



U.S. Army RDECOM-ARDEC  
RDAR-MEE-M  
Picatinny Arsenal, NJ

# *Armament Related Corrosion Studies & Sensor Prototyping*



***TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.***

**U.S. Army Corrosion Summit 2010**

Presented by: Daniel P. Schmidt  
February 11, 2010

## Report Documentation Page

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- Overview
  - ARDEC & our mission
  - Accelerated Corrosion Facility at Picatinny
- On-going Corrosion Studies
- Materials Printing / Corr Sensor

## Armament Research, Development & Engineering Center (ARDEC)

### Vision:

Innovative Armaments Solutions for Today and Tomorrow

### Mission:

To develop and maintain a world-class workforce to execute and manage integrated life-cycle engineering processes required for the research, development, production, field support and demilitarization of munitions, weapons, fire control and associated items

### Locations:

- Picatinny Arsenal, NJ
- Benet Labs (Watervliet Arsenal), NY
- Rock Island Arsenal, IL
- Adelphi & APG, MD

**Providing the lethality technology for over 90% of the Army's munitions**



**AMC**



**RDECOM**



**ARDEC**

# Overview: ARDEC Mission



Electro Magnetic Gun



Small/Cannon Caliber Ammunition



M777A2 Lightweight 155mm Howitzer



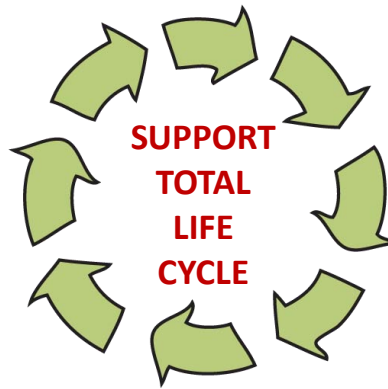
Insensitive Munitions Technology

## Research & Development

## Demilitarization

## Production

## Field Support



Excalibur



Gunner Protection Kits



M110 Semi-Automatic Sniper System



M240B 7.62MM Machine Gun



40mm Multi-Shot Launcher

## Atmospheric Exposure



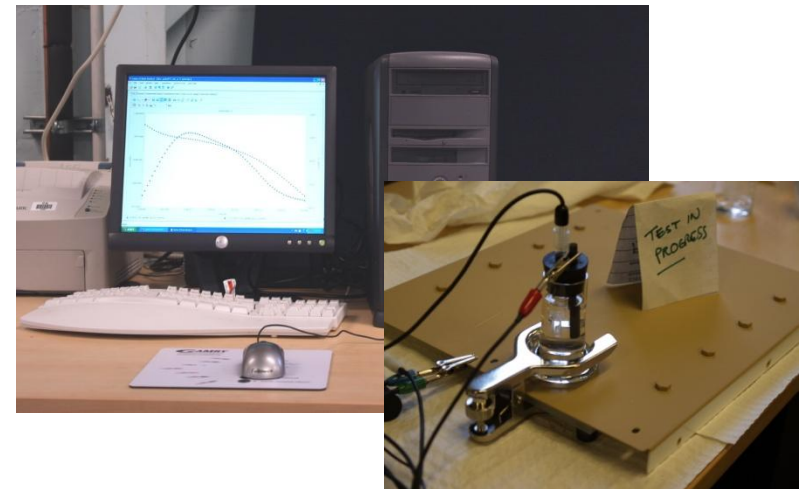
## Cyclic Corrosion Chambers



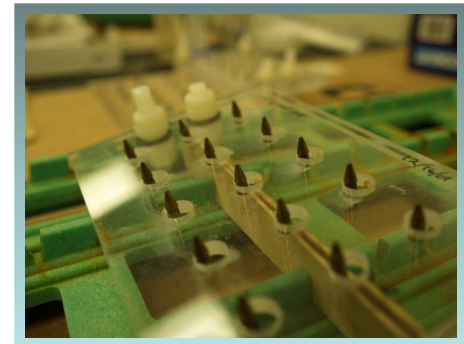
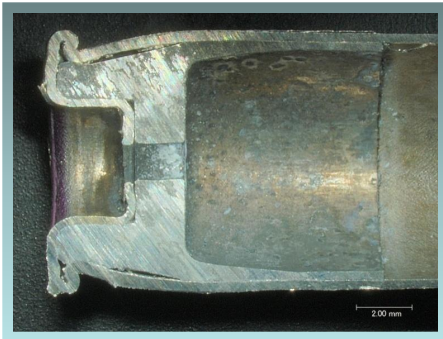
## Weathering Chambers



## Electrochemical Analysis



Several on-going corrosion studies at ARDEC related to Armament issues and concerns.



## Project: Lightweight Small Cal Ammo

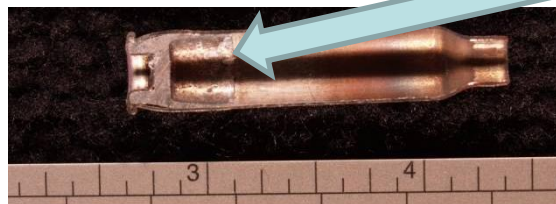
### Background:

- Designing/developing stainless steel cartridge case
- For structural support inserting Al plug

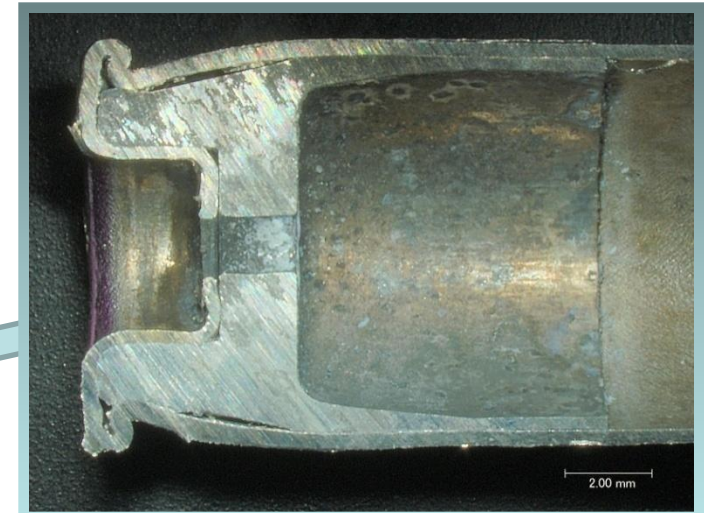
### Issue:

- Possible galvanic couples that could lead to corrosion
- 3 main galvanic couples of concern shown below:

1.	Plug Insert 7075 T6 Aluminum	Cartridge Case 305 Stainless Steel
2.	Bullet Jacket Cu Alloy 220	Cartridge Case 305 Stainless Steel
3.	Cartridge Links 1045 Carbon Steel	Cartridge Case 305 Stainless Steel



Courtesy of Wikimedia Commons (public domain)



## Project: Lightweight Small Cal Ammo

### Representative Materials

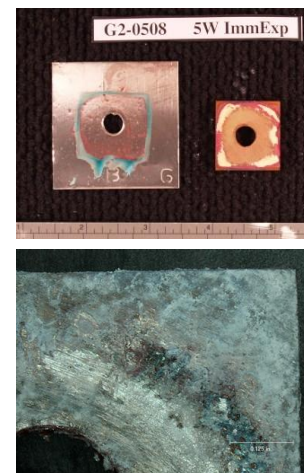
#### Testing:

- Representative materials were selected and specimen set-ups were made for several different tests

#### Atmospheric Exposure

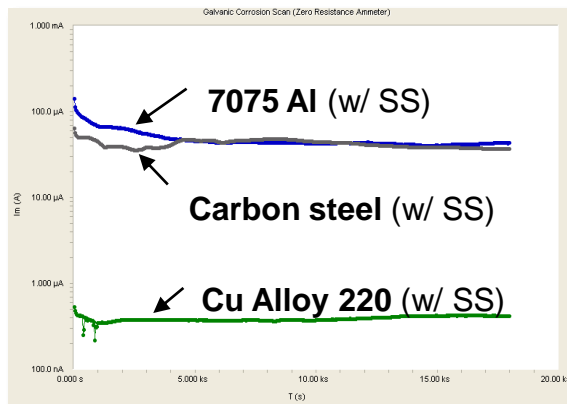
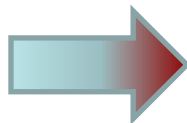
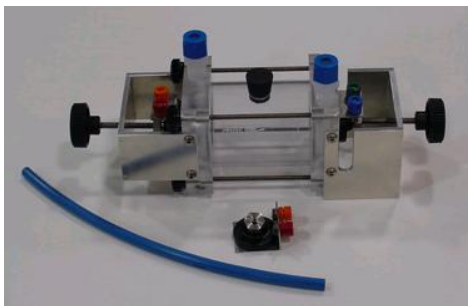


#### Constant Immersion



- Visual inspection
- Corr product analysis
- Weight loss
- Corrosion morphology and location

#### Zero Resistance Ammeter (ZRA) Test



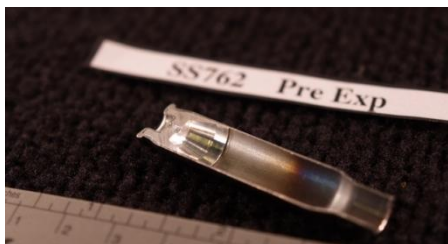
- Plot galvanic current vs. time
- Used to monitor galvanic interactions b/w electrodes
- Corrosion potentials can provide info on sacrificial protection

## Project: Lightweight Small Cal Ammo

### *Actual Components*

### Exposures:

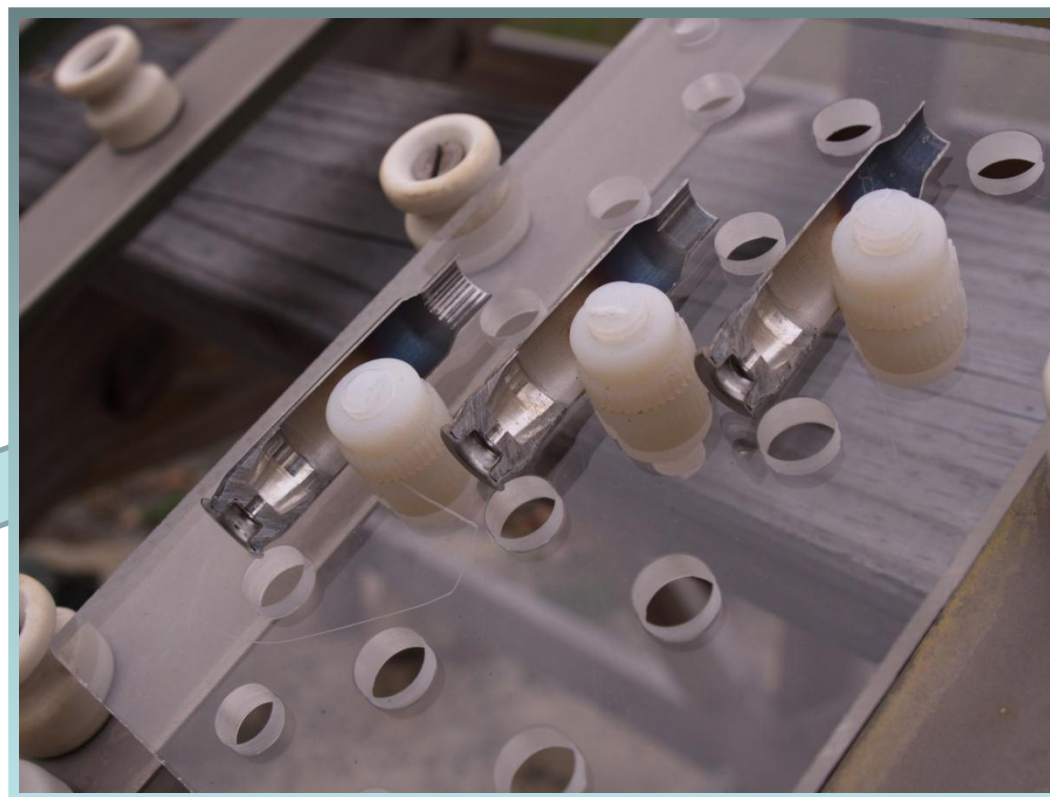
- Sample 7.62 SS cartridge cases were cross-sectioned lengthwise
- Specimen holders were designed to accommodate racks in atmospheric test yard
- Results will be compared with representative materials testing



7.62 SS cartridge after being cross-sectioned



Corrosion Instrumented Test Yard (CITY)  
at Picatinny Arsenal, NJ



## Project: M2A1 Ammo Can Coatings

### *Actual Components*

#### Background:

- Looking for alternative coatings to current liquid dip alkyd to improve/maintain performance, cost and environmental impact

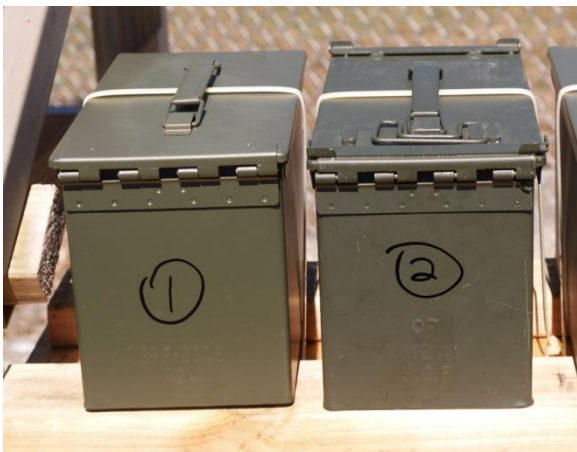
#### Issue:

- Epoxy powder formulation may be susceptible to UV degradation

#### Testing:

- Side-by-side exposure in Picatinny's Corrosion Instrumented Test Yard (CITY)

**April 2009**



**September 2009**



## Project: Small Cal Green Bullet

### *Actual Components*

### Background:

- Program initiative to create an environmentally-friendly bullet design

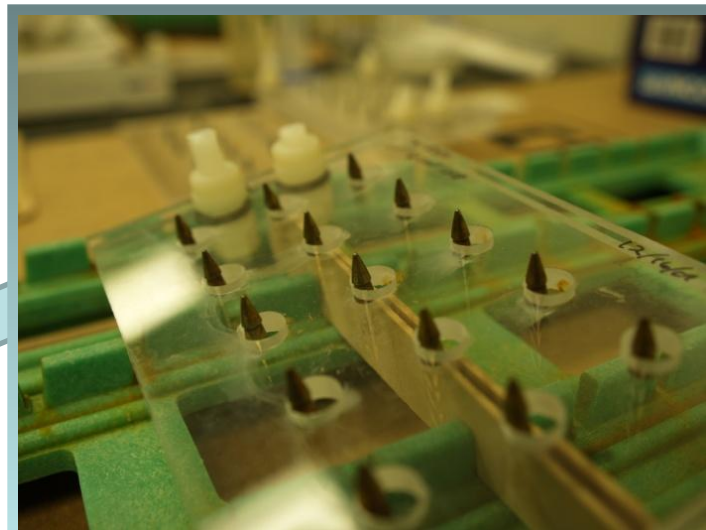
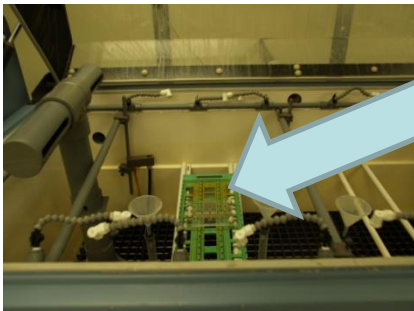
### Issue:

- Need to test corrosion resistance of coatings for penetrator protection

### On-going Testing:

- Qualitative comparison in 48hr salt fog exposures (ASTM B117)
- Electrochemical assessment ( $E_{oc}$ , EIS, etc.)
- Plan to do atmospheric exposures

Salt fog exposure in cyclic corrosion chamber



Electrochemical test set-up



## *Representative Materials*

## *Actual Components*

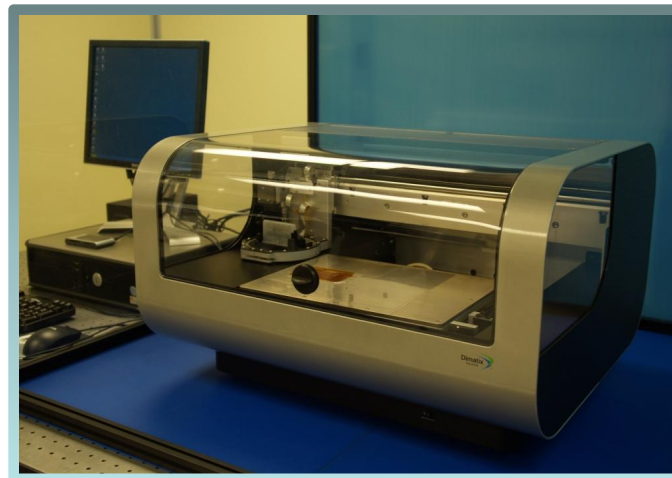
### **Advantages**

- **Cost**
- **Size**
- **Availability**
- **Security**
- **Reproducibility**

- **Geometry (shape)**
- **Interfaces and area ratios**
- **Manufacturing steps**
- **More realistic surfaces**
- **Residual stresses**

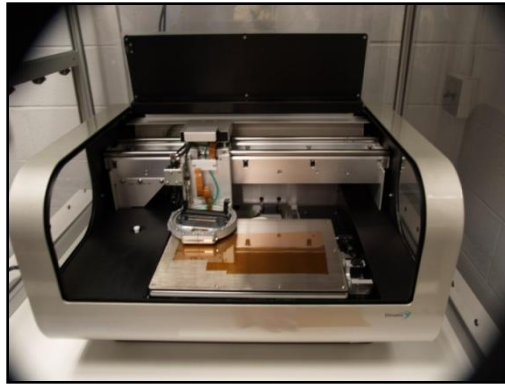


## Sensor design & prototyping using materials printing

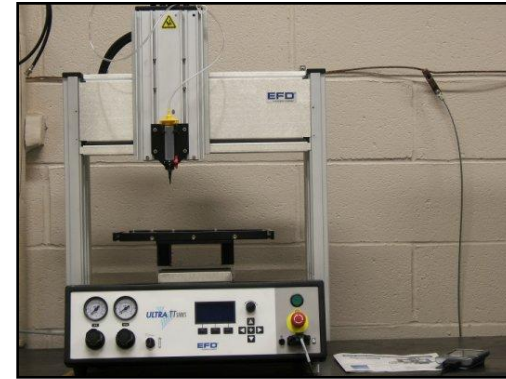


## What is MATERIALS PRINTING?

Nanoparticles (dispersed in solvents to form nano-inks) are deposited and then annealed to form patterns on a range of substrates.



Ink-jet Printing (Drop-on-Demand)

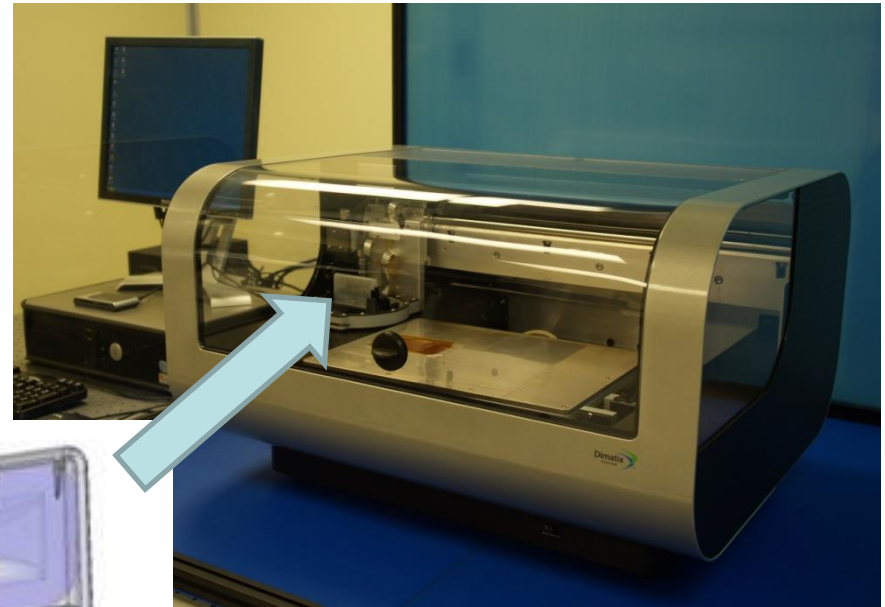
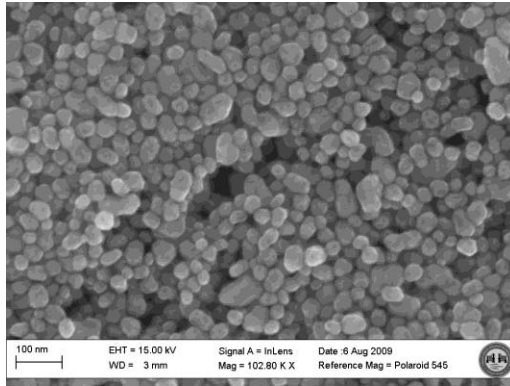


Direct Write

## Why is ARDEC interested?

- flexible substrate = fit electronics & larger payloads into munitions
- tailorable effects and applications
- ease of manufacturing / versatility
- lower cost (eg. sensors, electronics, fuzing)
- advanced materials

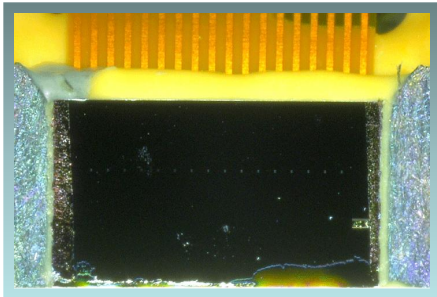
## Nano-Inks



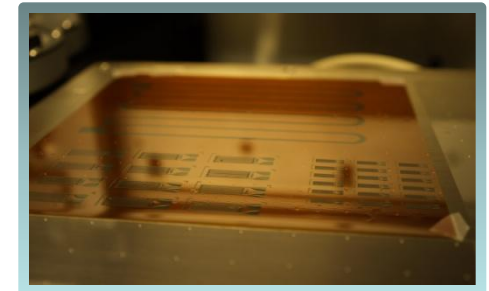
**Dimatix Materials Printer System**



**Print cartridge**



Bottom-up view of 16 piezo-controlled nozzles



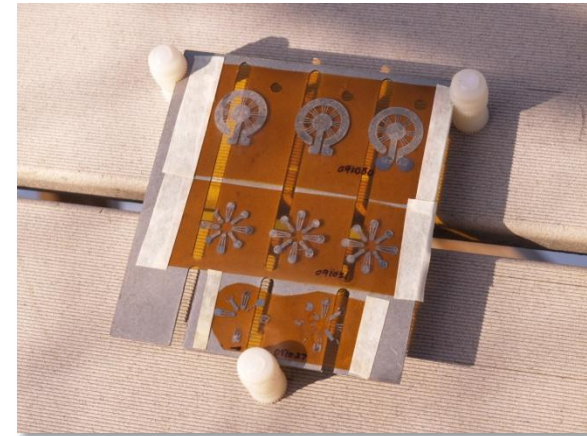
Ink deposited on flexible substrate (pre-anneal)



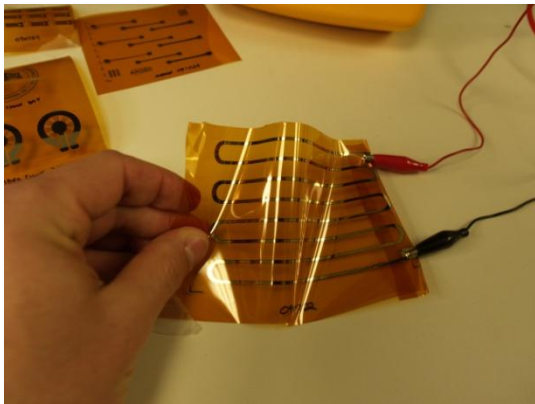
Flexible Initiator



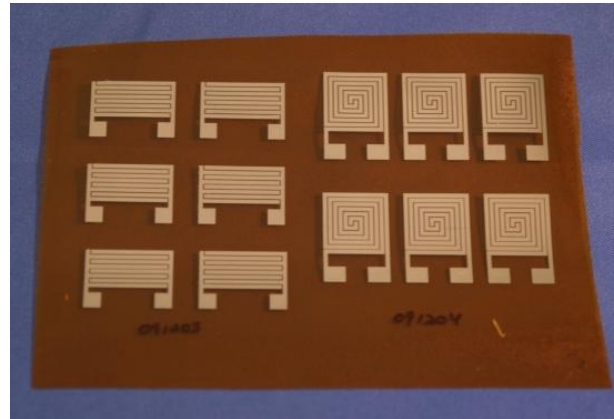
ARDEC Logo



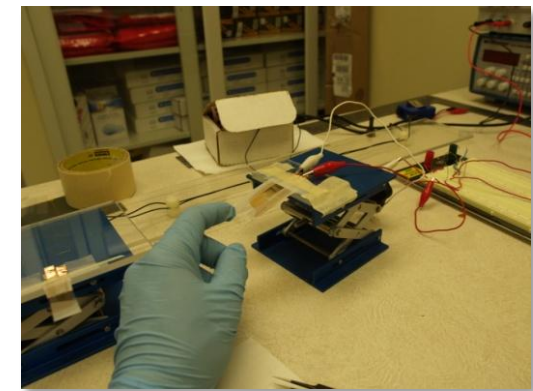
Corrosivity Sensors



Scratch Sensors



Capacitors



Strain Sensors

## Designed

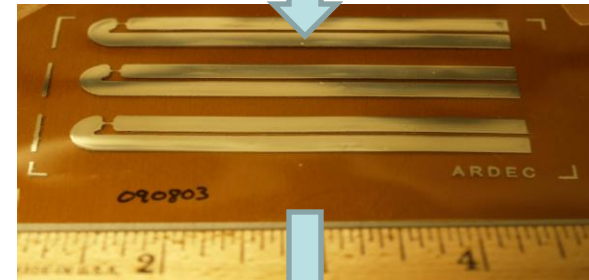
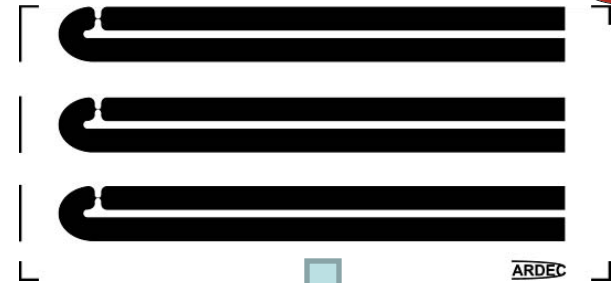
- used computer software to design pattern
- based on low voltage initiation of bridge-wire
- several iterations

## Prototyped

- material selection
- refined ink-jetting process parameters
- annealing steps
- also several iterations

## Tested

- loaded with primary and secondary explosives
- initiated devices with low voltages in blast chambers
- used witness plates to confirm detonations



**SUCCESSFUL**  
*now patent pending*

## Designed

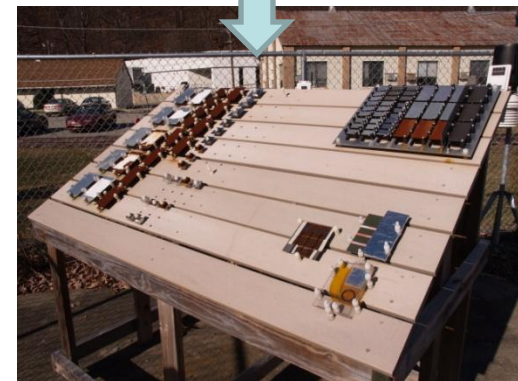
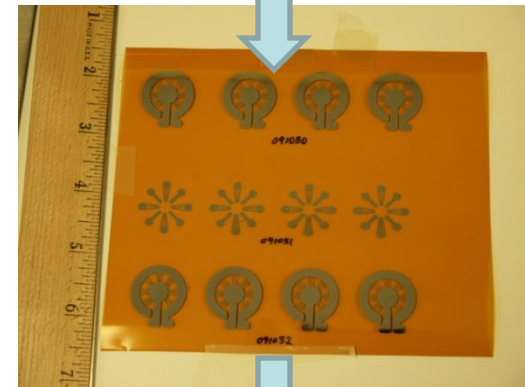
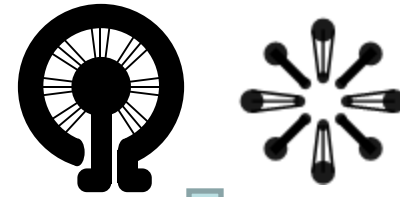
- used computer software to create 2 designs
- based on resistance and visual changes
- initial iteration

## Prototyped

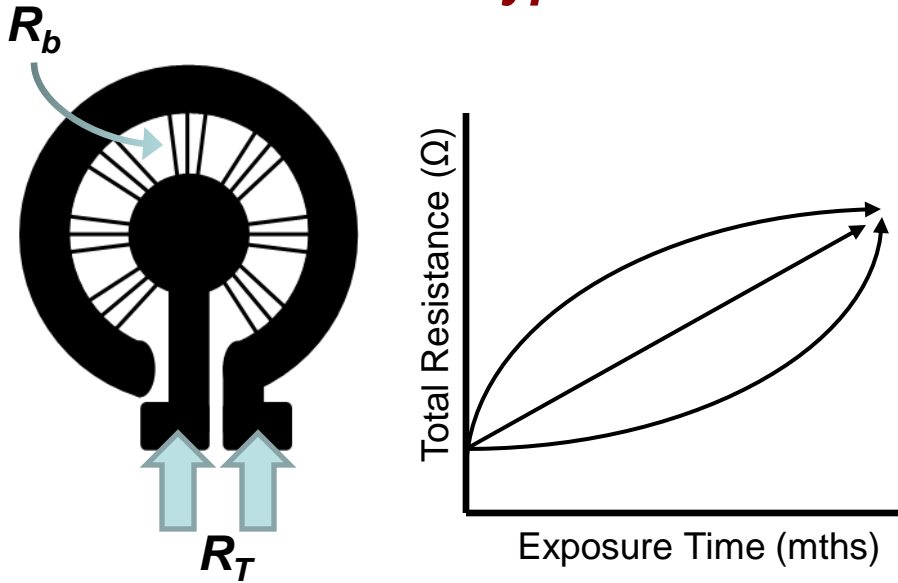
- material selection
- refined ink-jetting process parameters
- annealing and encapsulation steps
- initial iteration

## On-going Testing

- initiated exposure in C.I.T.Y. (atmospheric test yard)
- measure resistance and take pictures
- correlate results with exposure time
- new materials and designs

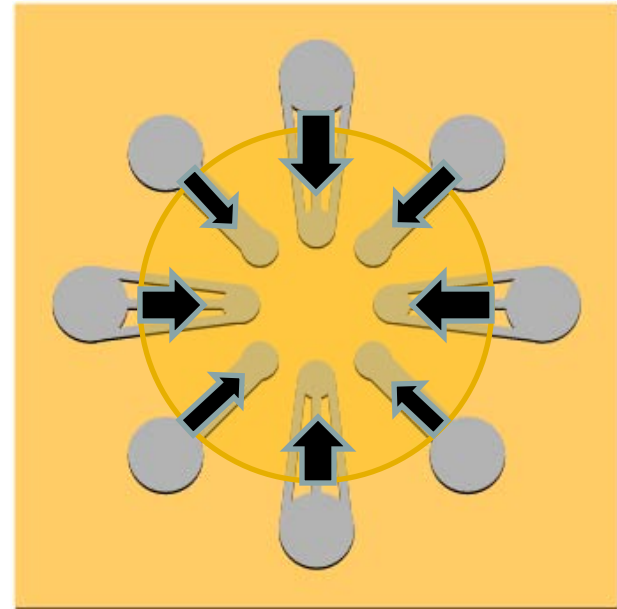


## Sensor Type A



$$R_T = R_b / 21$$

## Sensor Type B



- Several on-going corrosion studies at ARDEC
  - related to coatings and materials
  - atmospheric, chamber, lab-scale and electrochemical testing
  - using representative as well as actual components
  - developing new test methods
- Sensor design & prototyping using materials printing
  - several components have been made
  - corrosivity sensors currently being studied
  - plans for future designs and materials



**Questions...ask now if you're *lost*.**