Potters Industries Inc.
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Potters Conductives

Solving the Galvanic Corrosion Issue In EMI Shielding

Harry Fuerhaupter
Potters Industries Inc.
Research & Development Center
280 Cedar Grove Road, Conshohocken, PA 19428
TEL: 610-651-4780 EMAIL: harry.fuerhaupter@pottersbeads.com
www.pottersbeads.com

Outline

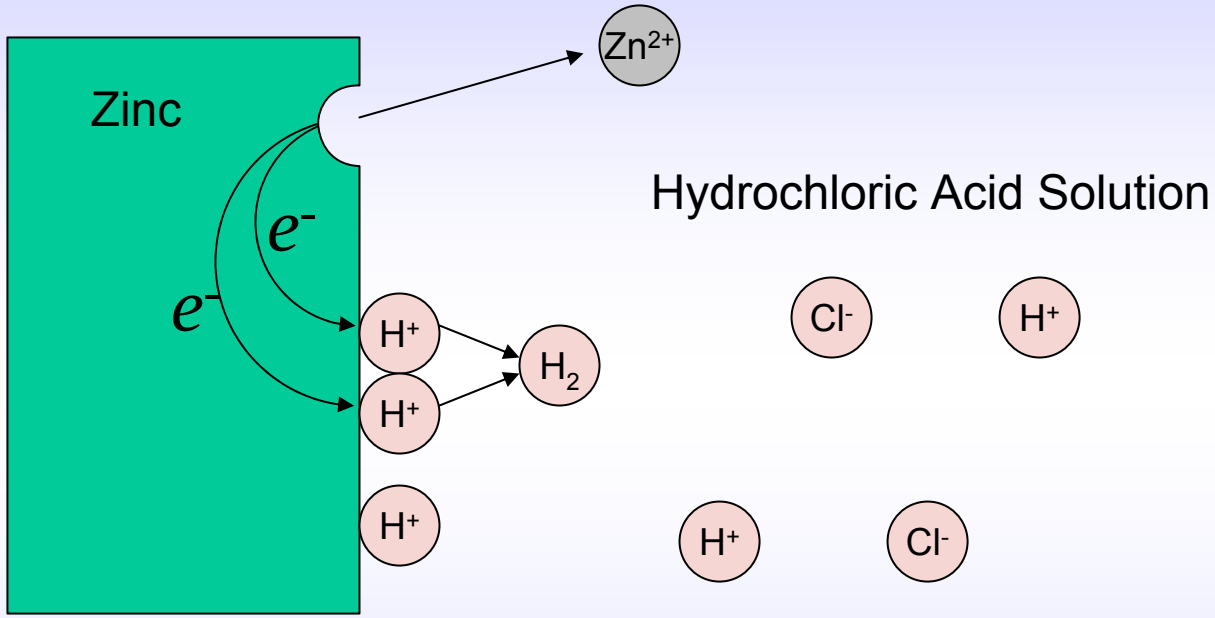
- What is galvanic corrosion
- Basic preventative measures
- Specific problem with conductive gaskets
- Unique behavior of conductive fillers
- New conductive filler for low aluminum corrosion

Types of corrosion

1. Uniform
2. Galvanic
3. Crevice
4. Pitting
5. Intergranular
6. Selective leaching
7. Erosion
8. Stress

Uniform corrosion

- Diagram of zinc in acid

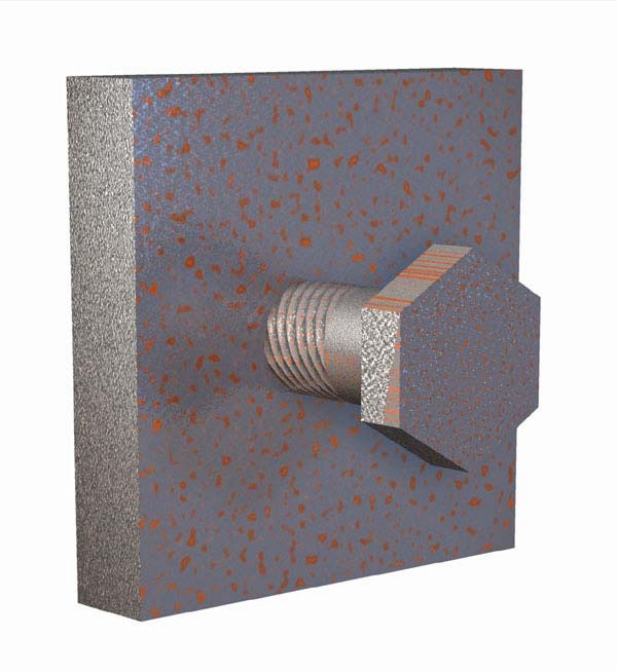


$$Zn \longrightarrow Zn^{2+} + 2e^-$$

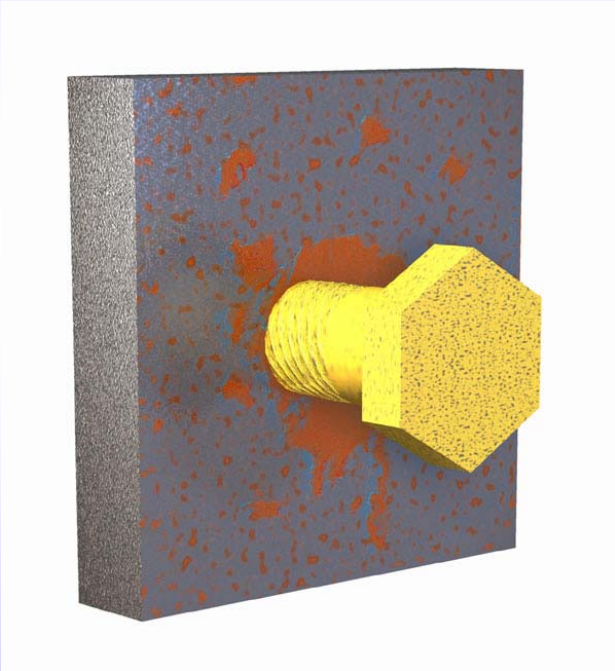
$$2H^+ + 2e^- \longrightarrow H_2$$

Galvanic Corrosion

- When two dissimilar metals contact each other in a corrosive environment, the less corrosion-resistant metal experiences *more corrosion* than when it is not in contact with the other metal.



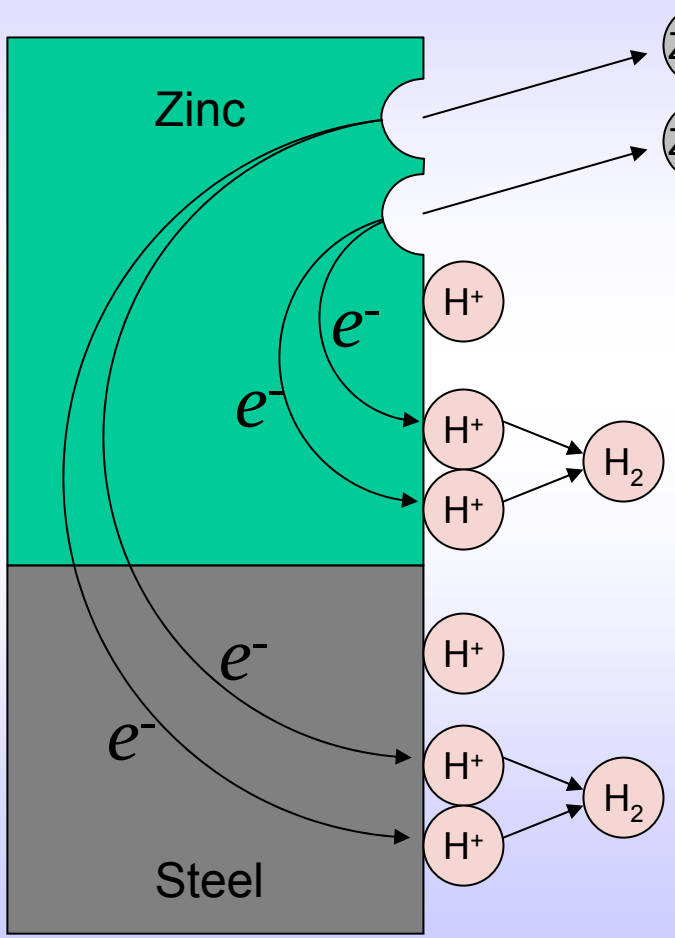
Steel bolt in steel plate



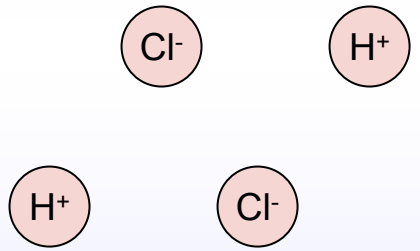
Brass bolt in steel plate

Galvanic corrosion

- Diagram of zinc/steel in acid



Hydrochloric Acid Solution



$$Zn \longrightarrow Zn^{2+} + 2\,e^- \quad \textbf{- 0.763 V}$$

$$2\,H^+ + 2\,e^- \longrightarrow H_2$$

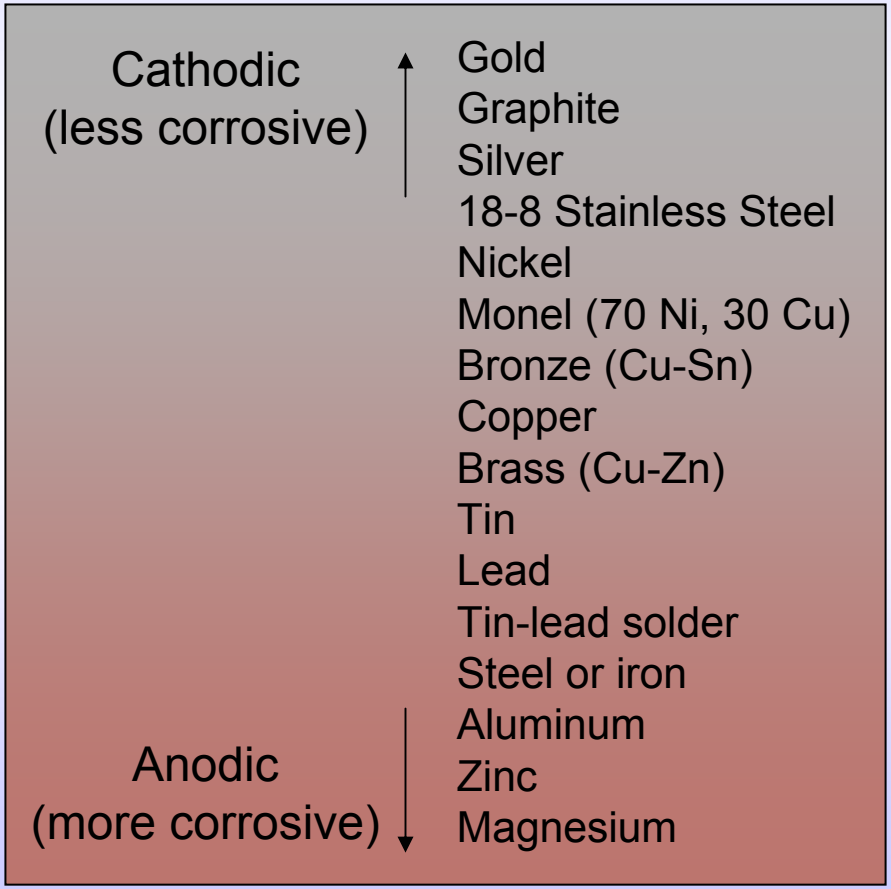
$$Fe \longrightarrow Fe^{2+} + 2\,e^- \quad \textbf{- 0.440 V}$$

Galvanic Corrosion

- The greater the *difference* in corrosion potential between two metals is, the greater the galvanic corrosion effect is.

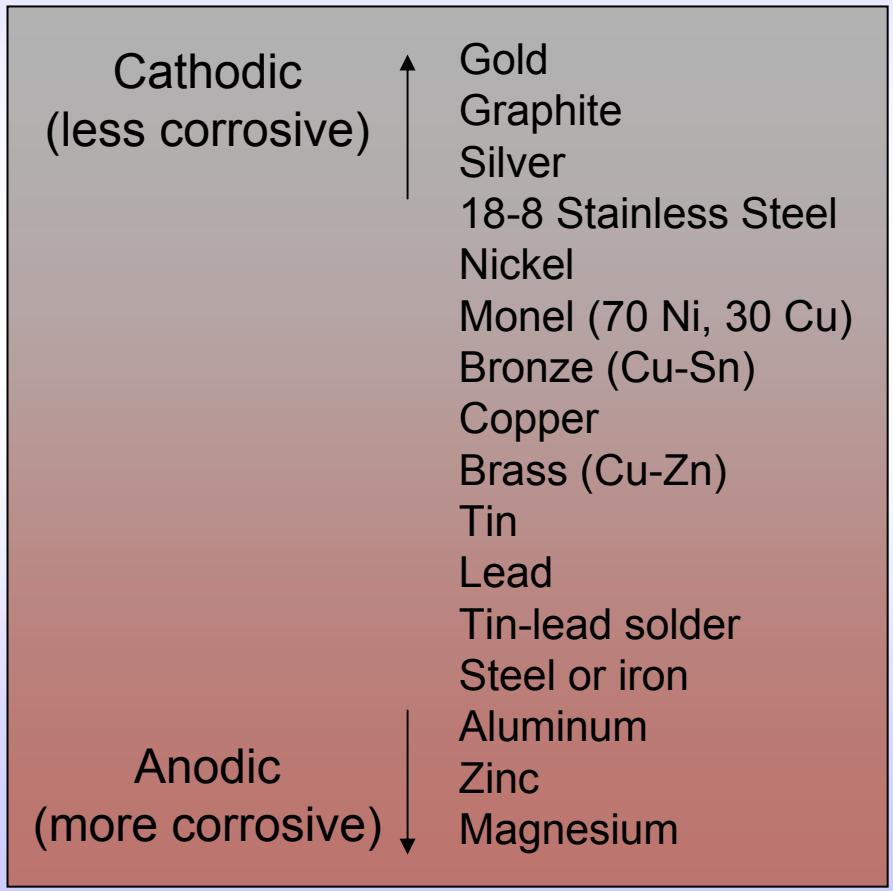
Galvanic series of some metals in seawater

(*Corrosion Engineering*, Fontana and Greene, 1978)



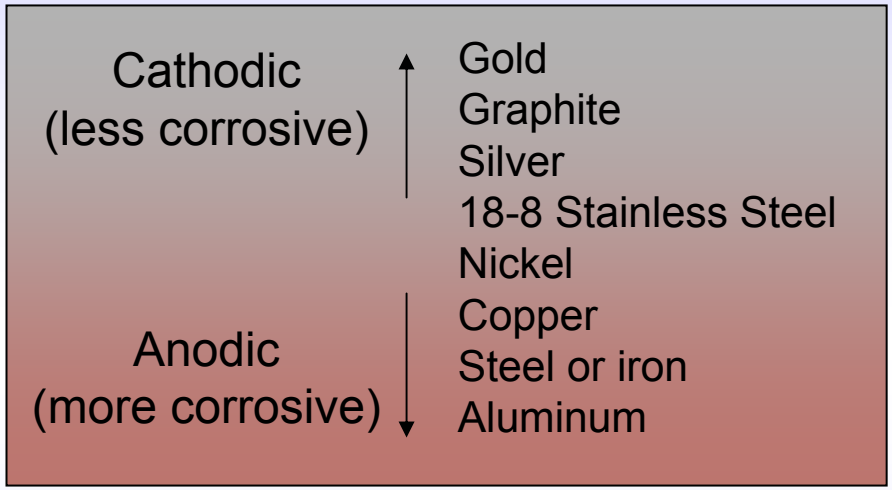
General prevention

- Eliminate one of the conditions necessary for galvanic corrosion.
  - Corrosive environment
  - Dissimilar materials
  - Contacting surfaces
- Coating
- Material matching
- Size ratio of anode/cathode
- Add sacrificial element even more corrosive



EMI Gaskets and Galvanic Corrosion

- Typically a concern with aluminum frames used in outdoor environment: base stations, aircraft, marine.
- Cannot avoid contact with aluminum because electrical contact is required.
- The fillers that are most galvanically similar to aluminum tend to oxidize and lose conductivity.



- The most conductive filler materials (silver or silver-coated) are resistant to oxidation, but they have large galvanic difference to Al.

The ideal filler would be ***galvanically similar to aluminum*** and ***resistant to oxidation***.

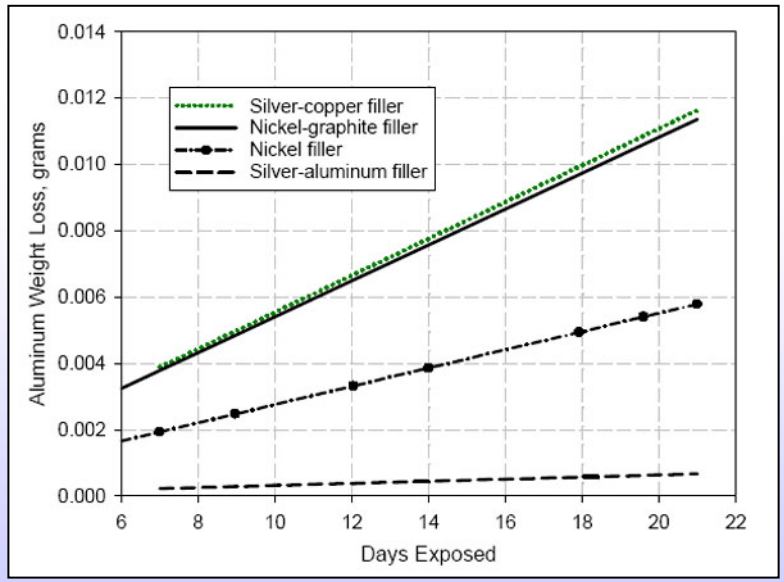
Unique Properties of Coated Powders

- A paper presented at IEEE EMC 2004* showed that the powder behaved galvanically more like the core material than the coating.

Open circuit potentials measured in 5% NaCl

Material	Potential Volts vs. SCE
Silver filled silicone elastomer	-0.086
Silver-nickel filled silicone elastomer	-0.100
Silver wire	-0.106
Nickel-graphite filled silicone elastomer	-0.157
Silver-copper filled silicone elastomer	-0.161
Silver-glass filled silicone elastomer	-0.281
Nickel metal	-0.367
Nickel filled silicone elastomer	-0.411
Silver-aluminum filled silicone elastomer	-0.746
Aluminum metal	-1.181

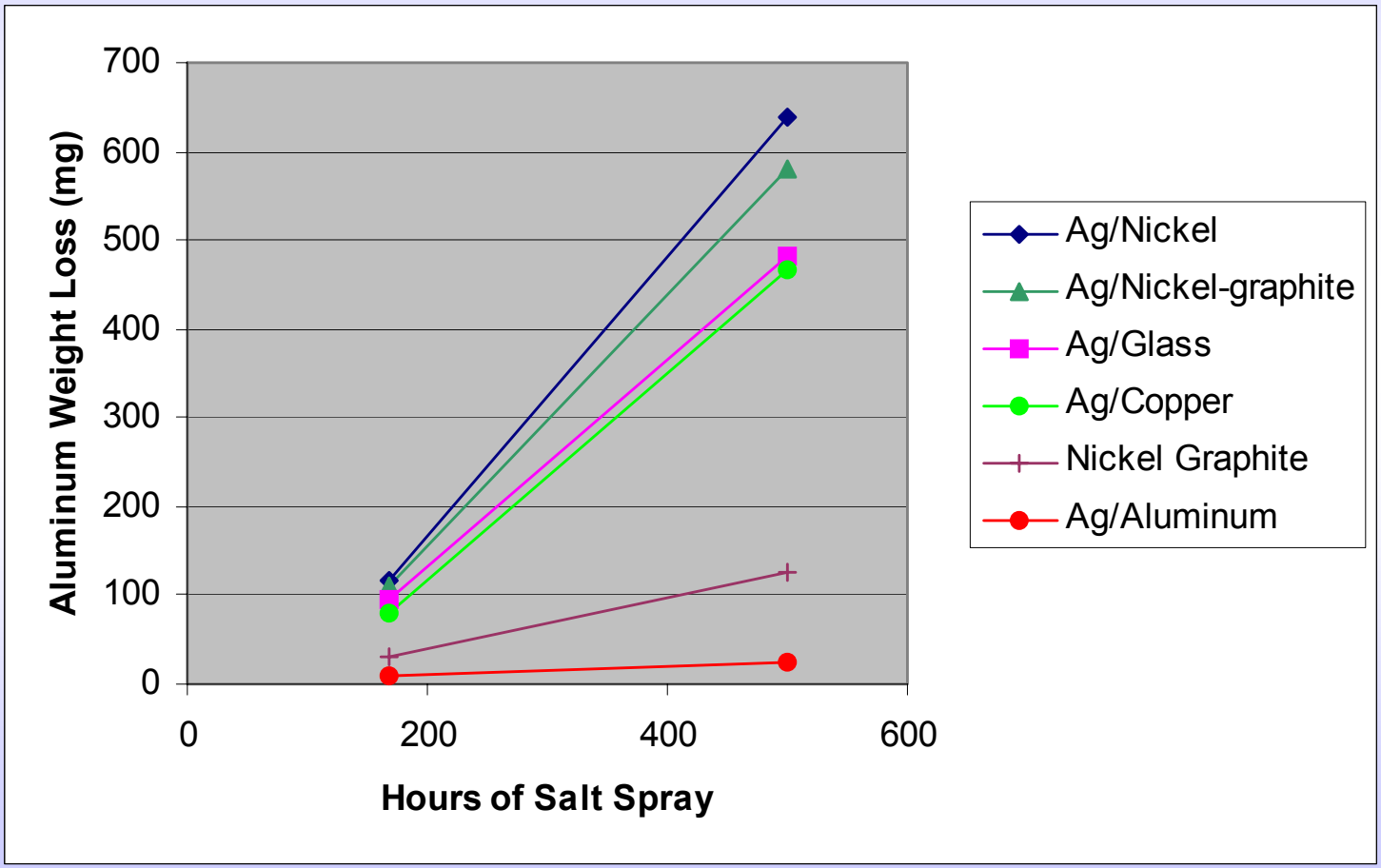
Salt Spray Corrosion



* A.R. Pawlowych, “Galvanically compatible elastomeric gasketing material for EMI shielding applications”.

Repetition of salt spray experiment

- Aluminum corrosion with fluorosilicone gaskets



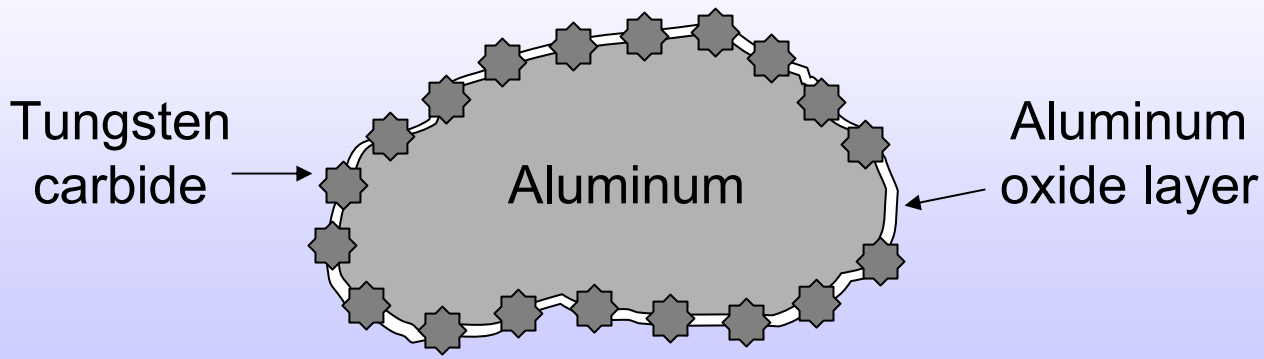
Rank by Electrode Potential

Ag/Nickel

Ag/Copper
Ag/Glass
Ni Graphite
Ag/Aluminum

A new filler for EMI shielding

- **Objective** – create a non-silver conductive particle with low corrosion properties but galvanically similar to aluminum.
- Untreated aluminum power is not conductive due to the natural oxide layer on the surface.
- The tungsten carbide penetrates the oxide layer and provides an electrical path to the aluminum core.
- Since tungsten carbide is galvanically inert, the filler creates virtually no galvanic corrosion on aluminum.



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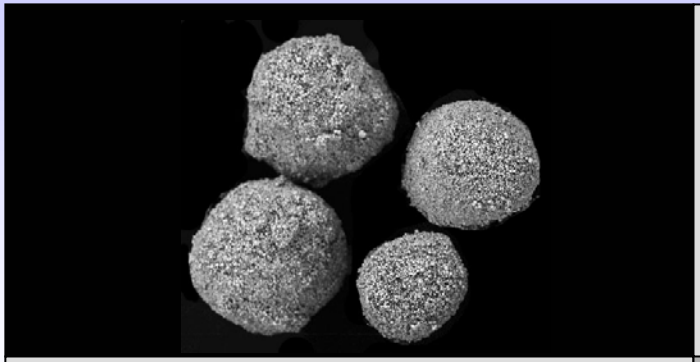
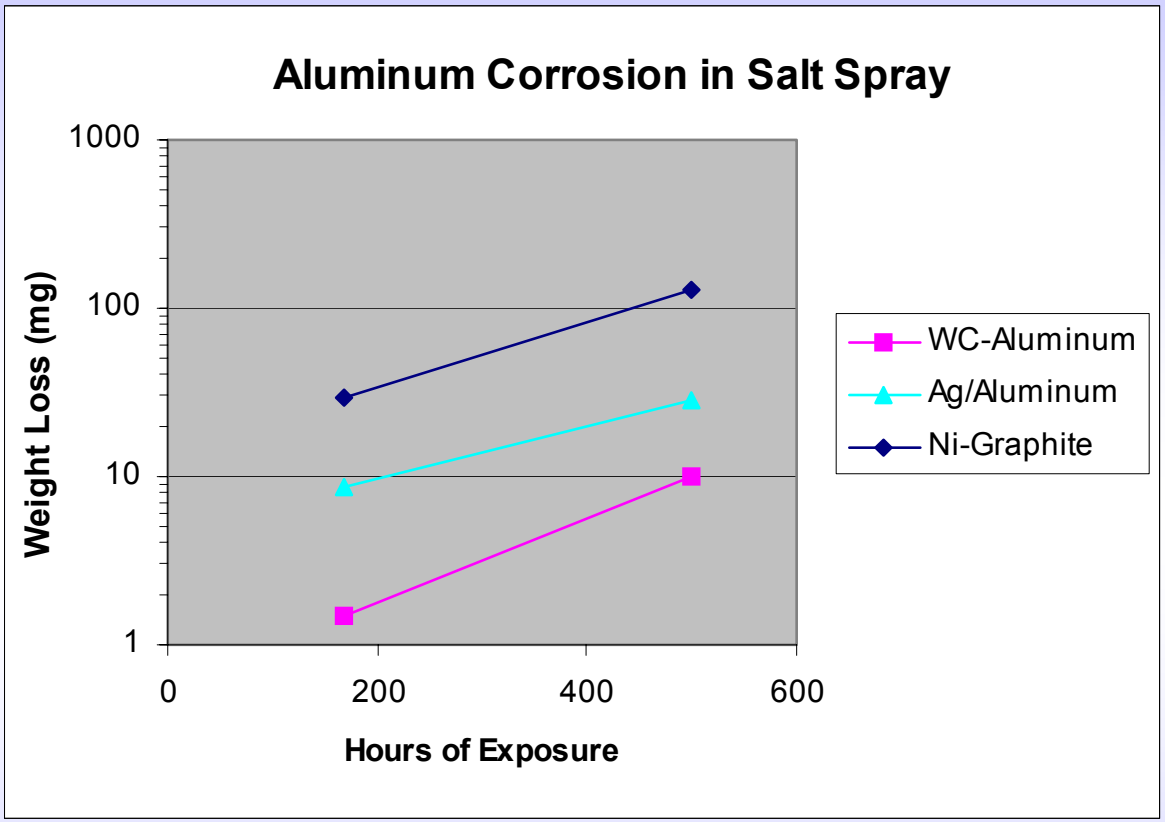
Galvan-O-Free Product Details

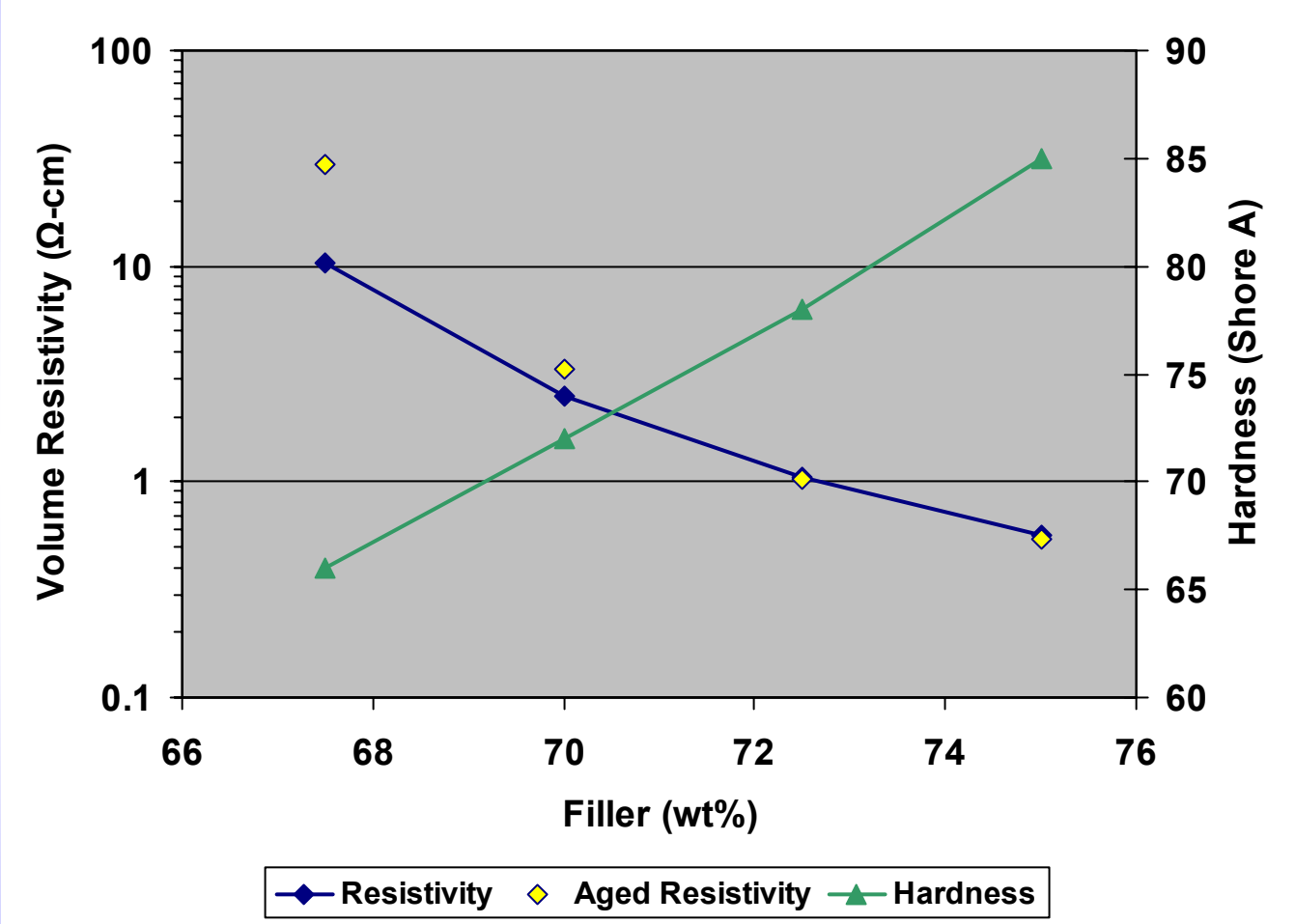
	GF-45 FIP Grade	GF-60 Molding Grade
Particle Size, µm		
D10	> 15	> 40
D50	35 – 50	55 – 80
D90	< 65	< 100
True Density	3.0 – 3.2	3.0 – 3.2
Tap Density, g/cc	1.7 – 1.9	1.7 – 1.9
Powder Resistivity, Ω-cm	< 0.8	< 0.8

WC-Aluminum Corrosion Testing



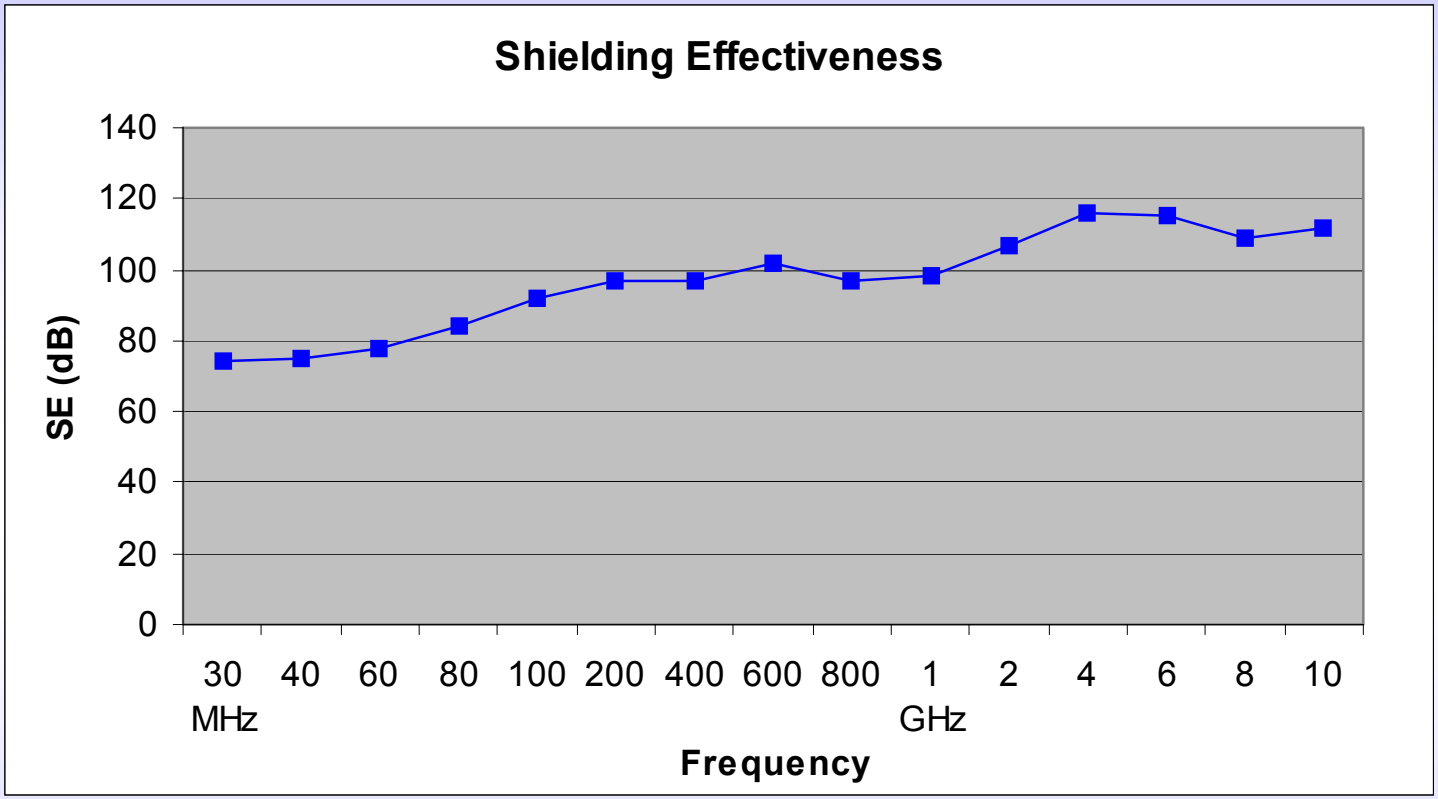
WC-Aluminum causes significantly less galvanic corrosion on aluminum than nickel/graphite and silver/aluminum

WC-Aluminum in Fluorosilicone Gasket



Aging = 48 hours at 200C

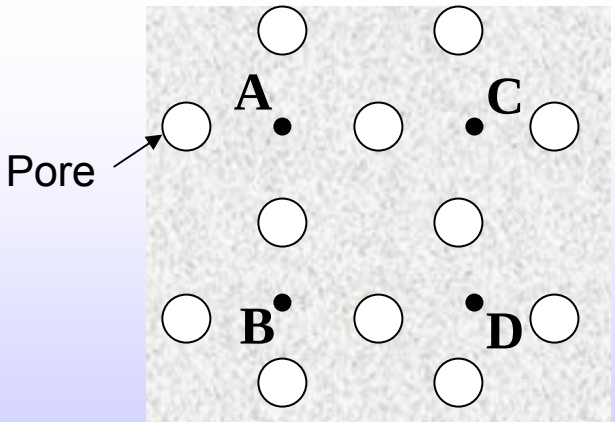
WC-Aluminum Shielding Effectiveness

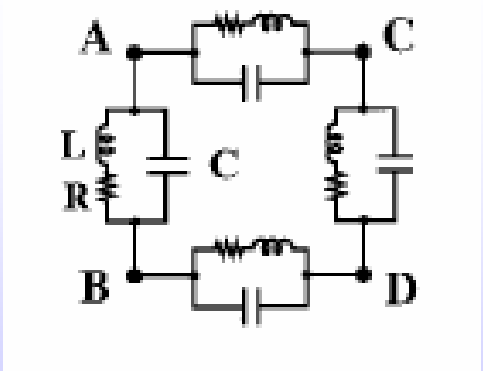


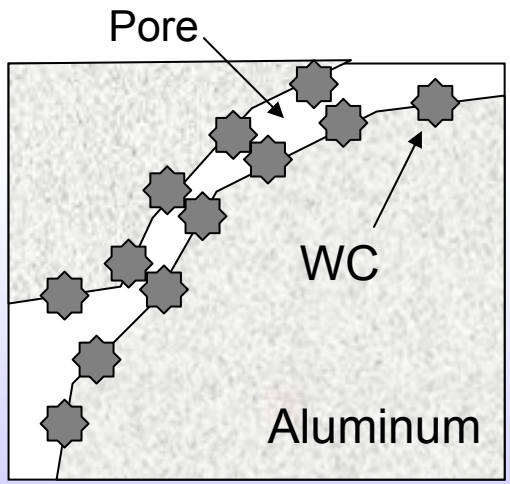
WC-Aluminum has excellent shielding effectiveness between 30MHz and 10 GHz

Theory of shielding at 1 Ω-cm

- Porous materials with relatively high volume resistivity have shown shielding capability
  - Nickel-loaded black rice husk: 80 dB @ 30 MHz to 60 dB @ 1.5 GHz
    *Journal of Materials Science, **39** (2004), pp. 6209 - 6214*
  - Carbonized wood ceramic: 50 dB from 30 MHz to 1 GHz
    *Journal of Porous Materials, **4** (1997), pp. 269 – 275*





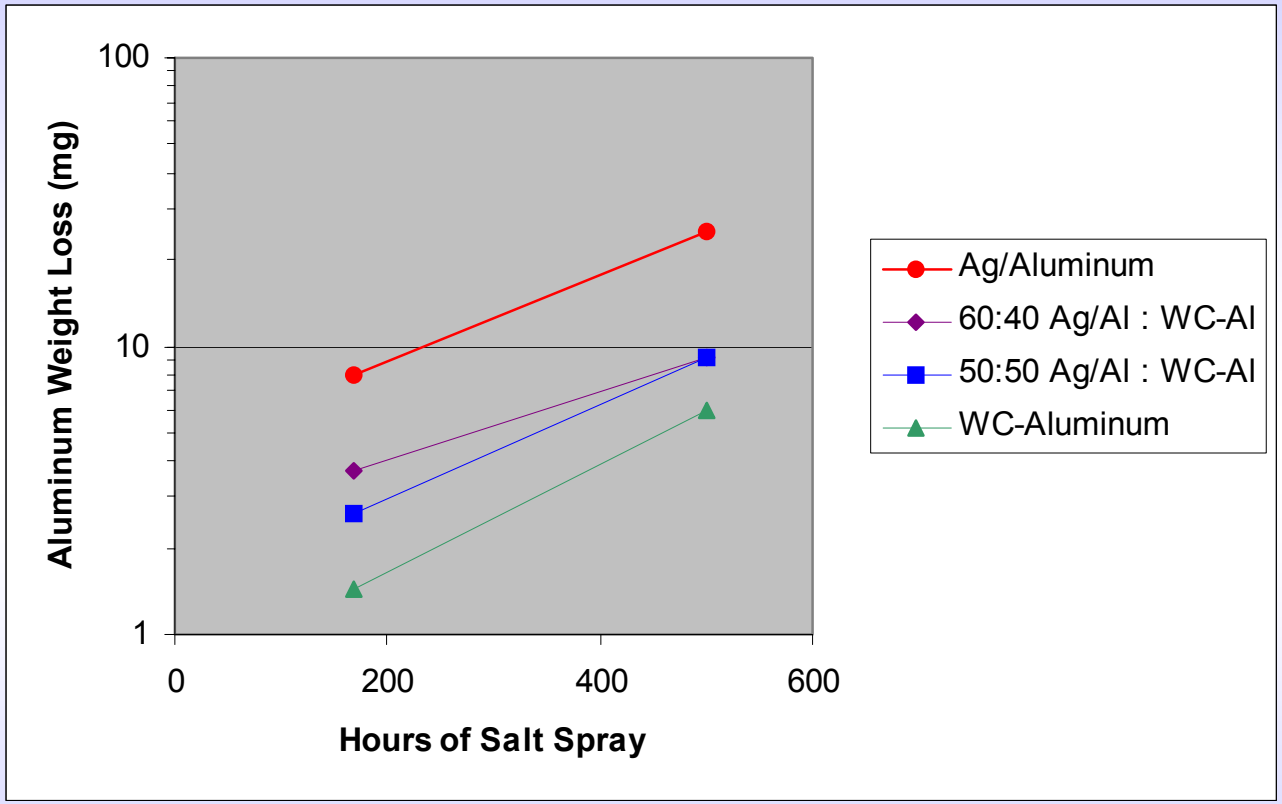


WC-Aluminum conductive filler applications

- WC-Aluminum filler materials have the right combination of properties to meet the challenges of corrosive environments.
- Some environments where WC-Aluminum could offer improved EMI gasket performance include:
  - High salt environments - marine
  - Outdoor enclosures exposed to various weather
  - High sulfur environments, such as exposure to fuel vapors
  - Strong chemical exposure, such as bleach for disinfection
  - Large thermal variations, *e.g.* aerospace and automotive
- Since WC-Aluminum contains no silver, the cost is closer to nickel-graphite.

Additional considerations

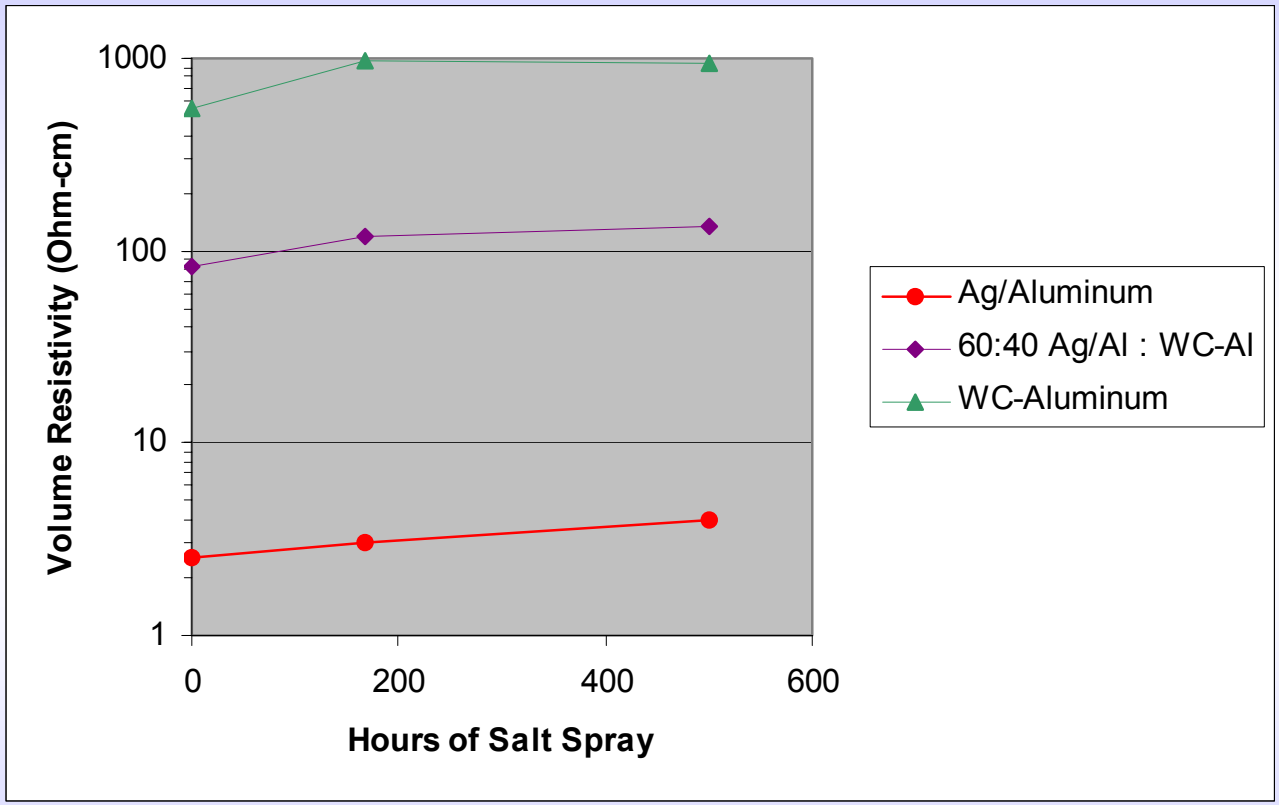
- Blending WC-Aluminum and Ag/Aluminum



The amount of aluminum corrosion caused by Ag/Aluminum can be reduced by addition of WC-Aluminum

Additional considerations

- Blending WC-Aluminum and Ag/Aluminum



The gasket resistivity of WC-Aluminum can be significantly decreased by addition of Ag/Aluminum

Summary

Reduction of galvanic corrosion in EMI gaskets can be accomplished by remembering a few key rules:

- **For finger stock – match materials and keep contact area small**
- **If possible, keep corrosive elements out with secondary seal**
- **For conductive elastomer gaskets in contact with aluminum substrate, Ag/Aluminum and WC-Aluminum have the lowest corrosion potential**