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Outline

• Overview
  o ARDEC & our mission
  o 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
Overview: ARDEC Mission

Research & Development

SUPPORT TOTAL LIFE CYCLE

Demilitarization

Production

Field Support

Electro Magnetic Gun
Small/Cannon Caliber Ammunition
Excalibur
M110 Semi-Automatic Sniper System
M240B 7.62MM Machine Gun
M777A2 Lightweight 155mm Howitzer
Gunner Protection Kits
40mm Multi-Shot Launcher

Insensitive Munitions Technology

Excalibur Gunner Protection Kits

Small/Cannon Caliber Ammunition

40mm Multi-Shot Launcher

M110 Semi-Automatic Sniper System

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
Overview:
In-House Corrosion Facility

Atmospheric Exposure

Cyclic Corrosion Chambers

Weathering Chambers

Electrochemical Analysis

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
Several on-going corrosion studies at ARDEC related to Armament issues and concerns.
Study: Galvanic Materials

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:

<table>
<thead>
<tr>
<th></th>
<th>Coupling</th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
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<tbody>
<tr>
<td>1.</td>
<td>Plug Insert</td>
<td>7075 T6 Aluminum</td>
<td>Cartridge Case</td>
<td>305 Stainless Steel</td>
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<tr>
<td>2.</td>
<td>Bullet Jacket</td>
<td>Cu Alloy 220</td>
<td>Cartridge Case</td>
<td>305 Stainless Steel</td>
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<tr>
<td>3.</td>
<td>Cartridge Links</td>
<td>1045 Carbon Steel</td>
<td>Cartridge Case</td>
<td>305 Stainless Steel</td>
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Studies: Galvanic Materials

Project: Lightweight Small Cal Ammo

Testing:

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

Atmospheric Exposure

Constant Immersion

Zero Resistance Ammeter (ZRA) Test

Representative Materials

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

- 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

Exposures:
- Sample 7.62 SS cartridges cases were cross-sectioned lengthwise
- Specimen holders were designed to accommodate racks in atmospheric test yard
- Results will be compared with representative materials testing
Project: M2A1 Ammo Can Coatings

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

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
### Representative Materials

<table>
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<tr>
<th>Advantages</th>
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<tr>
<td>Cost</td>
<td>Geometry (shape)</td>
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<tr>
<td>Size</td>
<td>Interfaces and area ratios</td>
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<tr>
<td>Availability</td>
<td>Manufacturing steps</td>
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<td>Security</td>
<td>More realistic surfaces</td>
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<tr>
<td>Reproducibility</td>
<td>Residual stresses</td>
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### Actual Components

- 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.

Why is ARDEC interested?

- flexible substrate = fit electronics & larger payloads into munitions
- tailorable effects and applications
- ease of manufacturing / versatility
- lower cost (e.g. sensors, electronics, fuzing)
- advanced materials
Materials Printing: Cartridge & Inks

Nano-Inks

Bottom-up view of 16 piezo-controlled nozzles

Print cartridge

Dimatix Materials Printer System

Ink deposited on flexible substrate (pre-anneal)
Materials Printing: Select Devices & Components

- Flexible Initiator
- ARDEC Logo
- Corrosivity Sensors
- Scratch Sensors
- Capacitors
- Strain Sensors
Materials Printing: Flexible Initiator

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
Materials Printing: Corrosivity Sensors

**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
Materials Printing:
Corrosivity Sensors

Sensor Type A

\[ R_T = \frac{R_b}{21} \]

Sensor Type B
Summary

• 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
Thank You!

Questions…ask now if you’re lost.