

THE USE OF ZINC-LEAD COMPOSITES TO PREVENT THE CORROSION OF LEAD

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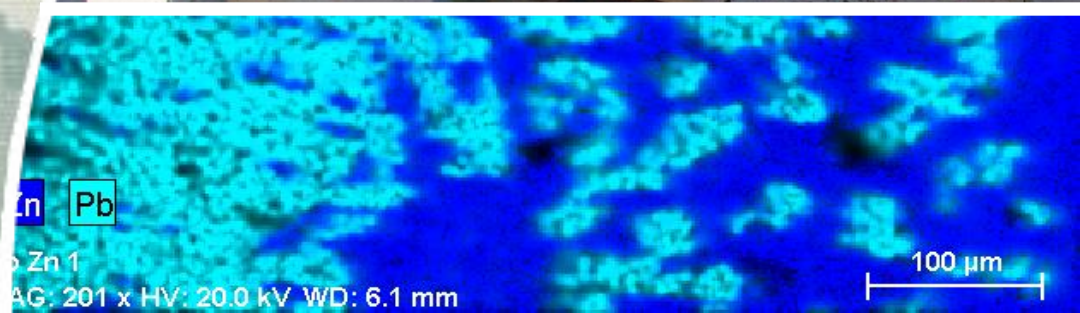
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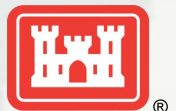
Lead – Oldest Industrial Pollutant

- Still widely used
 - ▶ Ballast
 - ▶ Radiation shielding
 - ▶ Ammunition
- Corrodes slowly—but corrosion products are serious hazard
- Lead hydroxide, lead carbonate, and lead sulfate can be distributed into the environment
- Lead poisoning is serious and difficult to reverse



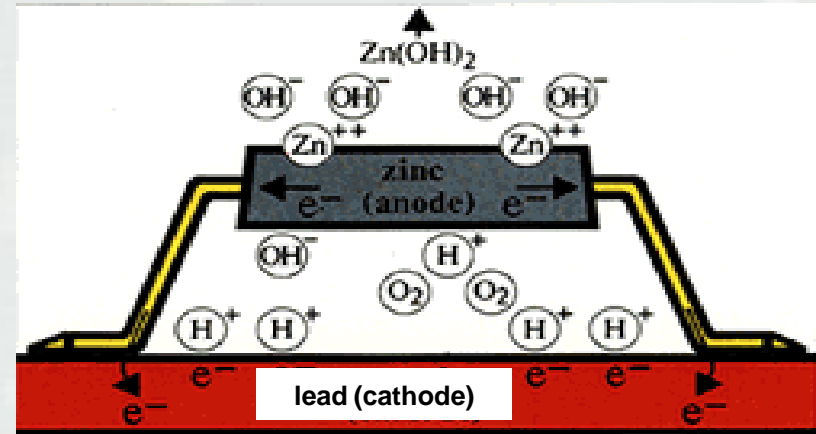
Controlling Lead Corrosion

- Maintain non-aggressive environment
 - ▶ Organic acids are biggest problem—think soil!
- Encapsulate in less corrosive metal
 - ▶ Bullets have copper jackets –bad choice
 - ▶ Shielding can be stainless steel clad
- **Cathodic protection** – an unused approach
 - ▶ Think zinc-plated lead, “galvanized lead”



Why Add A Layer of Zinc to Lead?

- Zinc can isolate the lead physically and galvanically protect it from corrosion
- Zinc will be released in low quantities and should pose no environmental risk



Zinc protects lead and copper from corrosion in the same way as it protects iron from rusting



Practical Galvanic Series

METAL	VOLTS
Commercially pure magnesium	-1.75
Magnesium alloy (6% Al, 3% Zn, 0.15% Mn)	-1.60
Zinc	-1.10
Aluminum alloy (5% Zn)	-1.05
Commercially pure aluminum	-0.80
Mild steel (clean and shiny)	-0.5 to -0.8
Mild steel (rusted)	-0.4 to -0.55
Cast Iron (not galvanized)	-0.50
Lead	-0.50
Mild steel in concrete	-0.20
Copper, Brass, Bronze	-0.20
Mill scale on steel	-0.20



How “Corrosion-Proof” Would A Lead/Zinc Composite Be?

Results of 24-hr Leaching Test with 0.1 N Acetic Acid

Sample Designation	Mass of Sample Slug (gm)	Concentration of Lead in Leachate (ppm)
Lead only #1	0.852	14.1
Lead only #2	1.23	14.1
Pb/Zn composite #1	0.952	<0.2
Pb/Zn composite #2	0.726	<0.2

Composite is 86 wt. % lead, 14 wt. % zinc

Pb/Zn slugs produced “non-detects” in leachate



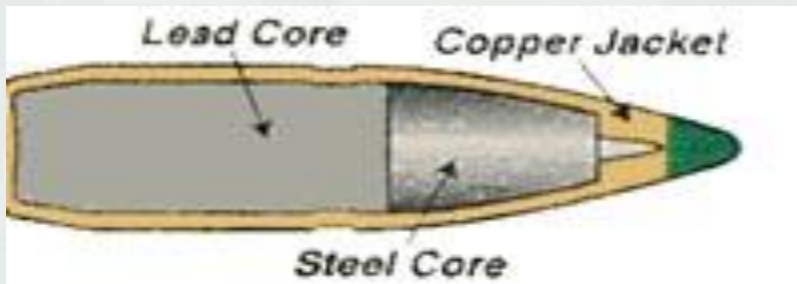
The Biggest Problem - Spent Bullets

- **Small arms training activities typically deposit between 1 and 2 million pounds of lead bullet debris into the soil at military training ranges annually**
- **Most common round is the M855 that is used in the M16A2, M4 carbine and the M249 SAW**



Ammunition for the M16A2 Infantry Rifle

Bullet from M855 Round (SS109)

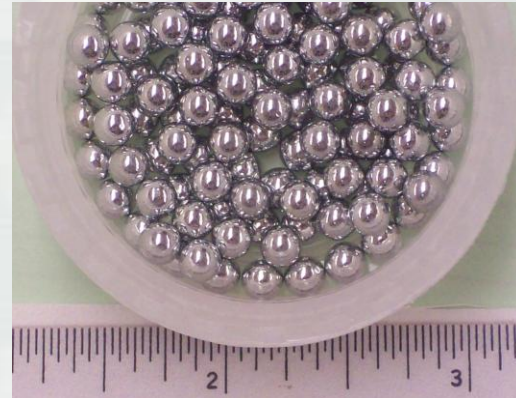


- The M855 replaced the M193 round
- Major difference is the steel penetrator
- Full metal jacket with boat tail design
- Weight - 62 grains (4.02 g)
(1 gram = 15.43 grains)
- Cartridge is 5.56 x 45 mm
- Contains 2 grams of lead

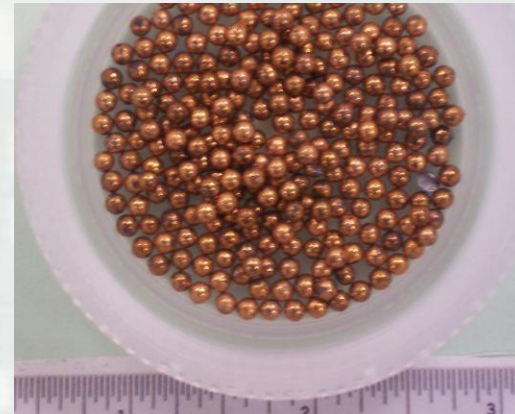


Commercially Available Plated Shot

- You can buy zinc-plated iron shot
- You can buy copper-plated (also nickel-plated) lead shot
- But no one manufactures a zinc-plated lead shot
- Copper and nickel on lead accelerate the corrosion of lead, zinc-plating would protect the lead



Zinc-plated iron shot



Copper-plated lead shot



How Can the Composite be Fabricated?

- Each bullet fragment should consist of zinc and lead
- All of the zinc should be accessible to etching
- Composite should be made efficiently and economically

- Possibilities:
 - ▶ Layers of zinc and lead heat-fused
 - ▶ Electroplating pieces and swaging
 - ▶ Mechanical plating and forming
 - ▶ **Exsolution from melt and forming**



SEM photomicrograph of Zn plating on Pb wire.

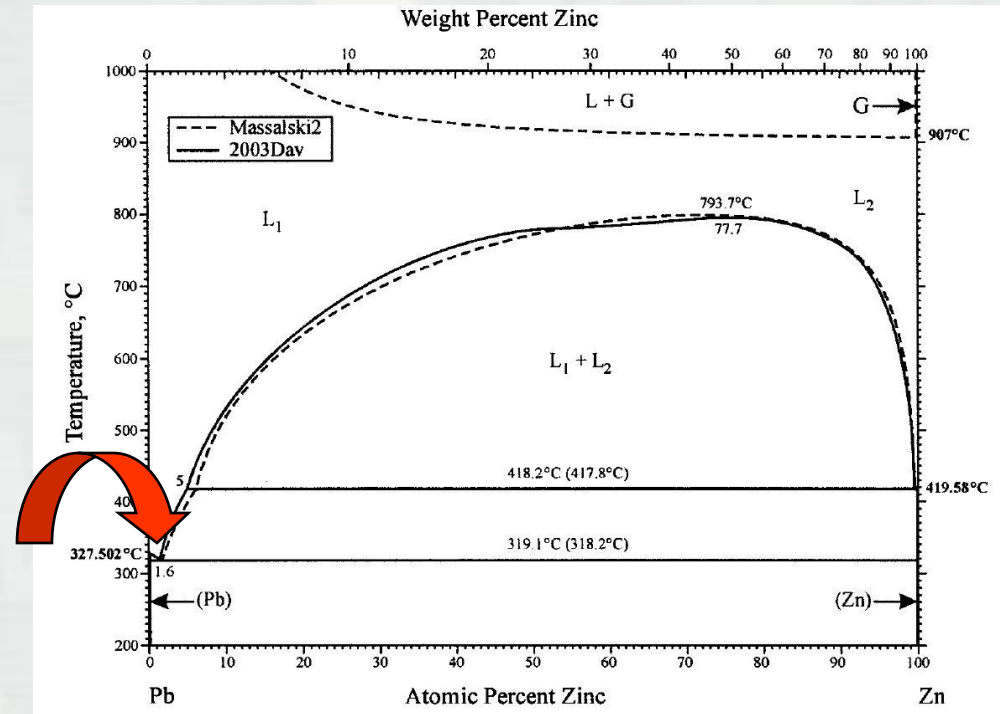
Coating is ~ 40 to 50 micrometers thick.



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Molten Zn and Pb Separate on Cooling

- Solidified layer of Zn contains very little Pb
- Zn solidifies and floats on Pb
- Casting can produce a composite that can be easily varied in the relative thickness of composite layers
- Total thickness of composite can be controlled
- Final formation can involve rolling, stacking and swaging, or fusing.

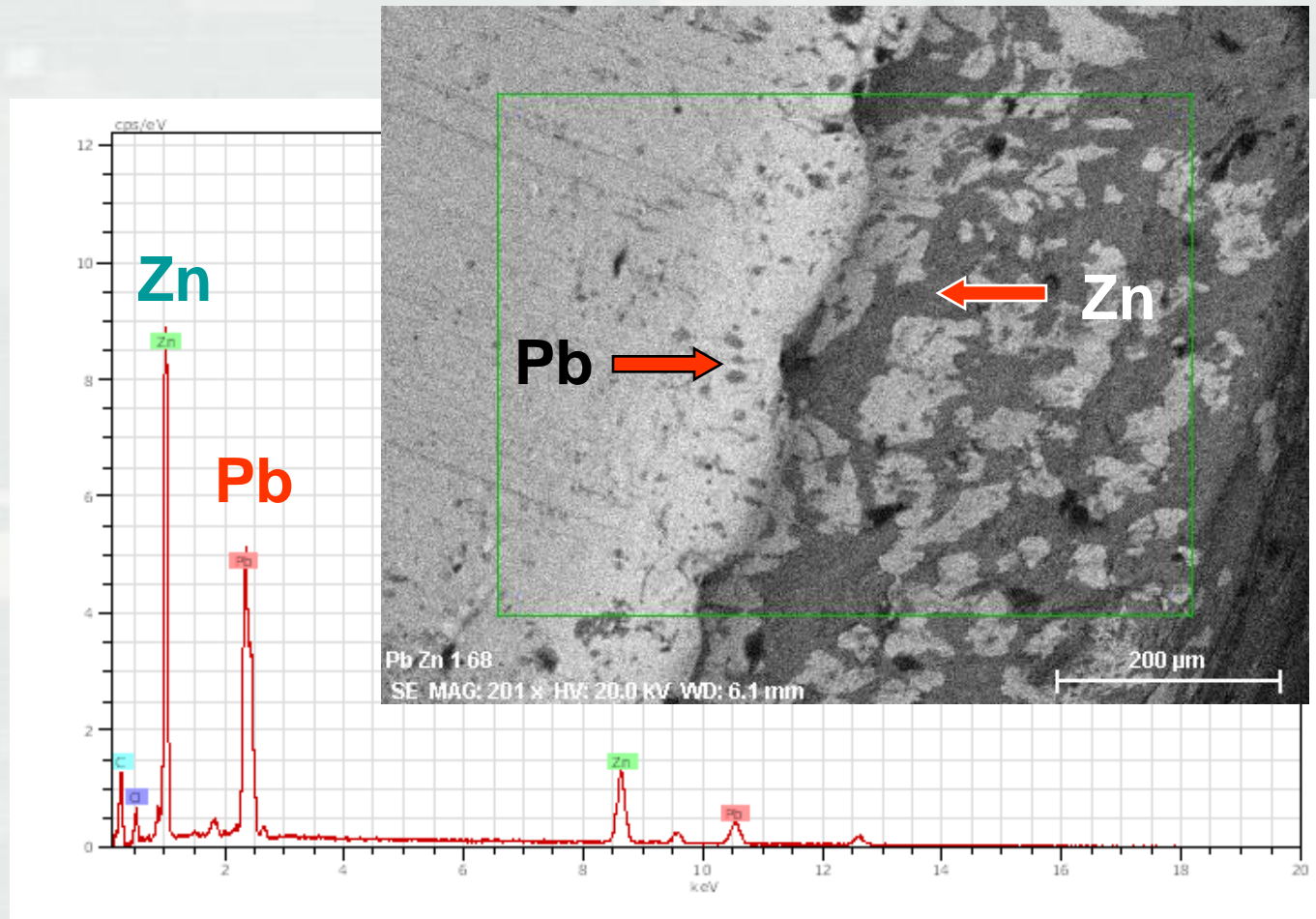


Zn-Pb Binary Phase Diagram
(from Okamoto, Journal of Phase Equilibria, Vol. 24, No. 5, 2003)



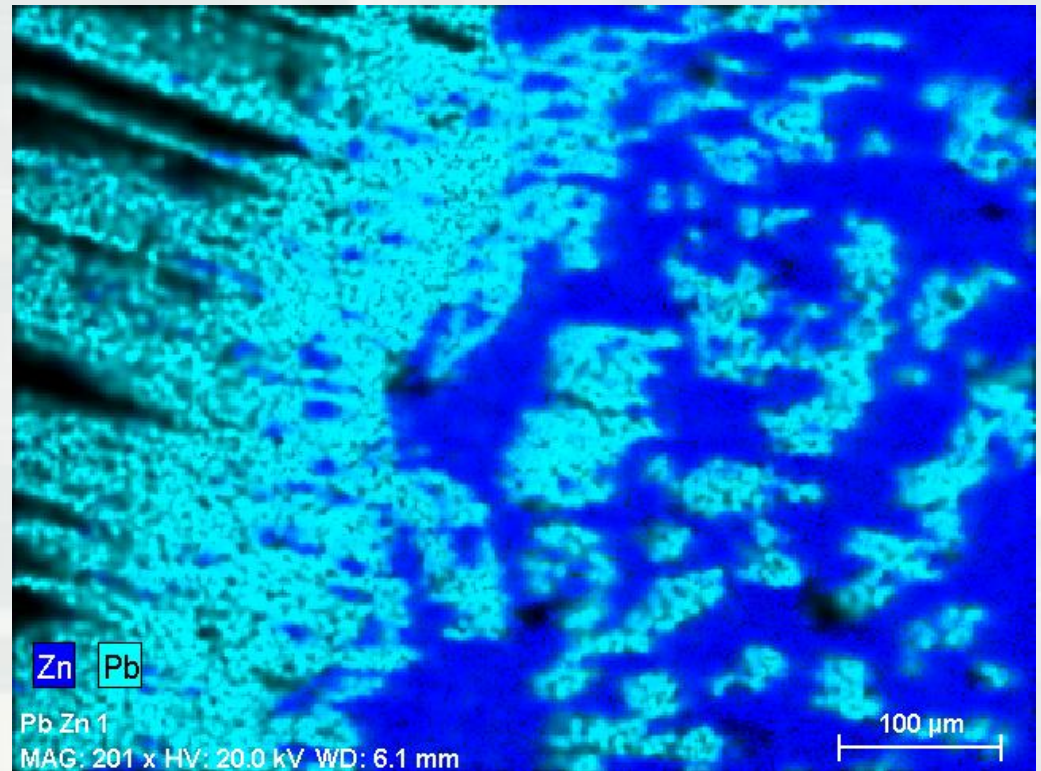
Interface of Zinc and Lead

- Strong bond from zinc to lead
- Minor mixing at immediate boundary
- Elemental XRF shows two near-pure phases



Elemental Map of Interface

- Irregular boundary but excellent separation
- Composite can be made on any scale since boundary layer is thin



Summary

- **Using lead/zinc composites instead of pure lead can greatly reduce the rate of corrosion of the lead and the loss of lead into surrounding soil and groundwater**
- **Several methods of producing the composite are available: fusing, plating, and now exsolution**
- **The Pb/Zn composite can probably be produced at a cost that will allow it to be competitive with the pure lead product**
- **The Army's U.S. Patent No. 6,095,052 and U.S. Patent No. 6,938,552 describe the basic technology and techniques for fabrication**
- **Adaptations and improvements should be able to proceed without major IP issues**



QUESTIONS?



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