WHITE PAPER

OVERCOMING GALVANIC COMPATIBILITY CHALLENGES IN EMI SHIELDING

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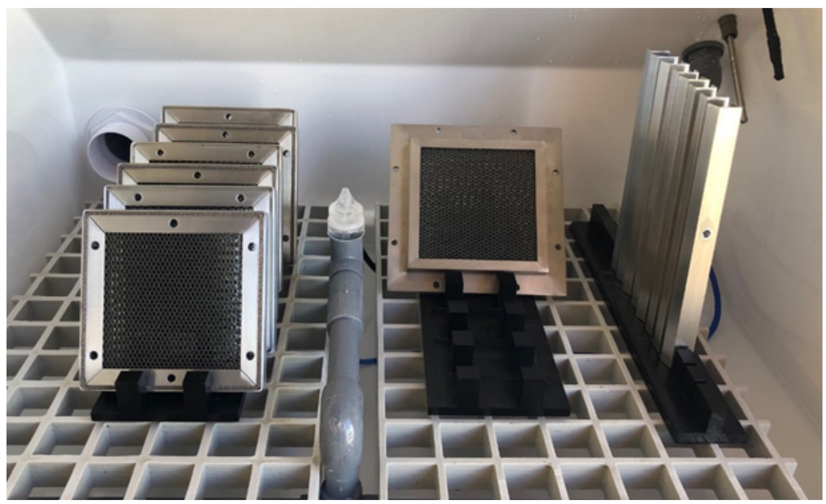


INTRODUCTION

What Is Galvanic Compatibility?

Galvanic compatibility refers to the ability of different metals to coexist within the same system, in the presence of an electrolyte (typically water) without forming an electrochemical (or galvanic) cell.

Metals (and alloys) with a similar chemical or material composition are typically better galvanic pairs compared to a pair of metals with different compositions.

What Is Galvanic Corrosion?

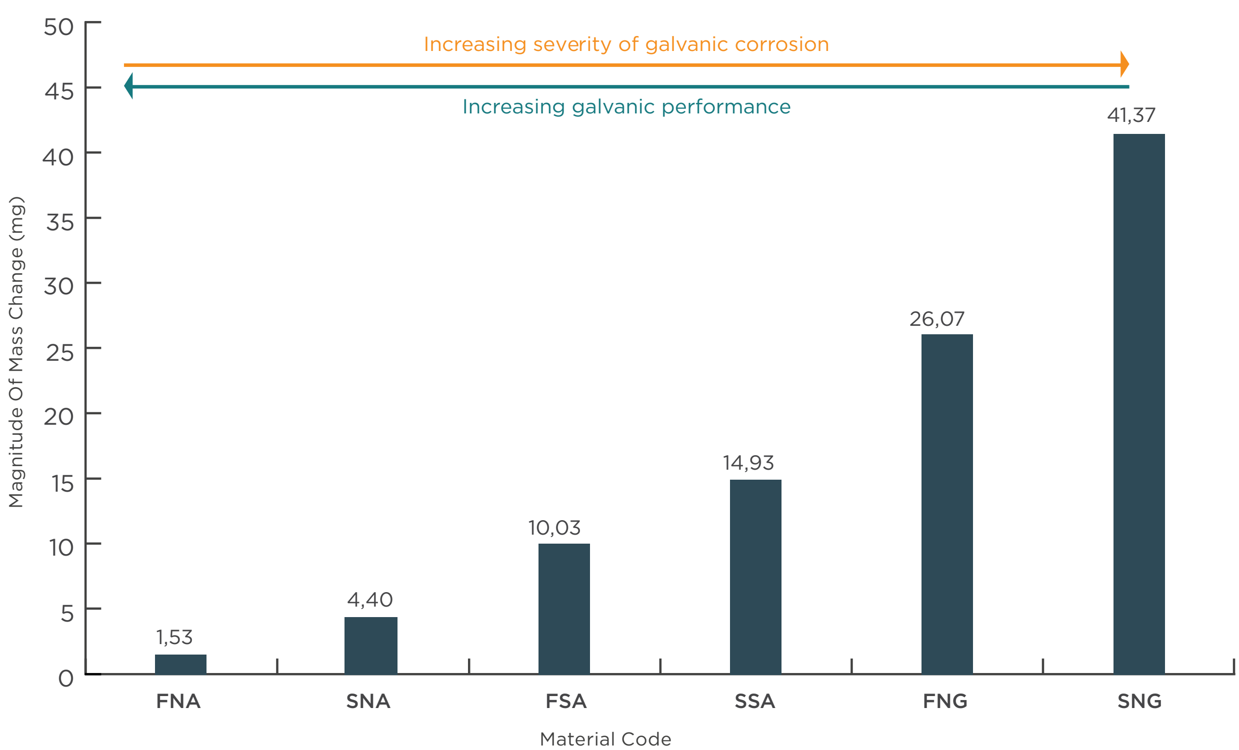
Galvanic corrosion, sometimes referred to as "bi-metallic corrosion" is an electrochemical process where one metal transfers its electrons to a dissimilar metal in the presence of an electrolyte.

This flow of electrons causes one of the metals to lose material into the electrolyte. This can be observed as corrosion "pits" in metalwork and once the system is dry, the lost material can sometimes be observed as precipitated metal salts.

Typically, corrosion is commonly associated with "extreme environments," however corrosion can be accelerated by a number of variables, such as those listed below:

- Elevated temperatures;
- High humidity;
- Extreme pH values (of the electrolyte);
- Frequent exposure to washdown fluids (frequent fluctuations in pH); and
- Precipitation of corrosion salts (corrosive self-propagation).

Magnitude Of Mass Change Against Gasket Material (Passivated Aluminium 6061-T6)



Impacts Of Galvanic Corrosion

It is critical to consider galvanic compatibility during the design process, as this is the point at which knowledge of the application and the application environment is richest.

The impacts of galvanic corrosion can vary. Below are some typical use cases of the impact of not addressing corrosion:

- Accelerated corrosion of other systems following the onset of corrosion;
- Poorer Structural integrity;
- Poorer / inconsistent electrical conductivity;
- Reduction in EMI Shielding Performance; and
- Corrosion salts could contaminate other systems (FOD).

Corrosion processes are present everywhere and completely eliminating their effects can be challenging.. This highlights the importance of managing the potential effects of corrosion at an early stage to protect vital infrastructure, devices or other applications that may be exposed to harsh environments.

Design Considerations to Minimize the Potential Impacts of Galvanic Corrosion

When designing products containing metal components, , it is important to consider the effects of corrosion early, taking into account the previously mentioned environmental variables that contribute to galvanic corrosion. Adopting the appropriate design strategy at the prototype stage will assist in efforts to mitigate the potential impacts of galvanic corrosion. It is important to highlight that at this stage, it can be difficult to eliminate corrosion without complete environmental isolation. This is not always possible given that many engineered products are designed to interface with other systems, technologies and sometimes the environment itself.

To implement strategic design, consideration of the following ideas can be utilized to minimize the impacts of corrosion:

1. **Environmental seals:**

   Selecting the most suitable environmental seal can successfully protect the system from exposure to some of the environmental conditions responsible for increased corrosion risk.

Did you know? / Examples of Real-World Galvanic Corrosion

The Statue of Liberty in New York, USA was subject to galvanic corrosion. Corrosion had occurred between the support structure made up of wrought iron and the copper exterior of the statue. This led to the rusting of the iron support structure.[1]

Another example of galvanic corrosion occurred in the aircraft carrier 'USS Independence.' The aluminum hull of the ship had a steel water jet propulsion system attached to it. The aluminium hull acted as an anode towards steel resulting in a corrosion reaction.[1]

2. **Matching of mating metal materials:**

   Matching of mating metals for mating components can help minimize the impacts of galvanic corrosion through a mechanism of minimization of the electrochemical potential difference of the two mating materials.

3. **Electrolytic, Electroless plating or passivation of metal components:**

   Plating or passivation processes minimize the impact of corrosion by coating a metal component with a layer of a different metal to reduce the surface exposure of the substrate metal to corrosion conducive environmental conditions. Guidelines for the matching of mating metals still applies with systems that are plated, so this should be considered when opting for utilization of a plated component. Plating or passivation techniques can be controlled to ensure an appropriate thickness and optimum coverage of the plating is achieved to meet the design application requirements. But in some cases, plating and passivation finishes can be considered as "sacrificial coatings," where they are designed to corrode favorably over the substrate metal and therefore prolonging the lifespan of the component.

4. **Painting or other coatings (galvanizing or powder coating):**

   Painting and other coatings can be used to coat the surface of metal components, protecting them from exposure to corrosive environments. The electrical properties of some of these coating systems can insulate the surface of the metallic components and therefore reduce (or completely negate) electrical performance characteristics. Selection of a paint or coating system should be carefully considered to ensure there is no compromise to the function of the design. Conductive paints, coatings and adhesives may be considered as an alternative to maintain electrical performance characteristics, whilst maintaining a painted or coated design requirement.

Measurement & Analysis of The Impacts Of Corrosion

Due to the complex nature of environmental conditions, exposure scenarios and material and product options within a system exposed to corrosion, it can be difficult to quantitatively measure or predict how product will perform in these types of situation.

However, qualitative data can be collected through environmental cycling testing techniques.

Various environmental conditions can be simulated using an appropriate environmental chamber. There are many different standards to define the variables previously discussed. There are a variety of industries and markets following different standard specifications therefore making the selection of an appropriate test method a complex task.

However, adoption of a set standard for direct comparison of product performance within a representative uniform environment can provide qualitative data and imagery informing product development decisions.

Standards such as ASTM B117 can serve as a comparative test method for materials. A basic summary of the conditions outlined in this standard, achieved through the proposer use of an environmental testing chamber, is as follows:

- 5% Sodium Chloride (NaCl) Solution as an electrolyte (free from other impurities);
- Dry, clean, and oil-free source of compressed air (for atomization of electrolyte);
- Humidification of air inlet into chamber through heated deionized water column;
- Temperature 40 ± 5 oC (to maintain both temperature & humidity of environment);
- Method of determining and controlling salt-fog "fallout" (even coverage of electrolyte over all samples); and
- Defined cycle time (in hours).

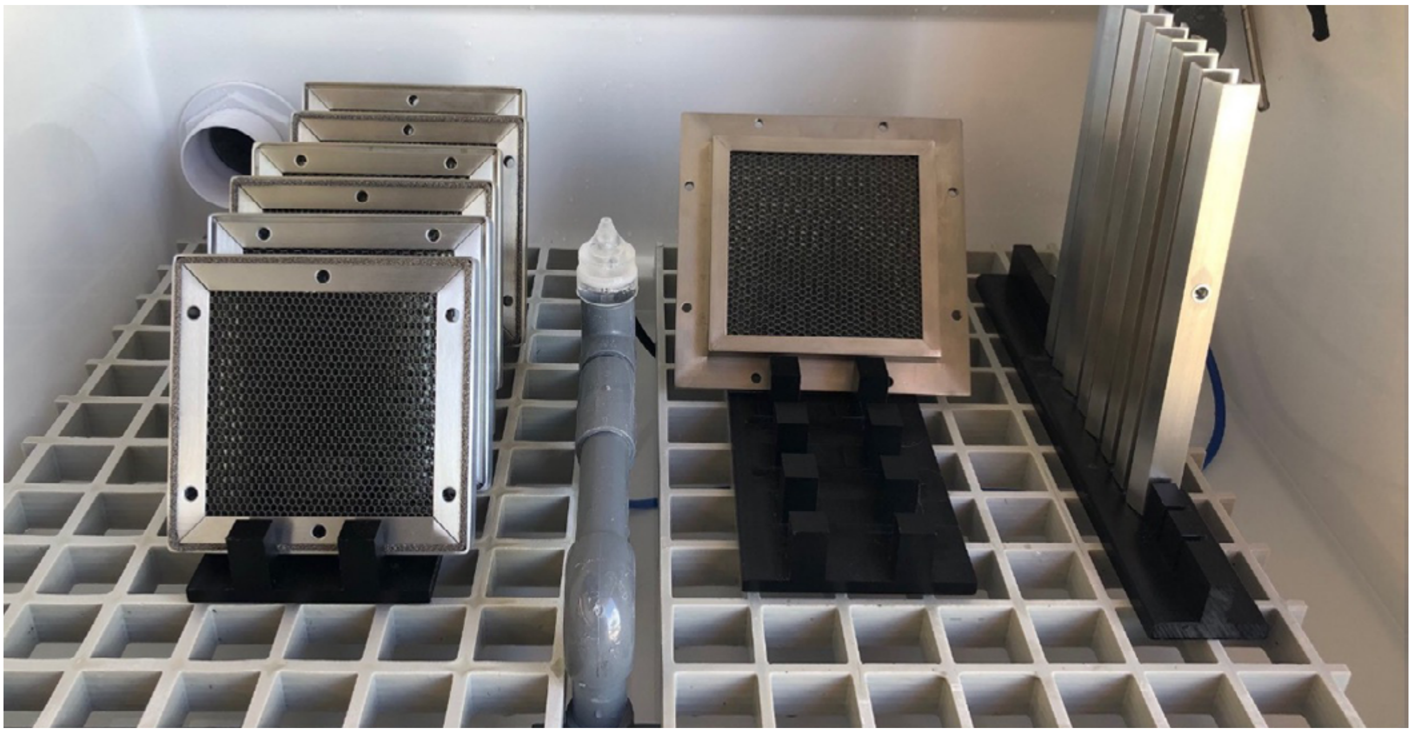
Examples Of Galvanic Corrosion Cyclic Testing

Aluminium Honeycomb Ventilation Panels

Cyclic corrosion testing was used to investigate the galvanic performance of different materials and passivated coatings within the Aluminium Honeycomb Vent product portfolio.

Various metallic components (inserts, rivets etc.) were used in combination with standard aluminium frame, aluminum honeycomb, and knitted wire mesh gasket materials to compare the galvanic compatibility of the raw material components used in the manufacture of complex EMI ventilation panel assemblies.

A variety of passivated finishes designed to reduce the impacts of corrosion of aluminium were also investigated and were referenced to a bare aluminum assembly as a control sample.



Vents & Vent materials in the Salt Fog Chamber prior to being subjected to a salt fog atmosphere for 168 hours according to ASTM B117.

Passivated Finish Findings

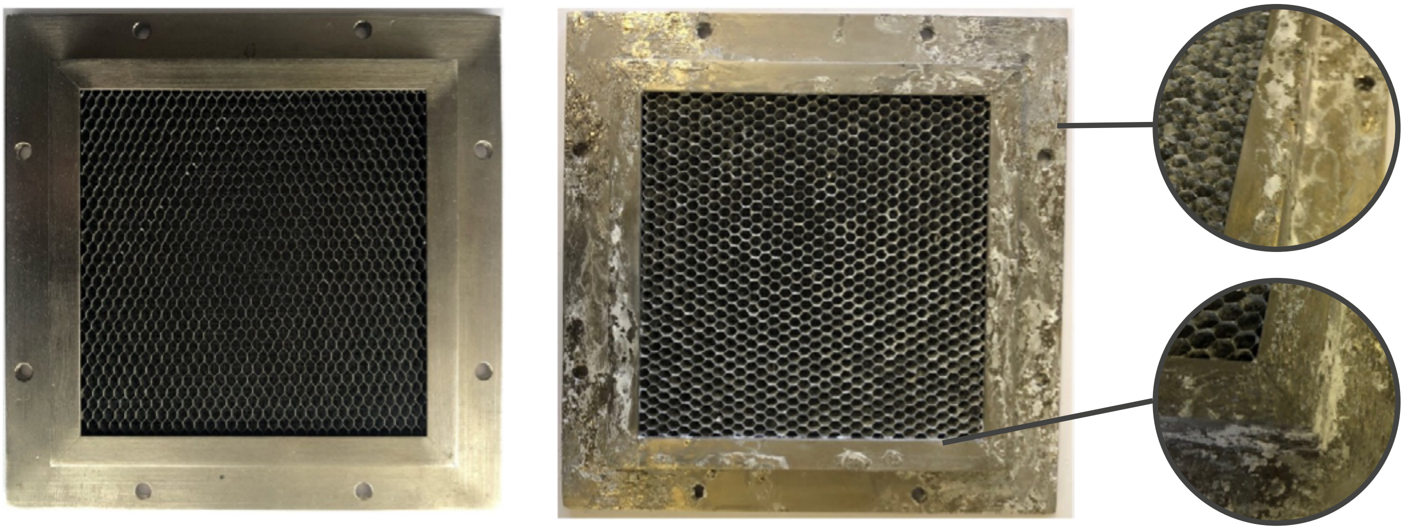
Through cyclic corrosion testing according to ASTM B117 conditions, the effectiveness of different passivated finishes with Aluminium Honeycomb Vent assemblies was determined.

Nickel plated finishes were determined to be the least efficient finishes in terms of bare aluminium corrosion performance as demonstrated by the imagery above.

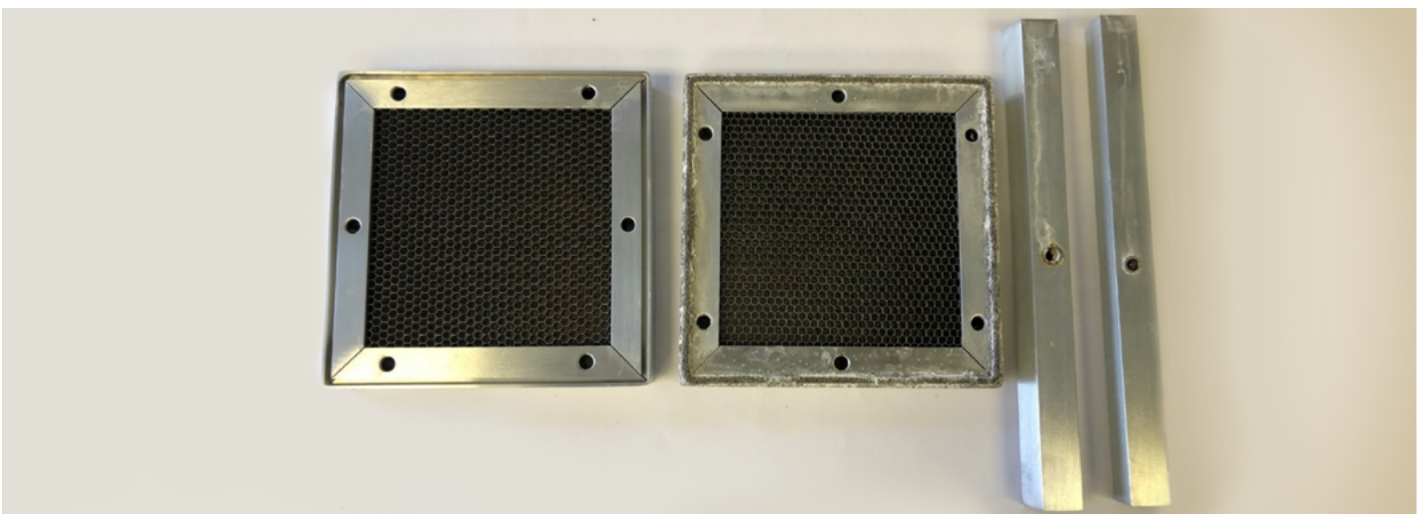
Other systems based on alternative passivation chemistry were also examined including Cr (VI) – Alocrom / Alodine 1200, Cr (III) – Surtec 650 and a Potassium Permanganate / Zinc based chemical passivation system.

The performance ranking of each of these systems was qualitatively assessed & listed in order of highest performance to lowest performance are as follows:

1. Cr (III) – Finish A
2. Potassium Permanganate / Zinc Passivation
3. Cr (VI) – Finish B
4. Nickel Plating



The front face of a Nickel plated Aluminium Honeycomb Vent before (left) and after (right) ASTM B117 Salt Fog Exposure. Significant corrosion and deposition of corrosion products has occurred on the surface of the vent.



Surtec 650 passivated vent samples following salt fog exposure.

Other metallic component findings.

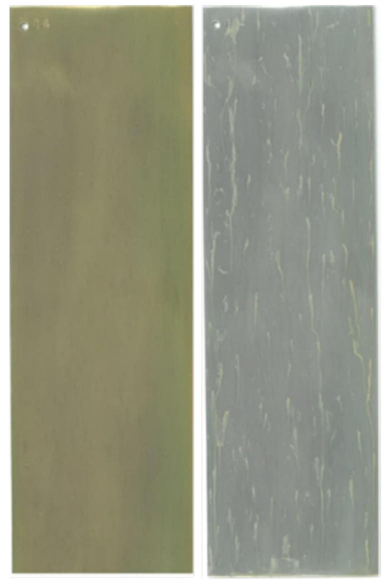
In addition to the testing of passivated finishes, when additional mating metal components are introduced to the assembly, signs of galvanic corrosion appear once more.

The more complex the assembly (multiple different components & different grades of different metals), the higher the likelihood for degradation due to corrosion.

From the experimental findings of salt-fog corrosion testing:

1. Knitted monel mesh gaskets tend to deliver poorer galvanic performance within aluminium assemblies;
2. Bright Zinc plated rivets, screws etc. also perform poorly in the same context; and
3. These observations were mitigated / minimized in cases where Surtec 650 passivated finish was selected.

Sample 16: Polished and etched Aluminium 6061-T6, before testing (left) and after testing (right).



Sample 14: Aluminium 6061-T6 Passivated with Alocrom 1200. Before (left) and after (right) salt fog testing.

Aluminium 6061-T6 sample treated with Surtec 650 passivation, prior to testing (left) and after testing (right).

SUMMARY

Galvanic corrosion is a highly complex and critical topic that needs to be considered in each unique environmental application scenario. Qualitative determination of an engineered component's performance with a simulated corrosive environment is possible, provided that an applicable test standard is adopted to define the corrosive environments and ageing times.

These factors should be considered when product designs are made for harsh environment applications. If critical systems are used in an applicational environment conducive to corrosion, then careful consideration of materials used should be made as a first step, with secondary and passive corrosion protection to be considered as a secondary failsafe allowing optimal corrosion resistant performance.

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References

[1] https://byjus.com/chemistry/galvanic-corrosion/

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