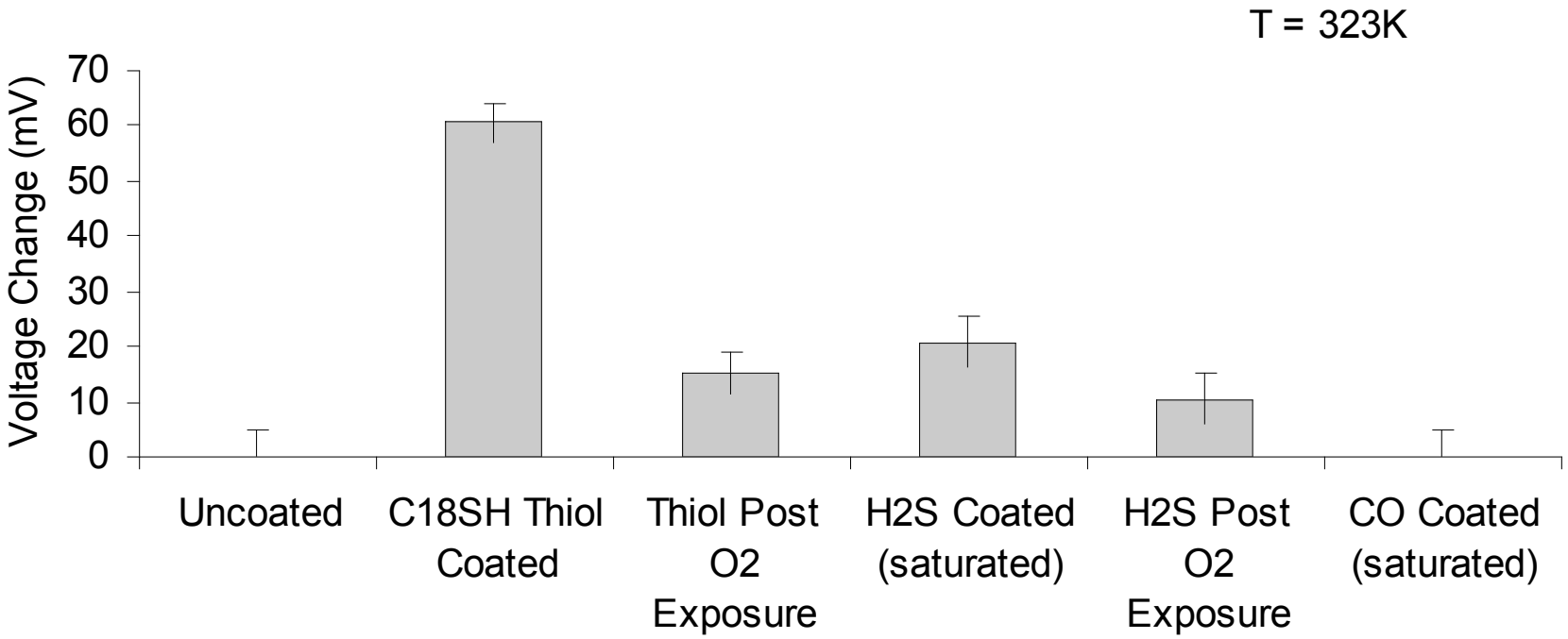


- C_nSH thiols form self-assembled monolayers (SAMs) on metal surfaces
- SAMs' tail group can serve as a platform for additional chemistry

1. Li et al. *Sens Act B*. *115*, **2006**, 86.

Self-Assembled Monolayers Functionalize MIS Sensors

Voltage Change on Addition of 400ppm Acetylene with H_2 Background

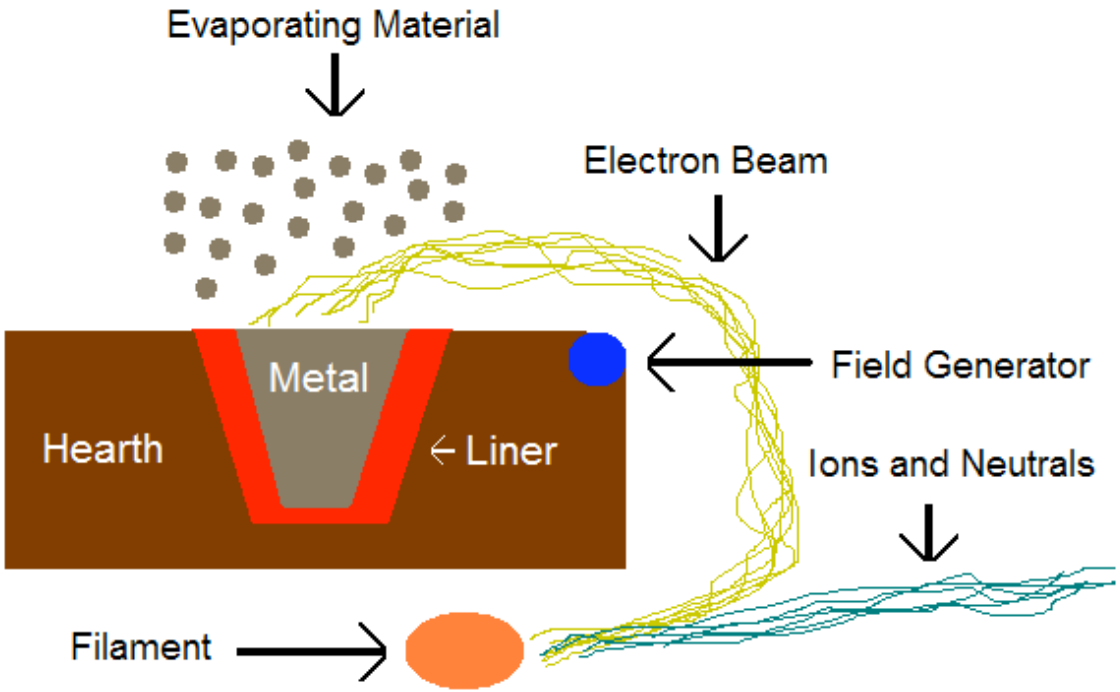


Preventing Oxidation May Lead to a Robust Acetylene Detector

→ Bimetallic Alloys

Bimetallic Alloys Allow for Sensors With Unique Properties

- Alloys can incorporate individual properties of both metals or create new electronic structures
- Deposited through electron beam evaporation



Recent Work Allows Rational Alloy Selection

Pd / Ag

- Silver is used as a promoter for industrial acetylene hydrogenation[1]
- SAMs deposited on silver resist oxidation better than palladium[2]

Pd / Cu

- Palladium-copper alloys resist restructuring under sulfur[3]
- SAMs deposited on copper resist oxidation better than palladium[2]
- Copper alloys very well with palladium[4]

Pd / Au

- Low weight percent gold alloys show heightened response to catalytic activities with sulfur[5]

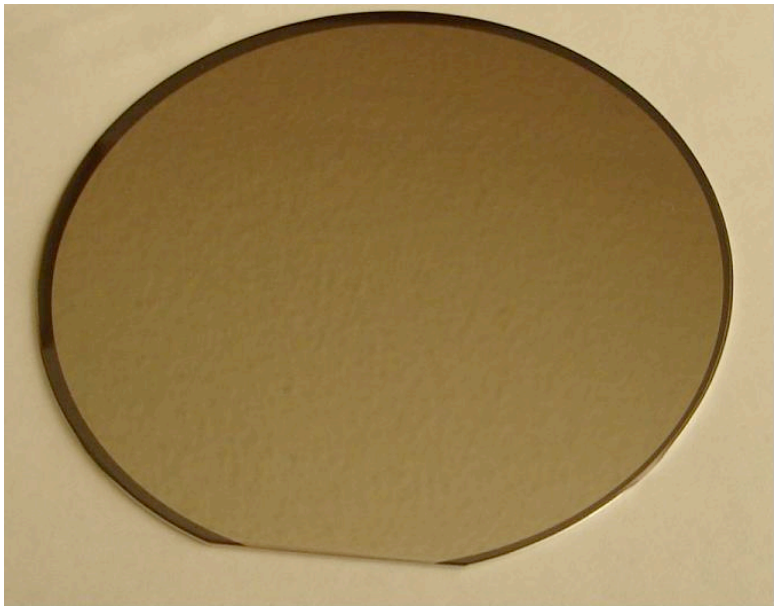
Pd / Ni

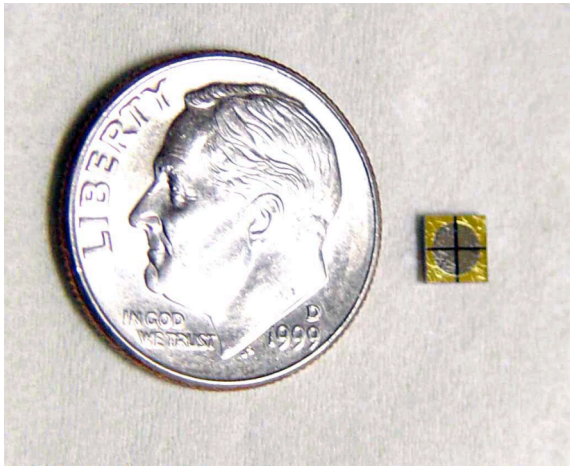
- Tightly binds acetylene and hydrocarbons[6]
- Recent DFT studies suggests Pd/Ni alloys may improve acetylene vs ethylene hydrogenation selectivity[7]

1. Khan et al. *Cat. Let. 108*, **2006**, 159.
2. Love et al. *J. Am. Chem Soc. 125*, **2003**, 2597.
3. Kulprathipanja et al. *J Mem Sci. 254*, **2005**, 49.
4. Ruban et al. *Phys Rev B. 59*, **1999**, 15990.
5. Venezia et al. *J Catalysis. 215, **2003**, 317.*
6. Medlin et al. *J Phys Chem B. 107*, **2003**, 217.
7. Goda et al. *J Phys Chem B. 110, **2006**, 11823.*

Sensors Prepared

Wafer	Metal 1	wt %	Metal 2	wt %
1	Pd	100	-	0
2	Pd	40	Ni	60
3	Pd	60	Ni	40
4	Pd	85	Ni	15
5	Pd	95	Ni	5
6	Pd	60	Ag	40
7	Pd	85	Ag	15
8	Pd	95	Ag	5
9	Pd	60	Au	40
10	Pd	85	Au	15
11	Pd	95	Au	5
12	Pd	60	Cu	40
13	Pd	85	Cu	15
14	Pd	95	Cu	5





All sensors are 50 nm thick and have ohmic contacts placed on both the metal and silicon sides

Conclusions and Ongoing Work

- Limitations in selectivity have prevented widespread implementation of MIS sensors
- Coatings and alloys may improve MIS sensor selectivity
- Sensors prepared at Sandia will be tested with a variety of techniques at the University of Colorado at Boulder

Acknowledgements:

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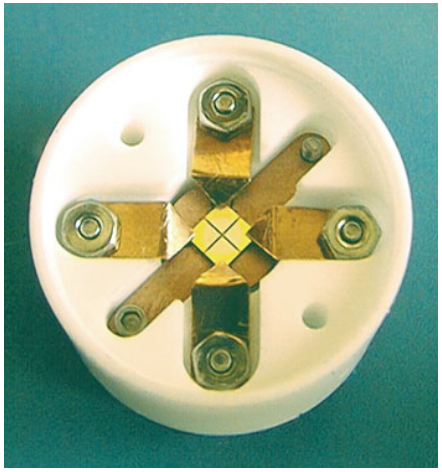
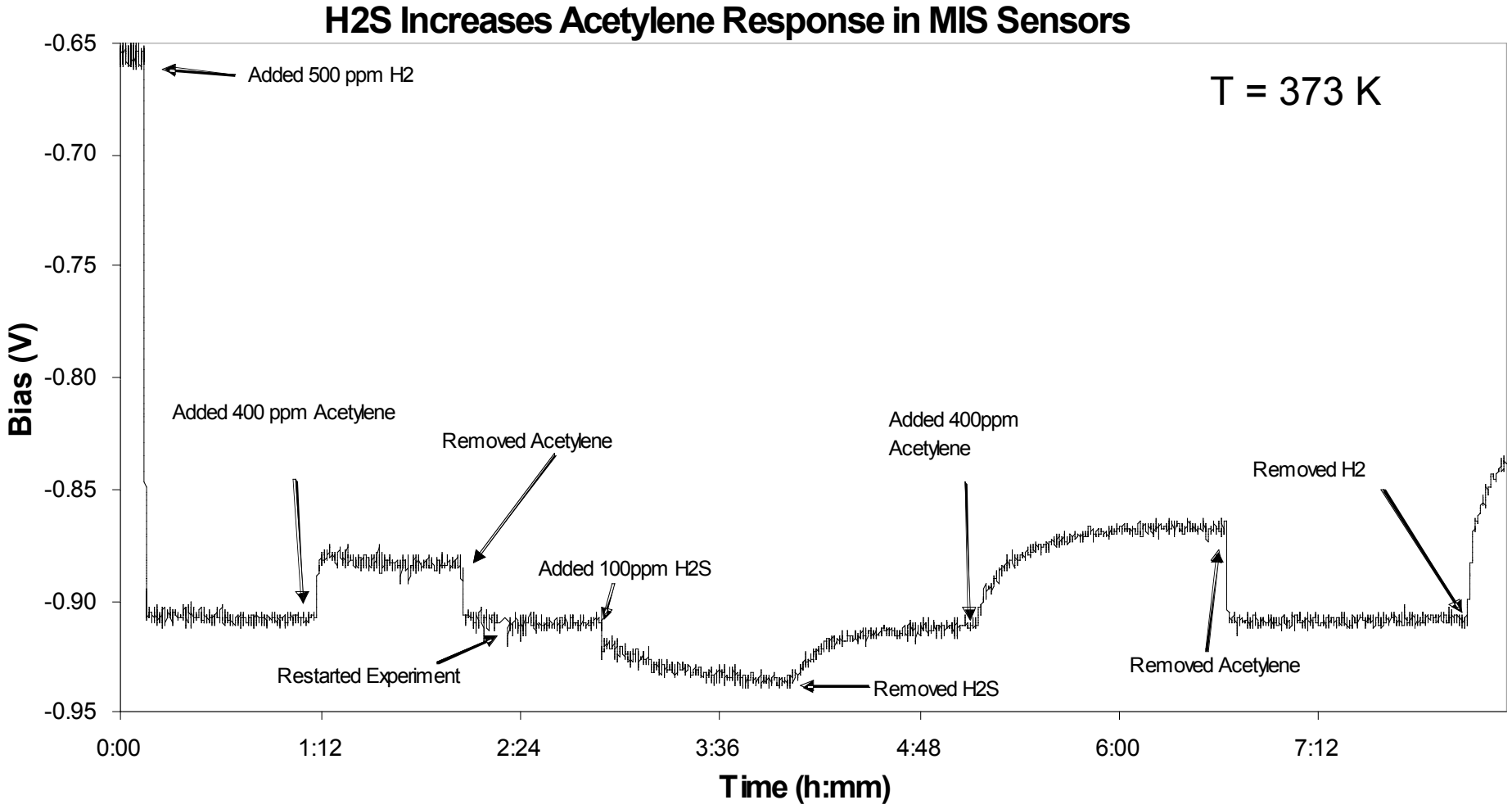


QUESTIONS?


H2S Increases Acetylene Response in MIS Sensors
T = 373 K
Added 500 ppm H2
Added 400 ppm Acetylene
Removed Acetylene
Added 100ppm H2S
Restarted Experiment
Removed H2S
Added 400ppm Acetylene
Removed Acetylene
Removed H2
Bias (V)
-0.65
-0.70
-0.75
-0.80
-0.85
-0.90
-0.95
0:00
1:12
2:24
3:36
4:48
6:00
7:12
Time (h:mm)