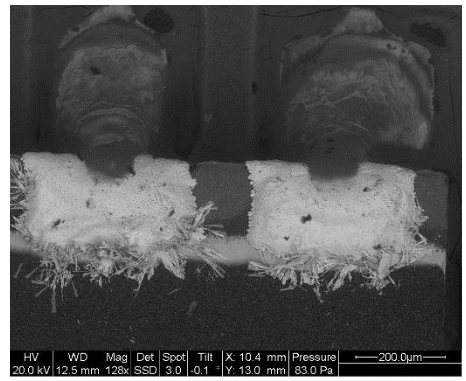
calce Corrosion Research

Improving robustness and testing of electronic products and systems

August 2019

Projections for strong growth in materials used to protect electronic products and systems

With the exponential expanse of electronics though the widening Intranet of Things (IoT) and the reliance on free air cooling, environmental protection of electronics from corrosion and other factors is becoming increasingly important. Significantly, financial research is projecting a strong growth for materials used to protect electronic products and systems. However, for these materials to be effective, it is important that the correct tests are conducted and that the test results are clear.



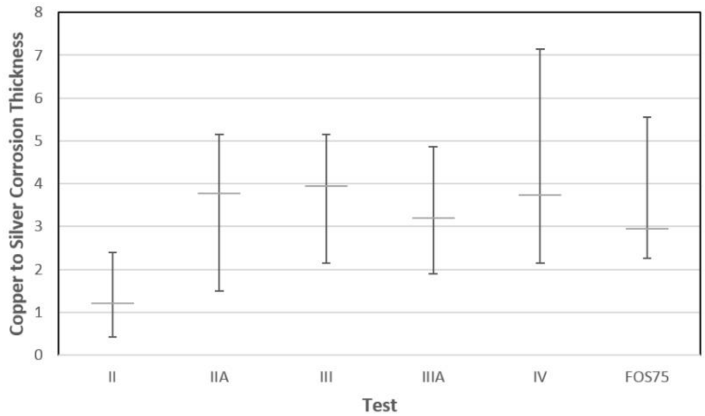
Silver Sulfide Corrosion of Chip Resistor Inner Termination

CALCE is conducting research to understand standard corrosion tests as well as examining the corrosion protection offered by materials used in electronics.

For questions related to CALCE's corrosion research, contact Dr. Michael Osterman. (osterman@umd.edu).

Why are standard corrosion tests not working?

Field failures of immersion silver board finish and chip resistors due to corrosion have raised concerns that standard corrosion test methods are inadequate for qualifying designs for use in potentially corrosive environments. These issues have led to an examination of harsher test methods, such as flowers of sulfur (FoS), to precipitate failure. However, it is important to understand why standard tests may work in some cases and not in others. To this end, CALCE is conducting and comparing standard corrosive test conditions such as those specified under EIA-364-TP65 Mixed Flowing Gas Tests and FoS at different temperatures. For the most part, mixed flowing gas tests combine chlorine, nitrogen dioxide, hydrogen sulfide, and, in some cases, sulfur dioxide in a chamber held at a constant temperature and humidity. The differences in tests are limited to variations in gas concentration by a factor of two and temperature/humidity conditions with variations of 25 °C and 20% RH. For FoS, sublimation provides ionized sulfur species in gas form within an enclosure at a fixed humidity based on a temperature and salt solution. A comparison of silver and copper corrosion reveals a significant difference under fixed duration tests. In particular, with the exception of the EIA-364-TP65 Class II test, the corrosion thickness of copper is more three times higher than silver. The figure below shows the difference in copper and silver over the examined tests.



Ratio of Copper and Silver Corrosion Product Thicknesses

A full report is available to CALCE members and corrosion research sponsors.

Are we measuring silver corrosion properly?

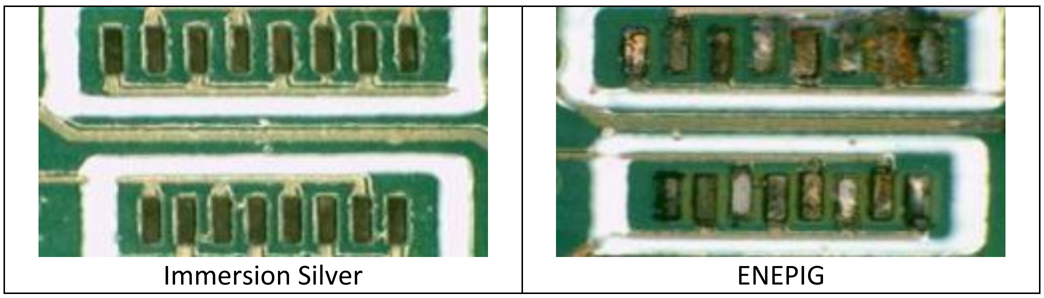
To qualify a material system for a particular life time in a corrosive environment, tests are developed to generate an expected corrosion state that may occur over the life time of a product. For instance, ANSI/ISA 71.04 (2013) indicates that in a moderate corrosive environment, a sulfur-based silver corrosion product will grow at a rate of 100 nm per month. Thus, a silver corrosion product thickness of 12 micrometers would be expected after a 10-year exposure to a moderate corrosive environment. To determine the likelihood of a product surviving such an environment, we would want to run a test that that produces a 12 micrometer thick corrosion product. To assure that we have achieved a desired corrosion state, witness coupons composed of metals of interest, such as silver and copper, may be used. However, even when using witness coupons, it can be difficult to gauge the corrosion thickness, since corrosion products, particularly silver sulfide based products, can be quite fragile. To address this issue, it is important to capture the corrosion product when handling the coupons. If the corrosion product is not captured, the amount of corrosion that has occurred may be inaccurately recorded.

Shedded Silver Corrosion Product

A full report is available to CALCE members and corrosion research sponsors.

Does ENEPIG provide better protection than immersion silver?

Printed wiring board surface finishes are designed to provide solderable surfaces and an electrical contact interface as well as to prevent corrosion and electrochemical migration. With regards to corrosion protection, immersion silver has received poor marks after field failures occurred in end-use locations with high sulfur content. Other surface finishes such as lead-free (SAC) hot-air-leveled solder have been found to be preferred. For high-performance applications and applications that may have long-term storage concerns, electroless nickel immersion gold (ENIG) may be used. However, concerns related to black pad have resulted in an interest in electroless nickel electroless palladium, immersion gold (ENEPIG). CALCE has conducted work on ENEPIG including a literature review and vibration and drop tests. In addition to durability testing, CALCE has also evaluated the robustness of ENEPIG under mixed flowing gas tests. Images of immersion silver and ENEPIG finished interdigitated fingers after 10 days after a mixed flowing gases exposure are depicted in the figure below.



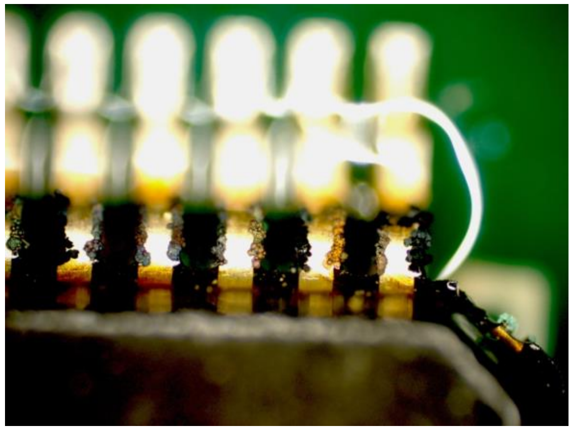
Corroded interdigitated fingers with Immersion Silver and ENEPIG surface finish

Test findings indicate that the tested immersion silver did not exhibit creep corrosion while the ENEPIG finished pads experienced edge and creep corrosion, which led to electrical shorts between adjacent ENEPIG finished fingers. These results indicate that care should be taken when considering the use of ENEPIG finish in products that may be subjected to corrosive environments.

A full report is available to CALCE members and corrosion research sponsors.

Does your conformal coating protect you from corrosion?

Conformal coatings are often used to protect printed wiring assemblies from failure due to moisture and corrosion. However, the coating may not be sufficient to protect lead terminations from failure. CALCE has examined acrylic, silicone, urethane, parylene, and atomic layer deposit (ALD) coatings for their effectiveness at preventing corrosion of nickel-palladium-gold-finished thin quad flat package (TQFP) lead wires. In the coating study, the coverage of each coating was examined, and assemblies were subjected to cycles of temperature cycling and mixed flowing gas exposure. Non-uniform coating thickness was observed on the TQFP lead wires, and little to no coating material was found on the lead wire edges for the acrylic, silicone, and urethane coatings. Further, corrosion was found to initiate and grow at the non-covered or thin coating regions. Parylene, which had the most uniform coating, was found to provide the best resistance to corrosion, while corrosion products were observed on the terminals of inspected parts protected by the other coatings. The primary takeaway for this study is that product manufacturers need to work with conformal coating houses to make sure adequate coverage is occurring in areas susceptible to corrosion. Parylene, which is vapor deposited, is preferred due to its uniform coverage. Silicone is not preferred for corrosion protection, particularly when sulfur-based corrosion is expected.



Copper corrosion of acrylic-coated terminals

A full report is available to CALCE members and corrosion research sponsors.

CALCE corrosion publications

The following are CALCE publications on corrosion testing and corrosion failure issues associated with electronic products and systems. For more information, visit the CALCE corrosion website: https://calce.umd.edu/corrosion-electronics.

- Influence of Varying H2S Concentration and Humidity Levels on ImAg and OSP Surface Finishes, Amer Charbaji, Michael Osterman, and Michael Pecht, *International Journal of Mechanical Engineering and Technology (IJMET), December 2015.*
- Corrosion of ImAg-Finished PCBs Subjected to Elemental Sulfur Environments, S. Zhang, R. Kang, and M. Pecht, *IEEE Transactions on Device and Materials Reliability*, Vol. 11, No. 3, pp. 391-400, September 2011.
- Reliability Assessment of Land Grid Array Sockets Subjected to Mixed Flowing Gas Environment, Shuang Yang, Ji Wu and Michael G. Pecht , *IEEE Transactions on Reliability*, Vol. 58, No. 4, pp. 634-640, December 2009.
- Investigation on Mechanism of Creep Corrosion of Immersion Silver Finished Printed Circuit Board by Clay Tests, Y. Zhou and M. Pecht, *55th Annual IEEE Holm Conference*, Vancouver, British Columbia, Canada, pp. 321-330, September 14-16, 2009.
- The influence of SO2 environments on immersion silver finished PCBs by mixed flow gas testing, Shunong Zhang, Michael Osterman, Anshul Shrivastava, Rui Kang and Michael G. Pecht, *International Conference on Electronic Packaging Technology & High Density Packaging*, 2009. ICEPT-HDP '09., Vol., No., pp 116-122, August 10-13 2009, DOI: 10.1109/ICEPT.2009.5270782.
- Assessment of Ni/Pd/Au-Pd and Ni/Pd/Au-Ag Pre-Plated Lead-frame Packages Subject to Electrochemical Migration and Mixed Flowing Gas Tests, P. Zhao, M. Pecht, S. Kang, and S. Park, *IEEE Transactions on Components and Packaging Technologies*, Vol. 29, No. 4, pp. 818-826, December, 2006.

- Mixed Flowing Gas Studies of Creep Corrosion on Plastic Encapsulated Microcircuit Packages with Noble Metal Pre-Plated Lead-frames, P. Zhao, and M. Pecht, *IEEE Transactions on Device and Materials Reliability*, Vol. 5, No. 2, pp. 268-276, June 2005.
- Palladium-plated Packages: Creep Corrosion and Its Impact on Reliability, J. Xie and M. Pecht, *Advanced Packaging*, pp. 39-42, February 2001.
- Effect of Corrosion on the Transfer Impedance of Zinc-Coated Steel Enclosures, J. Xie, M. Pecht, D. Barbe, S. Das, J. Nuebel, and B. Zand, *IEEE Transactions on Electromagnetic Compatibility*, Vol. 42, No. 1, pp. 71-76, February 2000.
- Corrosion of a Zinc-coated Steel Enclosure at the Contact Interfaces of Gasket Joints, J. Xie, M. Pecht, S. Das, J. Nuebel, and B. Zand, *IEEE Transactions on Components and Packaging Technologies*, Vol. 23, No. 1, pp. 136-142, March 2000.
- The Effect of Corrosion on Shielding Effectiveness of a Zinc-Coated Steel Enclosure, S. Das, J. Neubel, B. Zand, D. Hockanson, J. Xie, and M. Pecht, *the 1998 IEEE International Symposium on Electromagnetic Compatibility*, pp. 1041-1046, Denver CO, August 1998.
- Kinetic Modeling of Corrosion Film on Unloaded Precious Metal Plated Contacts, M. Sun, S. Javadpour, R. Martens, and M. Pecht, *Proceeding of 30th International Connector & Interconnection Technology Symposium 1997*, USA, pp. 227-244, 1997.
- Modeling the Effects of Mixed Flowing Gas Corrosion and Stress Relaxation on Contact Interface Resistance, S. Bhagath and M. Pecht, *ASME Journal of Electronic Packaging,* Vol. 115, pp. 404-409, Dec. 1993.
- Corrosion Modeling in Micorelectronic Packaging, A. Christou, X. Shan, and M. Pecht, International Journal of Microcircuits and Electronic Packaging, Vol. 15, No. 1, First Quarter 1992.
- A Corrosion Rate Equation for Microelectronic Die Metallization, M. Pecht and W. Ko, *The International Journal for Hybrid Microelectronics*, Vol. 13 (2), pp. 41-52, June 1990.
- A Model for Moisture Induced Corrosion Failures in Microelectronic Packages, M. Pecht, *IEEE Transactions on Components, Hybrids, and Manufacturing Technology*, Vol. 13 (2), pp. 383-389, June 1990.