ROCHESTER INSTITUTE OF TECHNOLOGY
MICROELECTRONIC ENGINEERING

RIT CHEMICAL SENSORS

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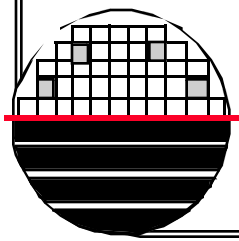
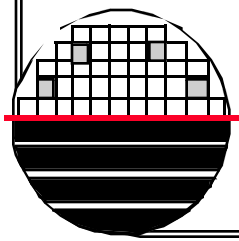


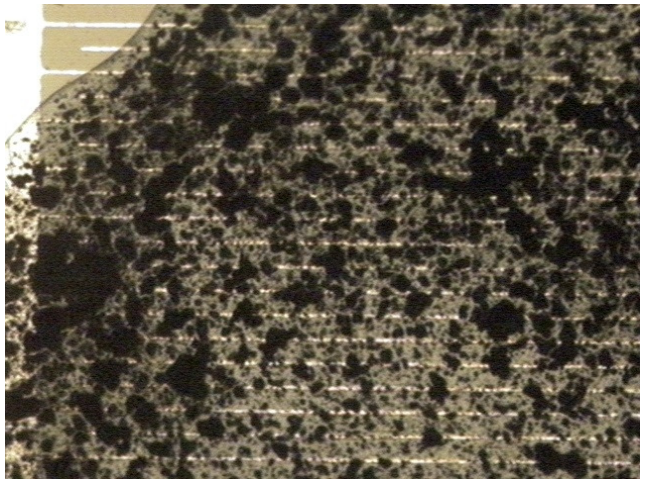
OUTLINE

Introduction
Chem Resistors
Modeling of Resistance Change
    Parallel
    Series
Coatings
Test Results

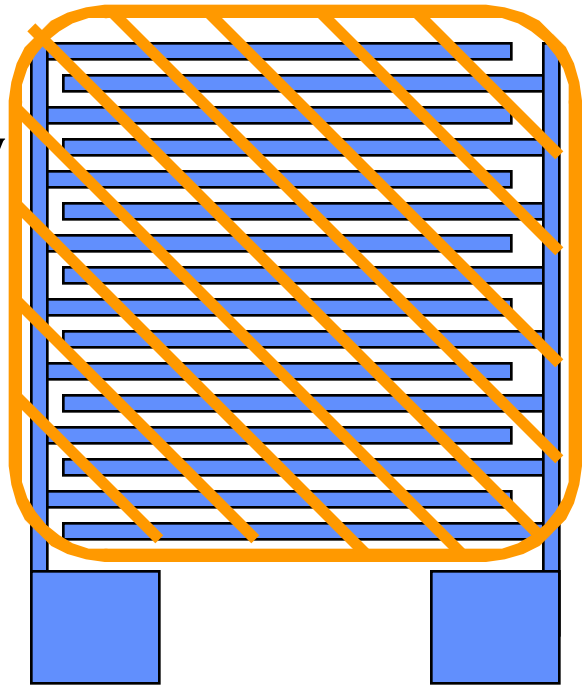


CHEMIRESISTOR

Simple interdigitated electrodes coated with a chemically sensitive layer that changes the resistance in response to a few ppm of some (or many) chemicals



For example: carbon black mixed with polymer, the polymer swells breaking some of the carbon black connections increasing resistance of the sensor



Resistor with
25µm gaps
25µm length
7250µm width

MODELING OF PARALLEL RESISTANCE CHANGE

If each resistor is identical with value equal to 400 ohms, what is the total resistance?

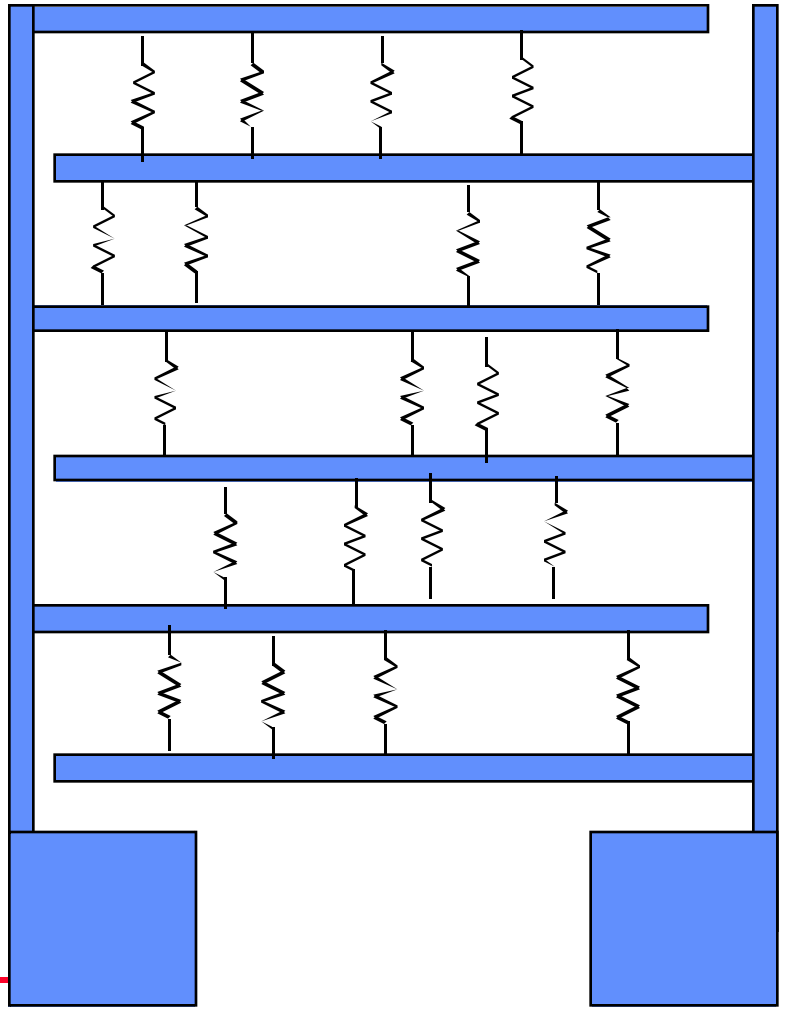
Answer 20 ohms

If two of the resistors in each row open circuits, what is the total resistance?

Answer 40 ohms

If two resistors in one row open circuits, what is the total resistance?

Answer 22.22 ohms or 11%



MODELING OF SERIES RESISTANCE CHANGE

If each resistor is identical with value equal to 400 ohms, what is the total resistance?

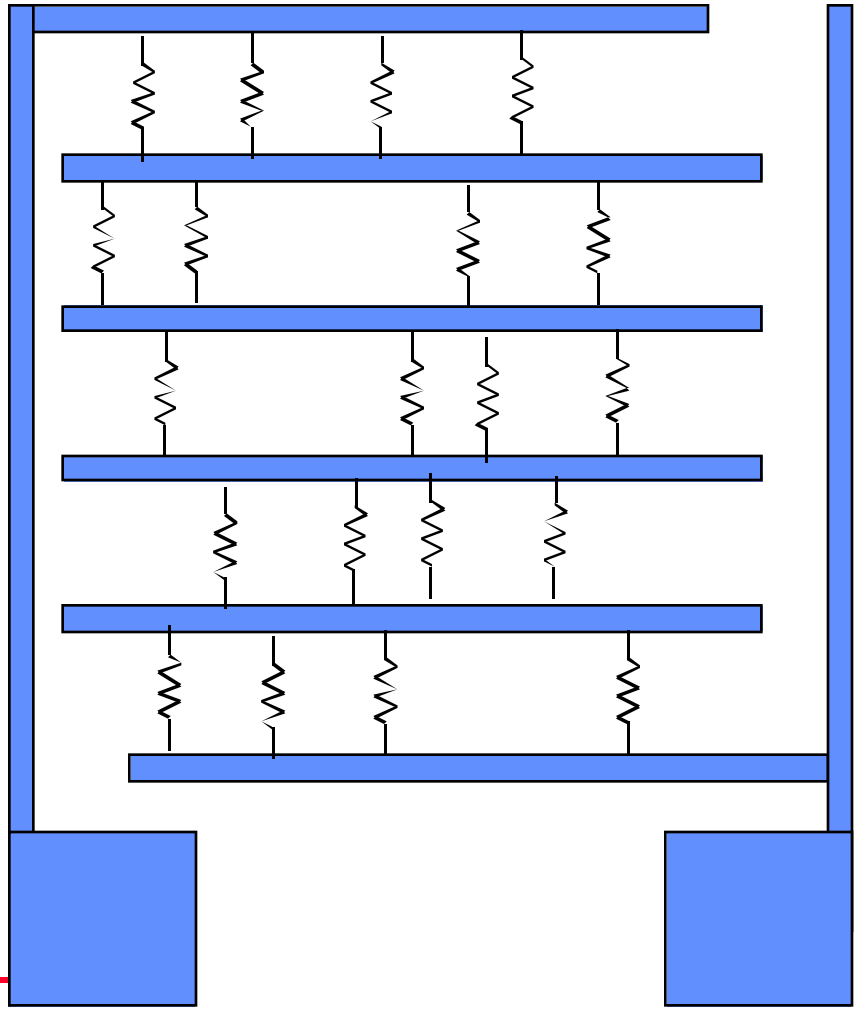
Answer 500 ohms

If two resistors in each row open circuits, what is the total resistance?

Answer 1000 ohms

If two resistors in one row open circuits, what is the total resistance?

Answer 600 ohms or 20%

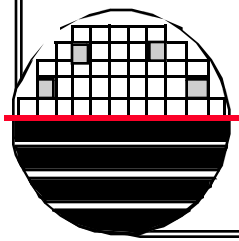


SUMMARY OF MODELING

Series architecture with coatings whose resistance increases in the presence of some chemical being detected gives more sensitivity

Parallel architecture with coatings whose resistance decreases in the presence of some chemical being detected gives more sensitivity.

If the coating is perfectly uniform and responds uniformly then both architecture approaches give identical results.

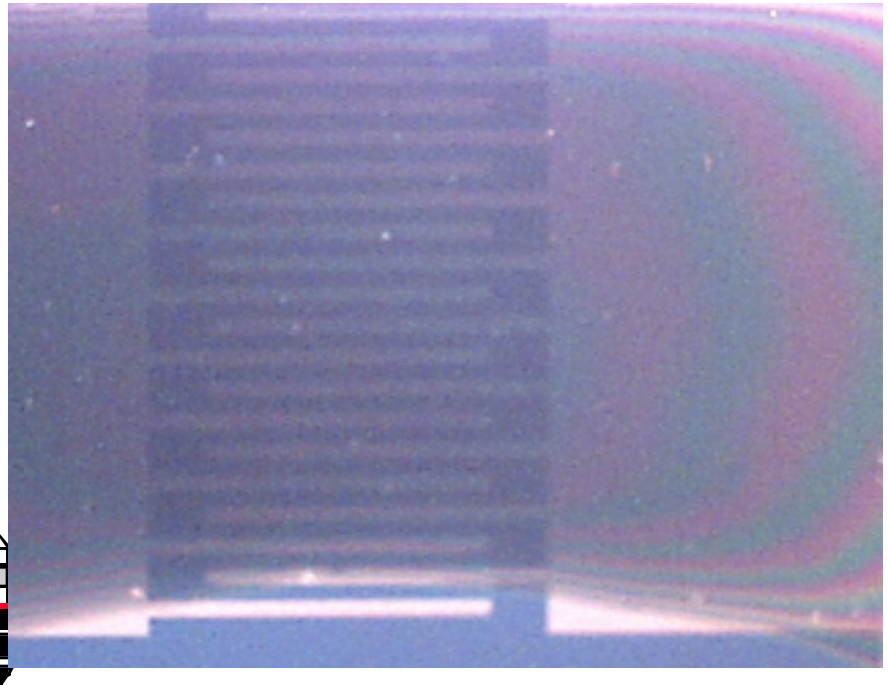


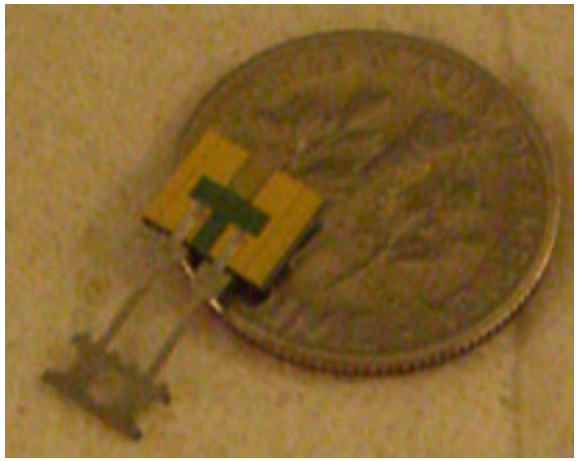
DEFINITION OF TERMS

ISE – Ion Sensitive electrodes
ISFET – Ion Sensitive Field Effect Transistor
Ionophore – compounds that allow specific ions to move through a membrane that they otherwise would not be able to pass through.
Oligomer – low molecular weight monomers often used with photocurable polymers
Polymer- major substance in a coating film, gives the film strength
Permselectivity – intrinsic ion selectivity of the polymer film itself
Plasticizer – increases the plasticity of a substance, making it more flexible, prevent cracking,
Solvent – any substance that dissolves another substance. Allows the substance to flow for coating purposes.
Phthalates – one type of plasticizer commonly used but is a Teratogen (causes birth defects) restricted use since 1976 in Europe
UV Blocker – blocks ultraviolet radiation
Rheological Properties – flow characteristics
Photoinitiator – causes cross linking in the presents of light
Crosslinker – used with low molecular weight monomers, causes cross linking

COATING TO DETECT ETHANOL

- 2 μm of (3,4-polyethylenedioxythiopene-polystyrenesulfonate) PEDOT polymer is applied to interdigitated electrodes and cured at 100 °C for 30 minutes
- PEDOT is a conductive polymer which upon exposure to ethanol vapors, will adsorb the ethanol causing the polymer to swell which results in a measurable change of resistance across the electrodes



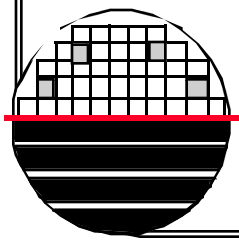


Steve Parshall, Dr. KSV
May 2006

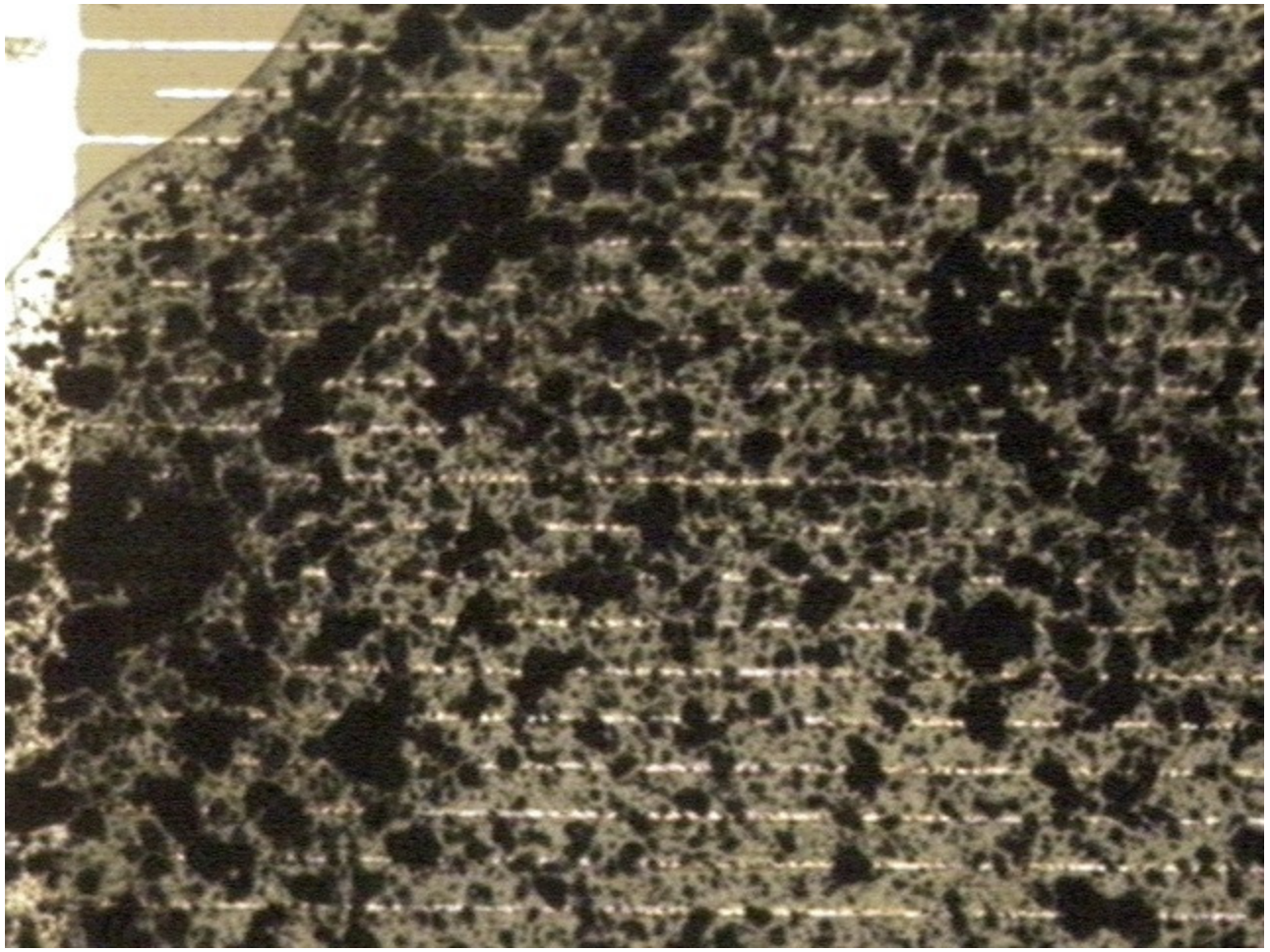
COATINGS

Carbon Black mixed with Airplane Glue (Bond 527 Multipurpose Cement) is sensitive to Acetone and isopropynol

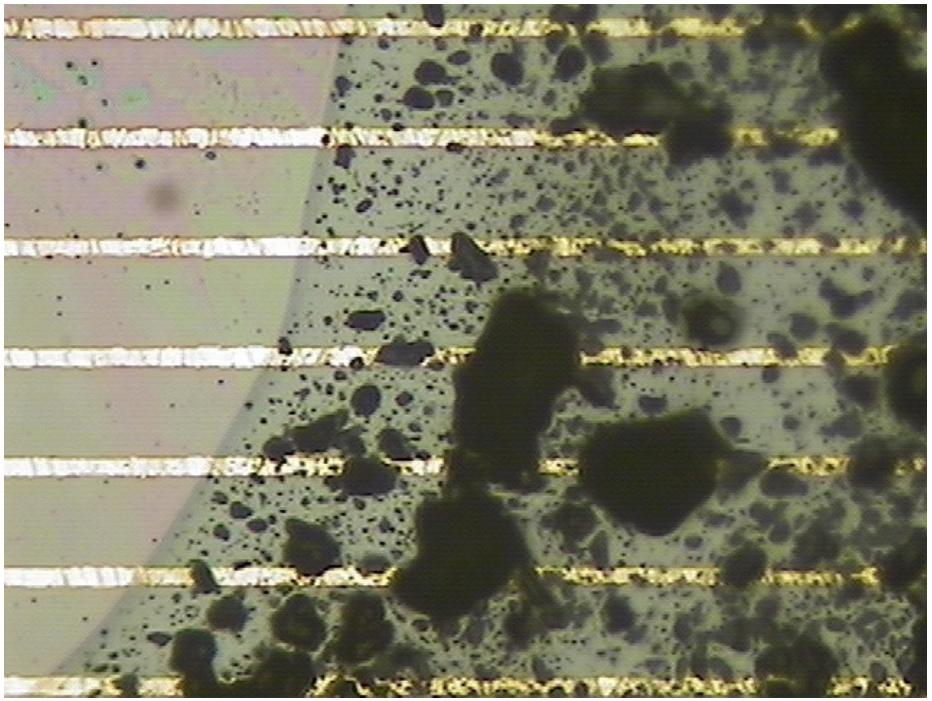
Carbon Black mixed with Nailpolish is sensitive to Acetone.

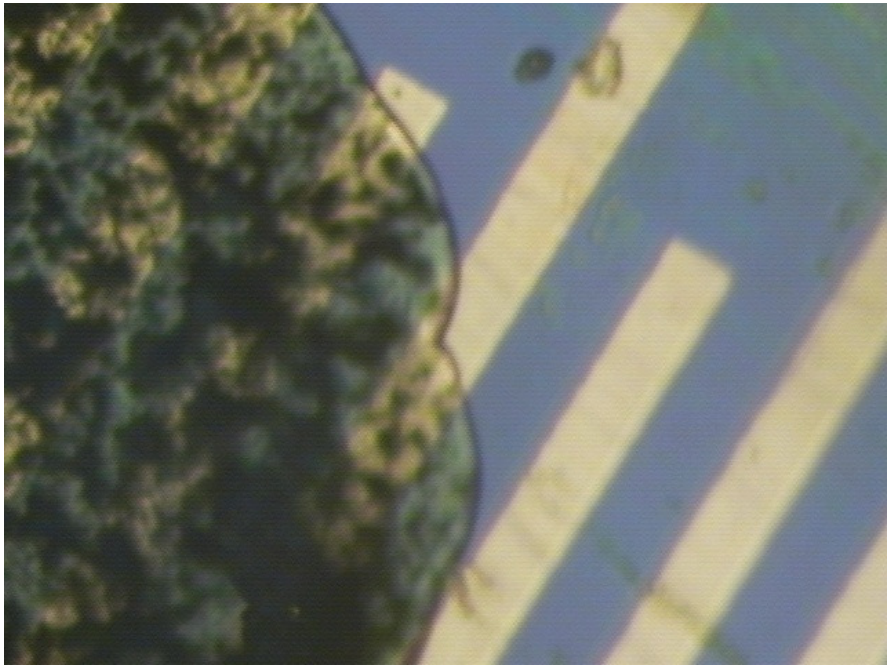


CARBON BLACK MIXED WITH AIRPLANE GLUE

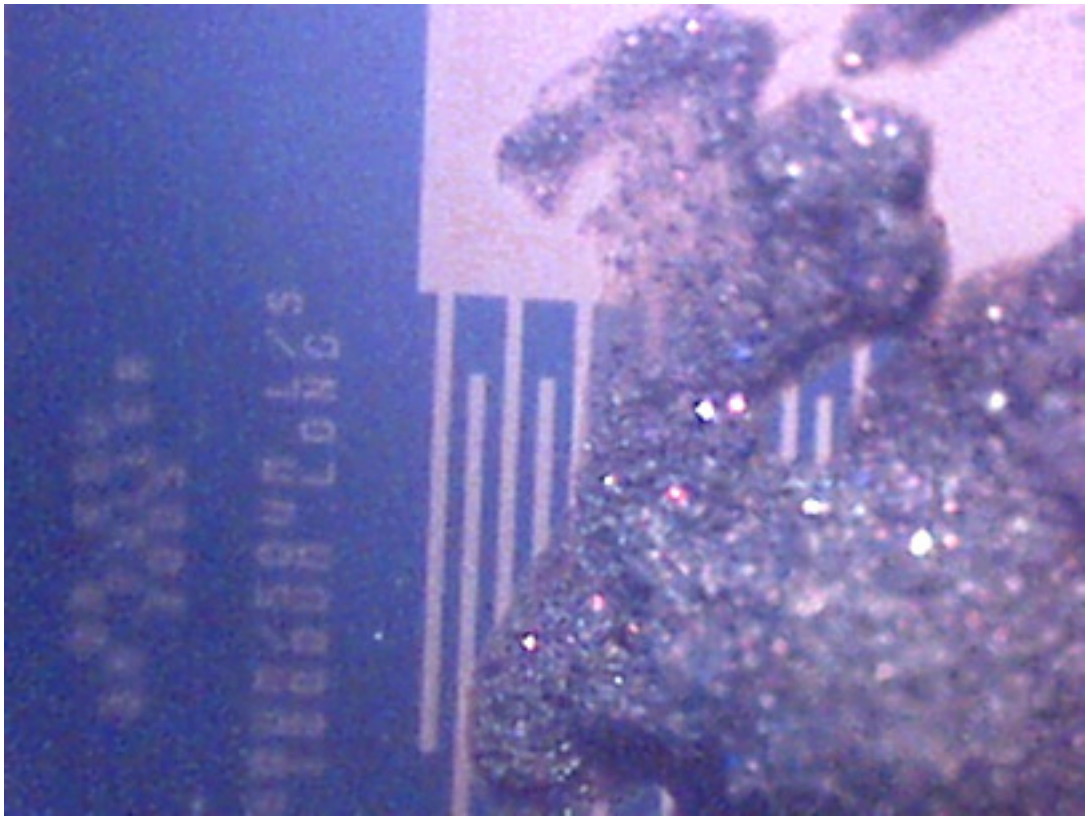


CARBON BLACK MIXED WITH AIRPLANE GLUE



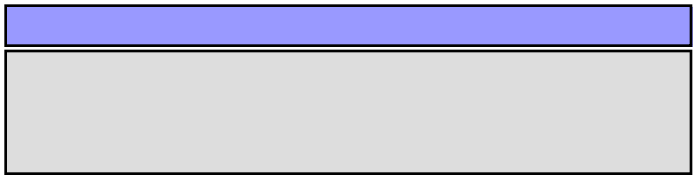


THICK COATING

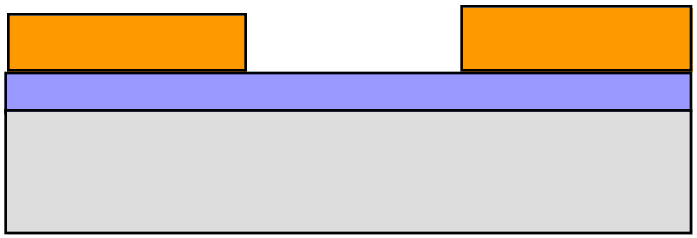


Thinner coatings are more sensitive

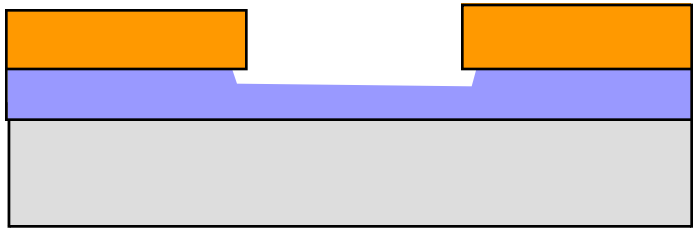
TYPICAL FABRICATION DETAILS



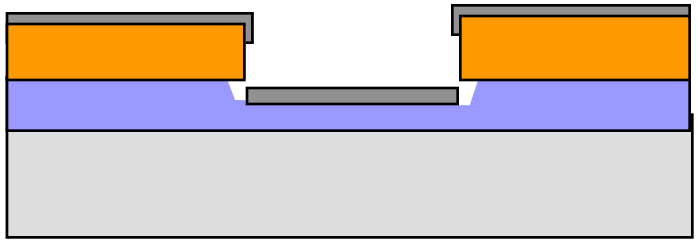
Glass wafer or Silicon wafer with 10,000Å oxide on it



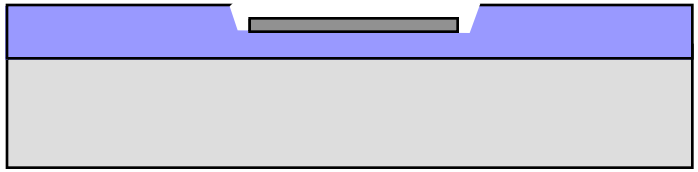
Normal Positive Photoresist Via



Over etch to create undercut



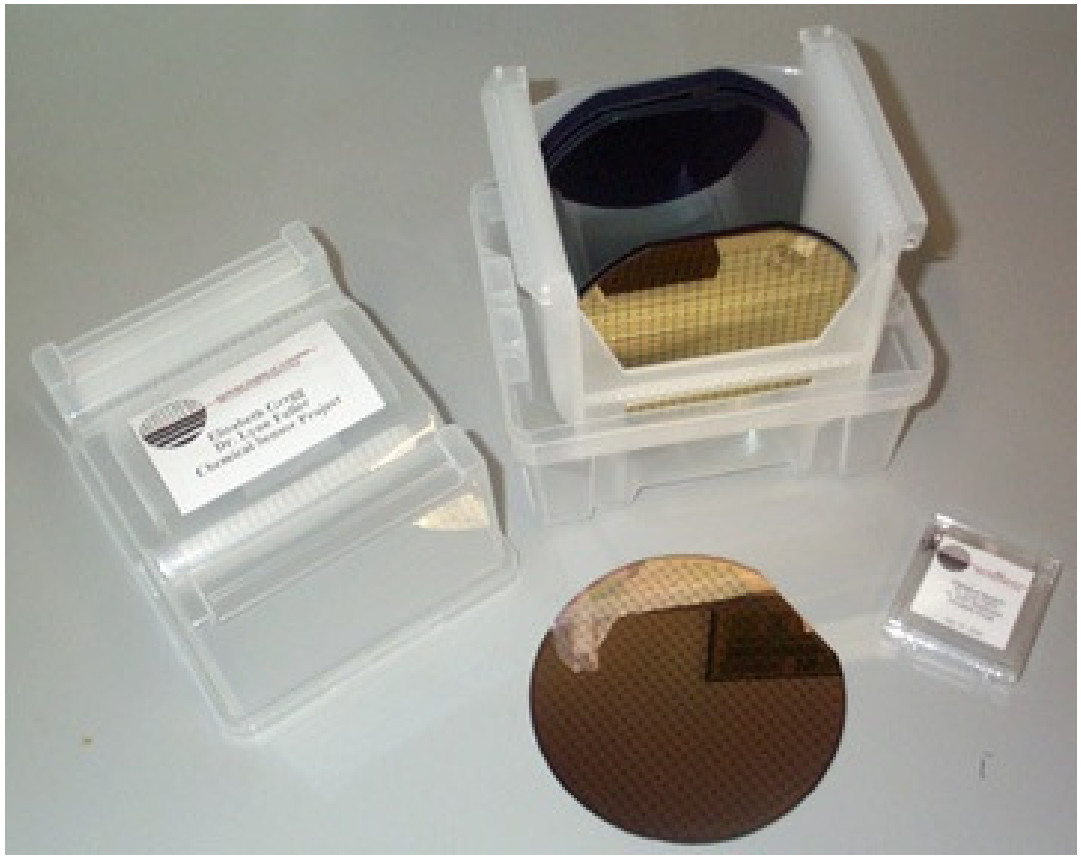
Deposit Metal for Fingers and Pads



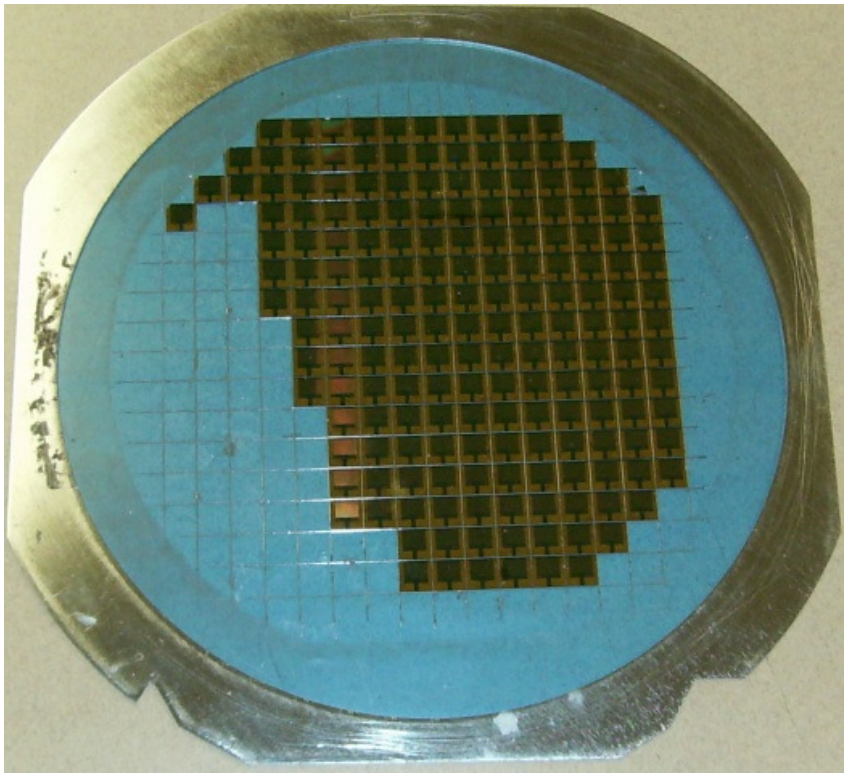
Lift-Off in Acetone and ultrasonic

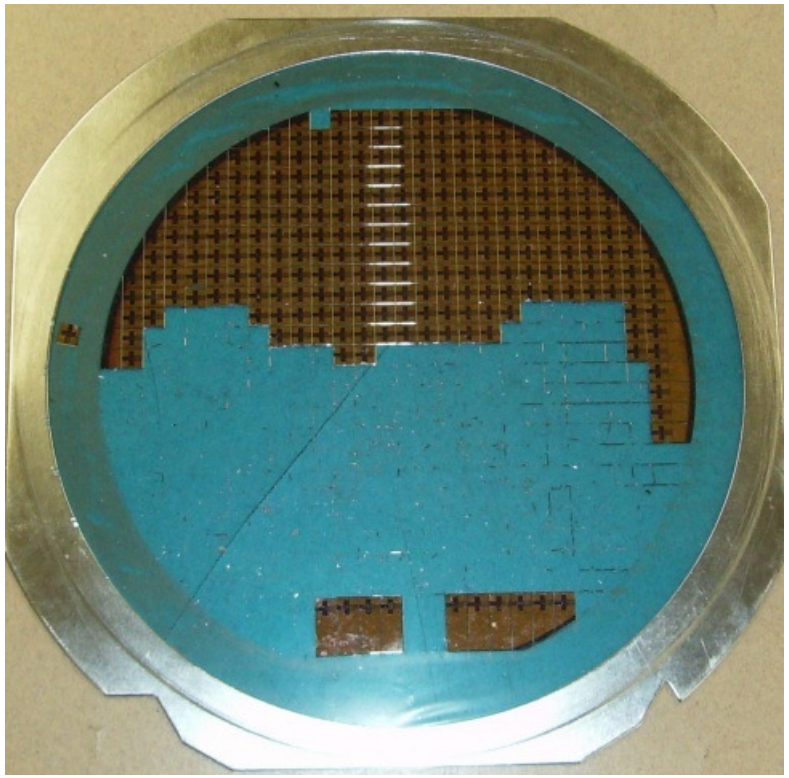
Many variations exist including: etch metal instead of lift-off, different metals or multiple layers of metal, solder bumps, etc

FINISHED WAFERS OF CHEMICAL SENSORS



WAFERS OF SENSORS CUT (SOME REMOVED)

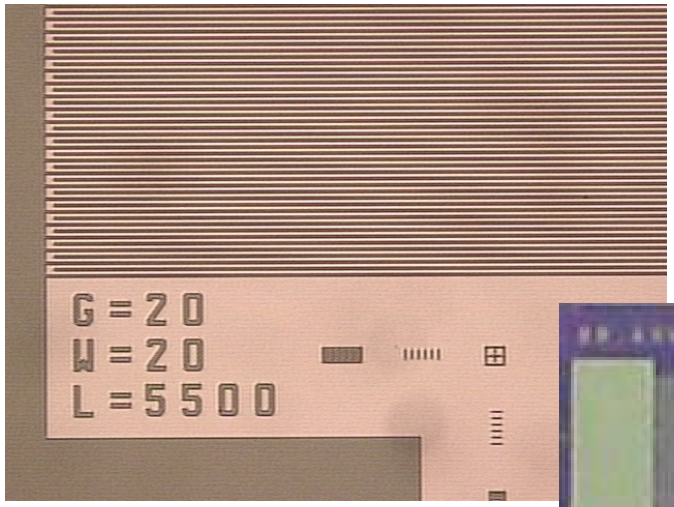




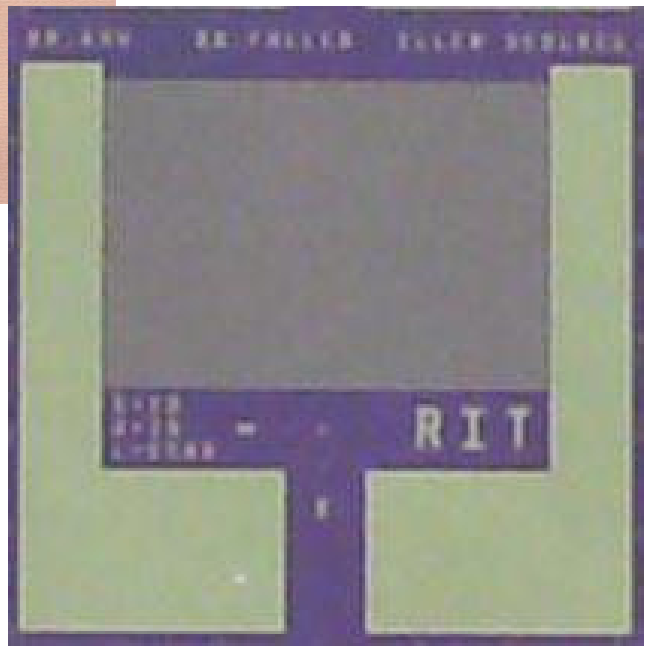
Ellen Sedlack

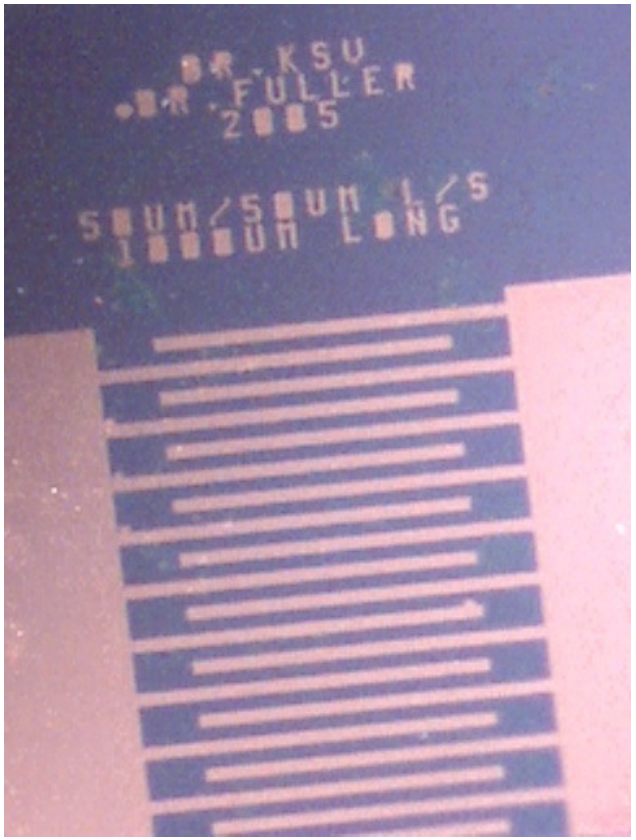
Rochester Institute of Technology
Microelectronic Engineering

PARALLEL ARCHITECTURE

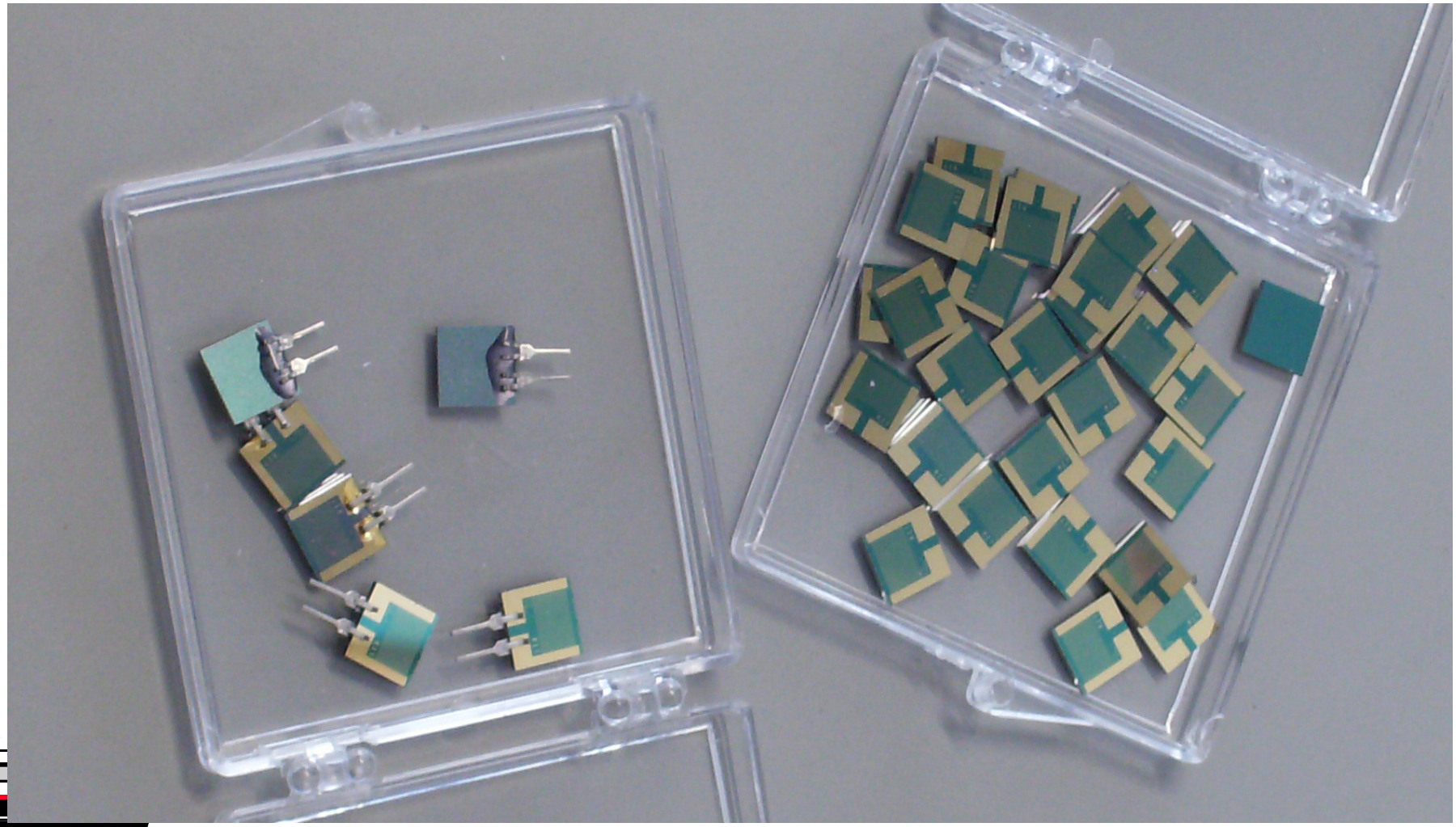


Ellen Sedlack

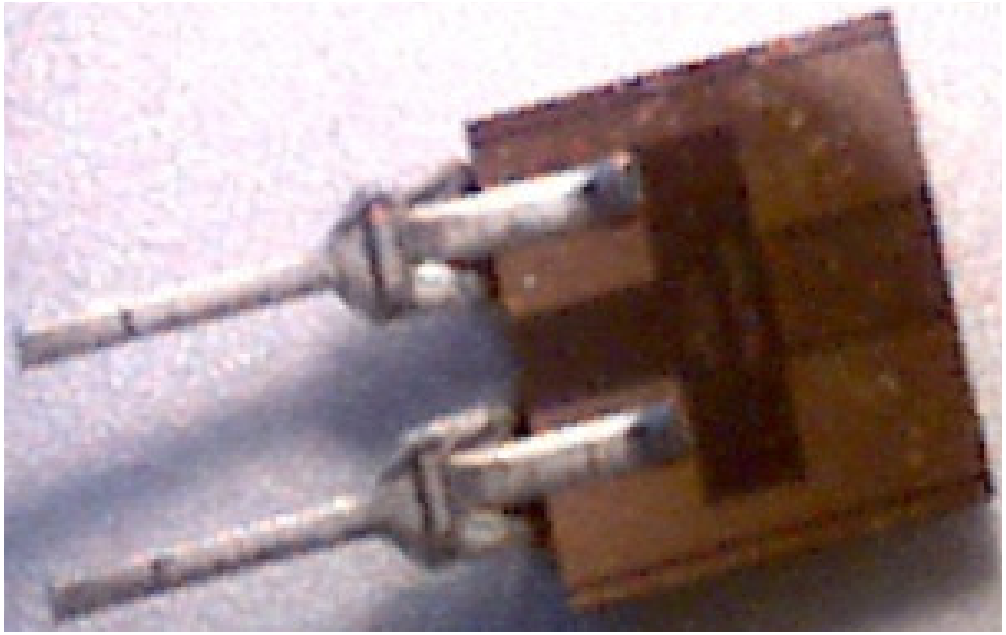


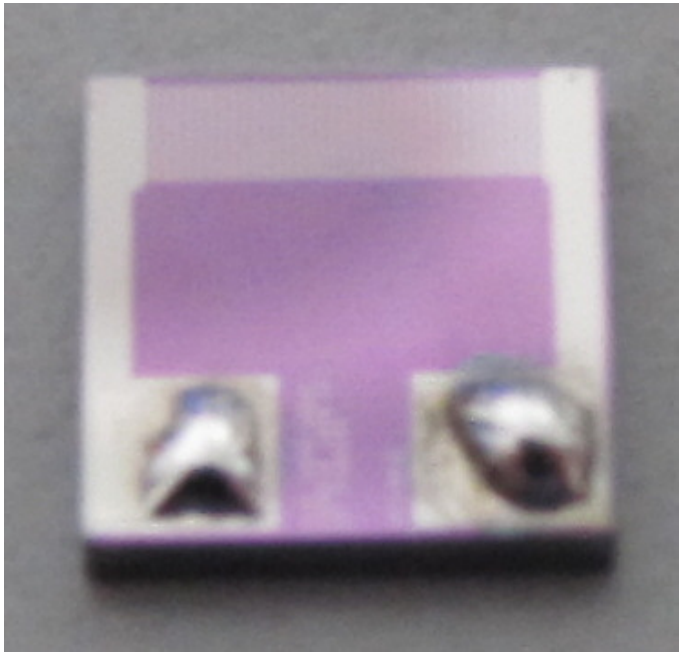


COMPLETED ELECTRODES



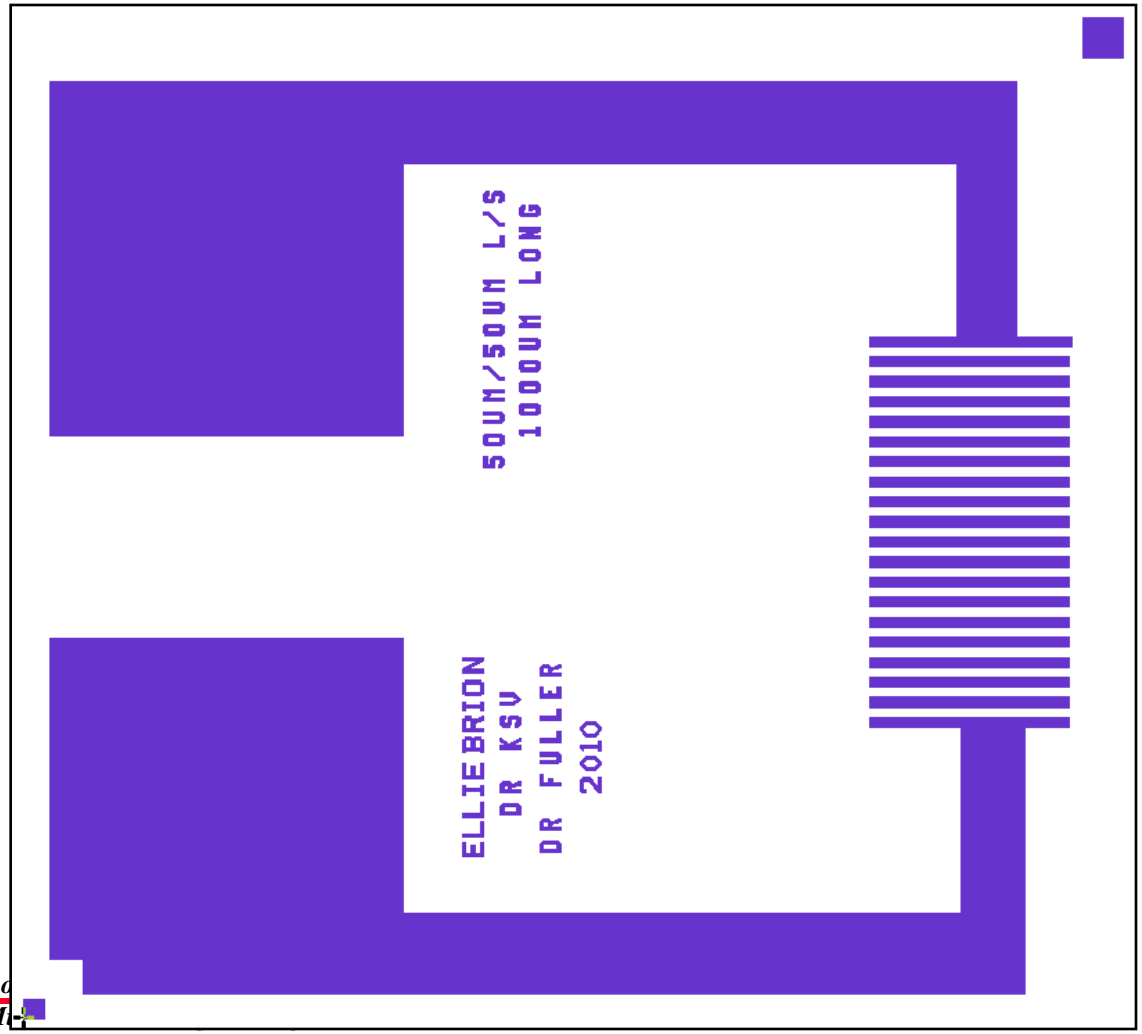
COMPLETED ELECTRODES





Left: Sensor chip (no coating) with clip on pins
Right: Sensor chip with solder connections

CHEMICAL SENSOR USING SERIES ARCHITECTURE



GAS CONCENTRATION CALCULATOR

Rochester Institute of Technology — **20-Mar-06**

Microelectronic Engineering — **Dr. Lynn Fuller**

Concentration Calculations:

When testing chemical sensors it is important to know the concentration of the chemical to determine the sensitivity. For chemicals that are available as a liquid but evaporate in a volume of air, one can use the following equation to find the concentration in parts per million (ppm)

Concentration (in ppm) = [Weight (mg) / Chamber volume (m^3)] X [Volume of one mole of air (L/mole) / Molecular weight of sample (g/mole)]

To use this spread sheet input values in the white boxes and results will be displayed in purple boxes

volume of liquid =	0.0002	ml
mass of liquid = volume x density	0.1632	mg
Chamber volume =	0.00025	m^3
Volume of air =	24.45	L/mole
molecular wt sample=	46.06952	g/mole
Concentration in ppm =	346	ppm

Example:

Chamber of 1 Liter = 1000 cm^3 = 0.001 m^3

Volume of air = 24.45 L/mole

note: valid at T=25°C and P=760 mm Hg

Data:

Chemical name	Chemical formula	Molecular weight	Density Kg/m^3	Select one entry = 1, others = 0
methanol	CH_3OH	32.04243	810	0
ethanol	CH_3CH_2OH	46.06952	816	1
2-propanol	$CH_3CH_2CH_2OH$	60.09661	804.13	0
acetone	CH_3COCH_3	58.08	784.58	0

Reference: http://www.ilpi.com/msds/ref/concentration.html

BAC = Blood Alcohol Concentra

BAC = wt. In gm of ethanol/100

BAC = wt. In gm of ethanol/210

Chamber Volume = 0.25

0.000163

210

0.137088

Ex: 0.0002ml ethanol in250 mL which is equivalent to 346 ppm

POLYMERS USED TO MAKE SENSORS

Air Plane Glue

Bond adhesives Co., Multipurpose Adhesive 527

From the MSDS:	Nitrocellulose (polymer)	25%-X%
	Trade Secret (plasticizer)	X%
	Acetone (solvent)	66%
	Isopropanol (solvent)	7%
Propylene Glycol	Monoethyl Ether (rheological properties)	4%

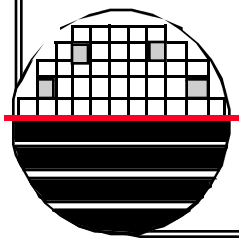
Nail Polish

Cellulose Acetate Solution

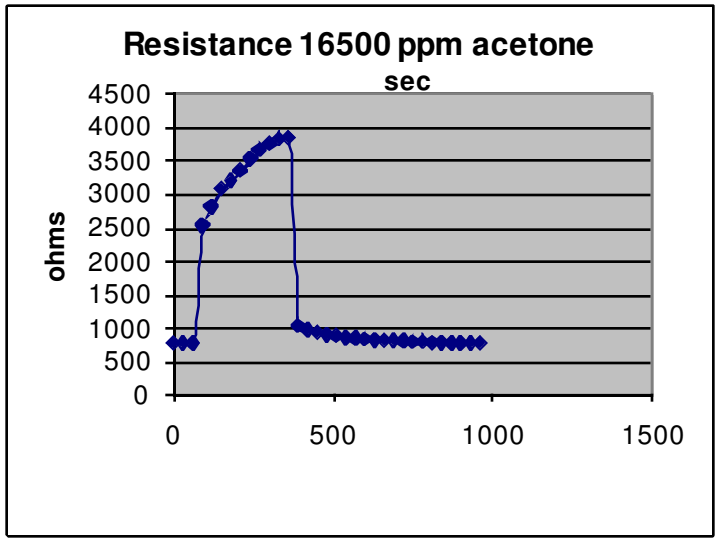
From the MSDS:	Nitrocellulose (polymer)	10%
	Di butyl Phthalate (plasticizer)	1%
	Camphor (aromatic)	5%
	Benzophenone-1 (UV Blocker)	1%
	Toluene (solvent)	5%
	Butyl acetate (solvent)	25%
	Ethyl Acetate (solvent)	45%
	Isopropyl Alcohol (solvent)	5%

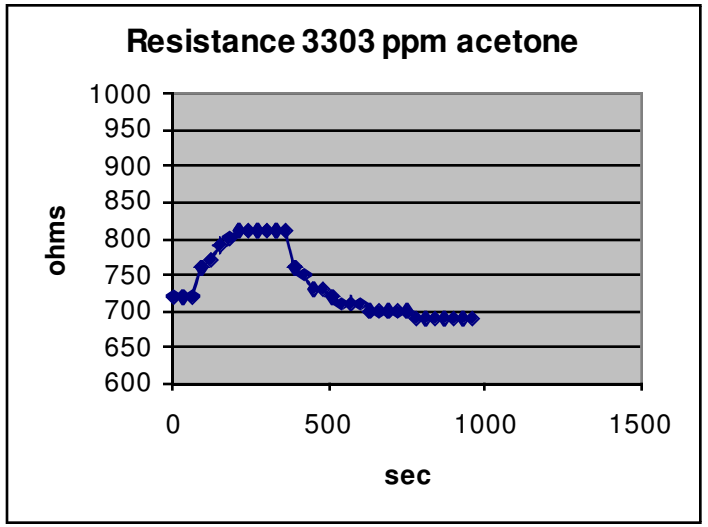
MECHANISM OF POLYMER SWELLING

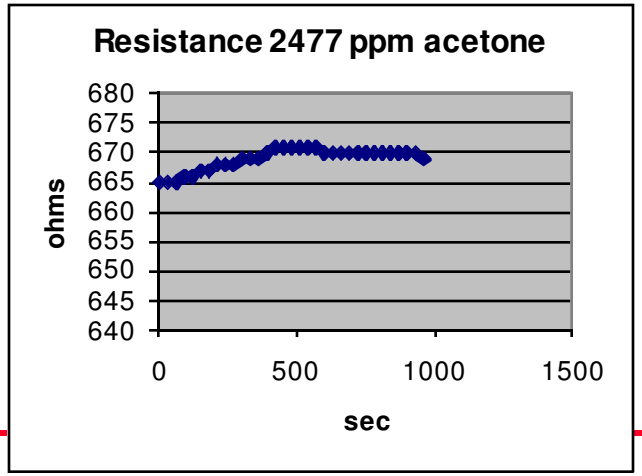
Solvents interact with the polymer, plasticizer or other additives in the film causing swelling. For example nail polish and airplane glue have the same base polymer, Nitrocellulose, which swells in the presence of acetone and both show acetone sensitivity. Nail polish does not show sensitivity to alcohol but air plane glue does so one explanation is that the alcohol sensitivity in air plane glue is due to the type of plasticizer used.

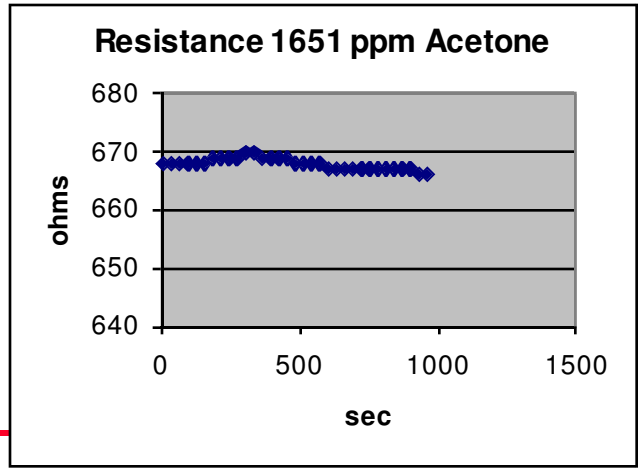


AIR PLANE GLUE / CARBON BLACK TEST RESULTS

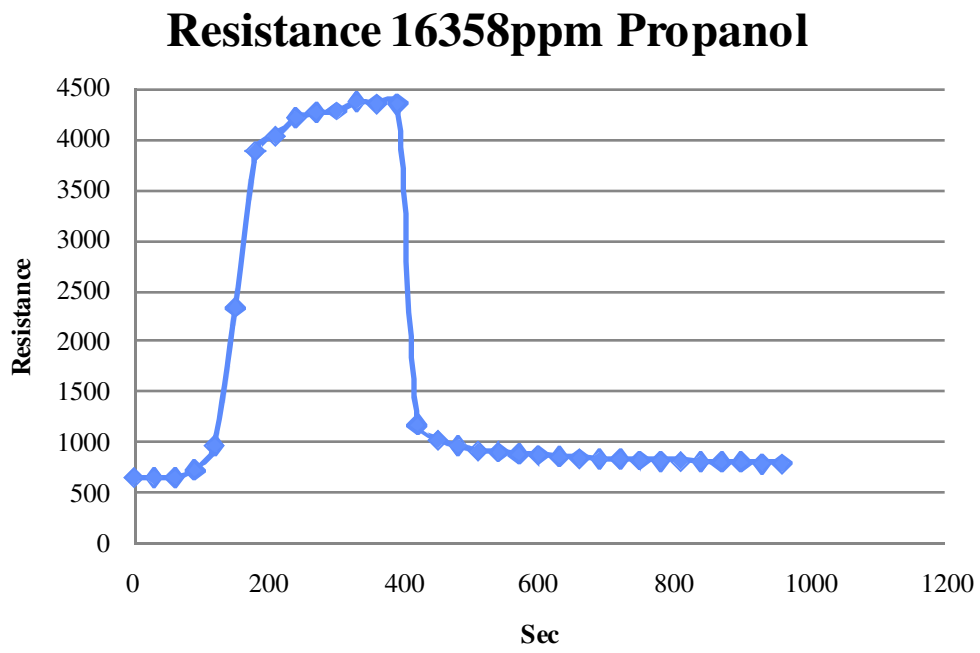


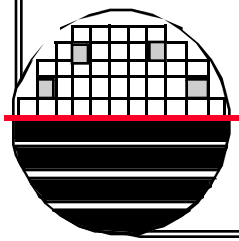






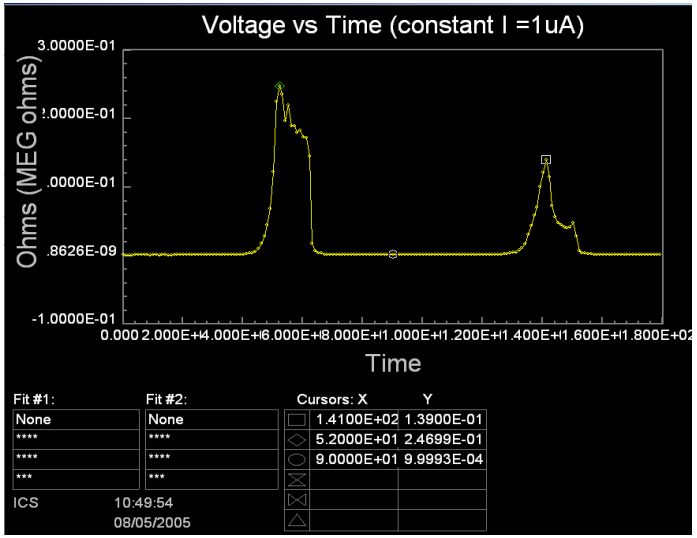
AIR PLANE GLUE RESPONSE TO PROPANOL



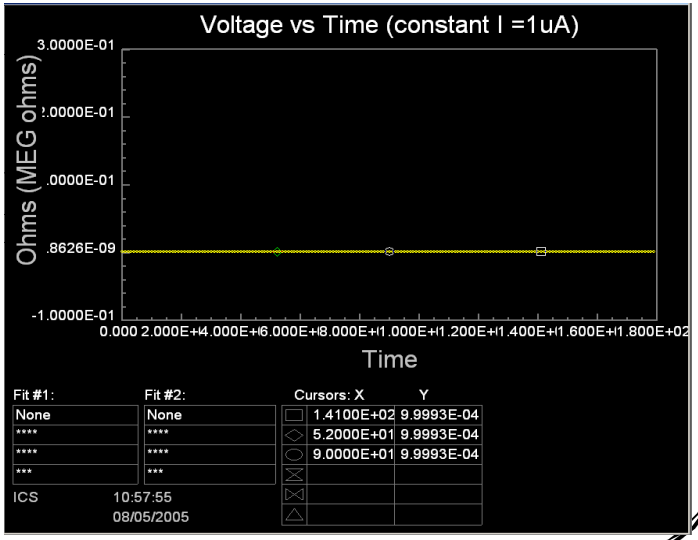


NAIL POLISH / CARBON BLACKRESPONSE TO ACETONE AND ISOPROPANOL

30s off, 30s on, 60s off, 30s on, 30s off
0.5 ml Acetone/ 125 ml bottle = 4000 ppm
Resistance goes from ~100 ohms (no vapor) to ~ 100,000 ohms (with vapor)



30s off, 30s on, 60s off, 30s on, 30s off
Isopropanol ~ 10,000 ppm
No Response



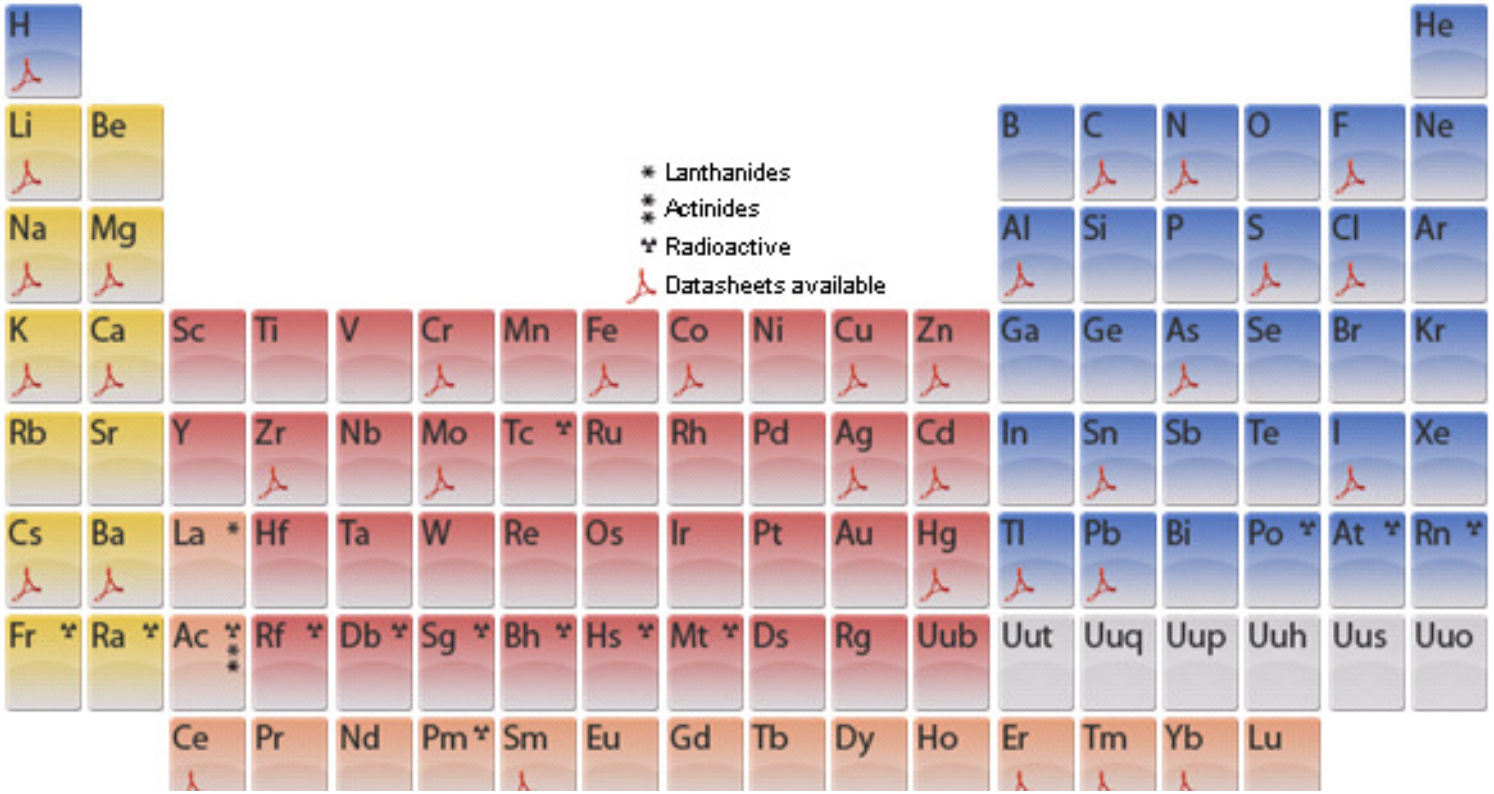
ELLIE BRION

SIGMA ALDRICH – SENSOR APPLICATIONS

http://www.sigmaaldrich.com/analytical-chromatography/analytical-reagents/sensoric-applications.html

Interactive Periodic System of Elements

Explore the interactive periodic table below to locate available data sheets that describe the preparation of the membranes, applicati guides, technical data and references.



SIGMA ALDRICH ION SELECTIVE MEMBRANES FOR CHLORINE

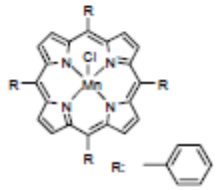
Fluka Analytical

sigma-aldrich.com

Sigma-Aldrich Chemie GmbH · Industriestrasse 25 · Postfach · CH-9471 Buchs / Schweiz
Tel. +41 / 81 755 25 11 · Fax +41 / 81 756 54 49 · Flukatec@sial.com

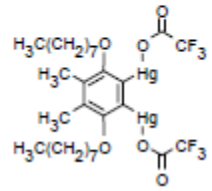
Two of 6 ionophores

Chloride



Chloride ionophore I
(*meso*-Tetraphenylporphyrin manganese(III)-chloride complex; Mn(II)TPPCl)
$C_{44}H_{28}ClMnN_4$ M, 703.12 [32195-55-4]

24897 **Selectophore®, function tested** 50 mg



Chloride ionophore II
(ETH 9009; 4,5-Dimethyl-3,6-dioctyloxy-o-phenylene-bis(mercurytrifluoroacetate))
$C_{28}H_{40}F_6Hg_2O_6$ M, 987.79 [1458889-57-2]

24901 **Selectophore®, function tested** 25 mg

One of several Cocktail Recipes

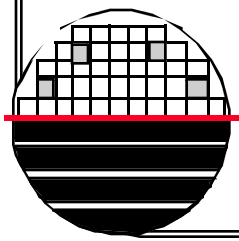
Electrochemical Transduction

Ion-Selective Electrodes

Application 1 and Sensor Type [1,2]
Assay of Cl^- activity with solvent polymeric membrane electrode based on Chloride ionophore II.

Recommended Membrane Composition

2.00	wt%	Chloride ionophore II (24901)
0.03	wt%	Tridodecylmethylammonium chloride (91661)
64.97	wt%	Bis(2-ethylhexyl) sebacate (84818)
33.00	wt%	Poly(vinyl chloride) high molecular weight (81392)



ELECTRODE ARRAYS AVAILABLE FROM RIT

ELECTRODE ARRAYS AVAILABLE FROM RIT

MODEL #	METAL MATERIAL	SUBSTRATE MATERIAL	TYPE	WIDTH	SPACE	LENGTH	NUMBER OF ELEMENTS	PRICE EACH
Ta50-10-37Si	Ni/Ta/TaN	Silicon*	SERIES	50 µm	50 µm	1000µm	37	$5.95 each
Ta50-37-20Si	Ni/Ta/TaN	Silicon*	PARALLEL	50 µm	50 µm	3700µm	20	$5.95 each
Ta20-37-40Si	Ni/Ta/TaN	Silicon*	PARALLEL	20 µm	20 µm	3700µm	40	$5.95 each
Ta10-37-100Si	Ni/Ta/TaN	Silicon*	PARALLEL	10 µm	10 µm	3700µm	100	$5.95 each

MODEL #	METAL MATERIAL	SUBSTRATE MATERIAL	TYPE	WIDTH	SPACE	LENGTH	NUMBER OF ELEMENTS	PRICE EACH
Ta50-10-37G	Ni/Ta/TaN	Glass	SERIES	50 µm	50 µm	1000µm	37	$9.95 each
Ta50-37-20G	Ni/Ta/TaN	Glass	PARALLEL	50 µm	50 µm	3700µm	20	$9.95 each
Ta20-37-40G	Ni/Ta/TaN	Glass	PARALLEL	20 µm	20 µm	3700µm	40	$9.95 each
Ta10-37-100G	Ni/Ta/TaN	Glass	PARALLEL	10 µm	10 µm	3700µm	100	$9.95 each

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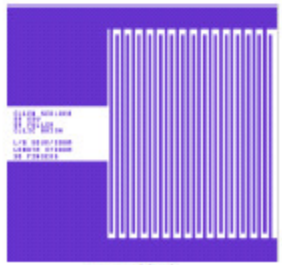
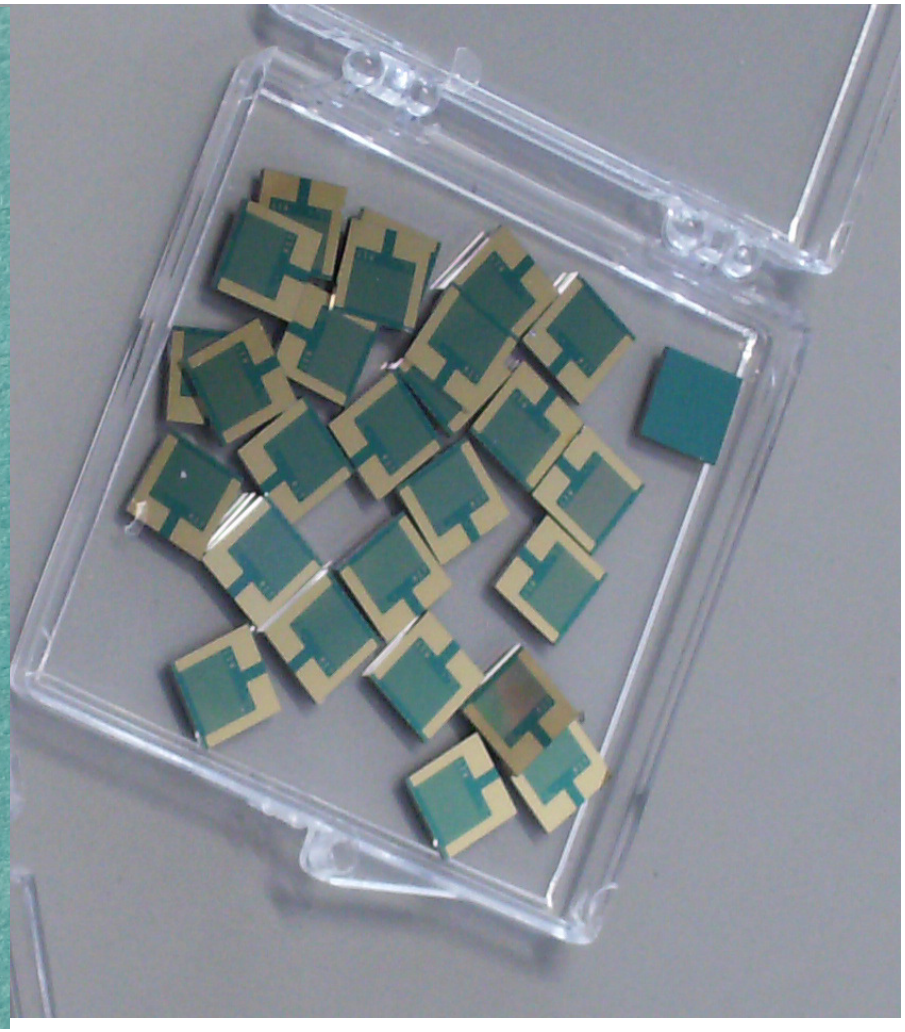
Series



Parallel

Silicon* is 6500Å oxide on silicon
Size 4.8 mm x 4.8 mm x 0.67 mm
Solder Pads for Interconnect
Other metals available

RIT ELECTRODE ARRAYS



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