SAND2022-15461C

Sandia National Laboratories

High Energy X-ray Photoelectron Spectroscopy of COTS Electronics Interfacial Failure Modes

Samantha G. Rosenberg[1], Melissa L. Meyerson[2], Matthew A. Kottwitz[1], Rupesh Rajendran[3], Matthew Reingold[1], Nhu M. Lam[1], Brandon D. Young[4], Preet Singh[3], Josh Kacher[3], J. Elliott Fowler[1]

[1]Materials Characterization and Performance Department, Sandia National Laboratories, Albuquerque, New Mexico, United States of America; [2]Nanoscale Sciences Department, Sandia National Laboratories, Albuquerque, New Mexico, United States of America; [3] School of Materials Science and Engineering, Georgia Institute of Technology, Atlanta, Georgia, United States of America; [4] Microsystems Packaging and Polymer Processing Department, Sandia National Laboratories, Albuquerque, New Mexico, United States of America

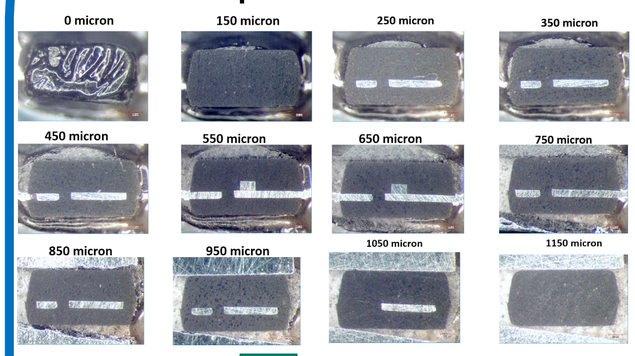
sgrosen@sandia.gov

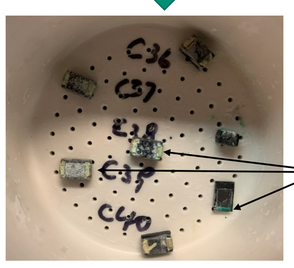
Overview:

Commercial of the shelf (COTS) parts are exposed to extreme environments (e.g. high humidity and/or high heat) during their service life that could compromise their ability to meet performance standards. Such failures can have drastic consequences. In this study we replicate likely environmental conditions for two common electrical COTS parts, capacitors and diodes, and study the permeation of corrosion and associated failure modes. In partnership with Georgia Tech, we employed a new, safer method for sectioning the parts that, unlike the standard method, does not rely on boiling hot acid. This method was used on both capacitors and diodes before exposing them to either water fog or 5% NaCl salt fog at 50 °C for 100 hours. SEM revealed corrosion of the capacitors when exposed not only to salt-fog, but water as well. This corrosion was corroborated with HAXPES at BNL's NSLS-II and with AES at SNL. In contrast, the diodes proved to be somewhat resistant to corrosion permittivity.

Preparation of Capacitors & Diodes

Capacitors

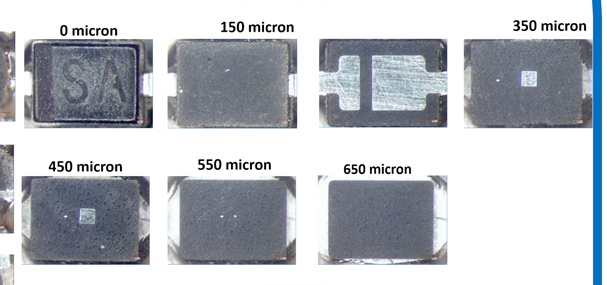


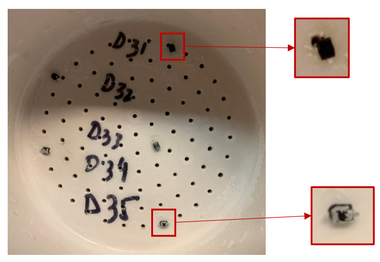


Samples were sectioned to different depths, and then placed in the 5% NaCl or water fog chamber at 50°C for 100 hours

Green corrosion products and white salt present after exposure

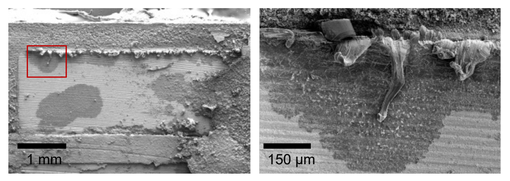
Diodes



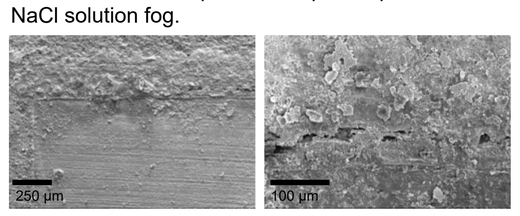


SEM Analysis of Capacitors & Diodes

Capacitors



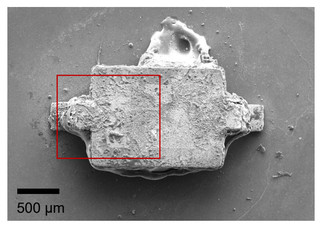
SEM of corroded capacitor samples exposed to 5% NaCl solution fog.

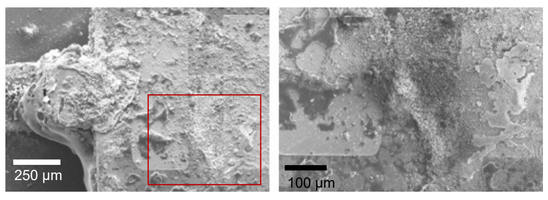


SEM of the corroded capacitor exposed to pure water fog.

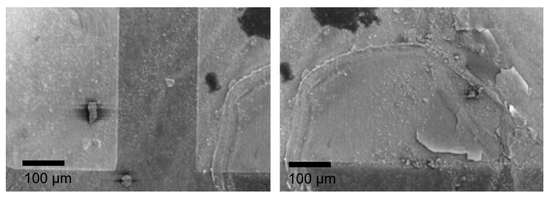
Most corrosion products are formed at the interface, indicating a galvanic effect of non-similar metals in contact. Water fog creates less corrosion than salt fog; however, interfaces still showed corrosion products.

Diodes



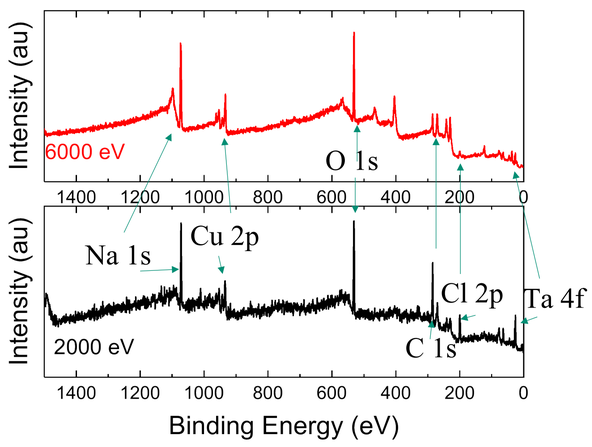


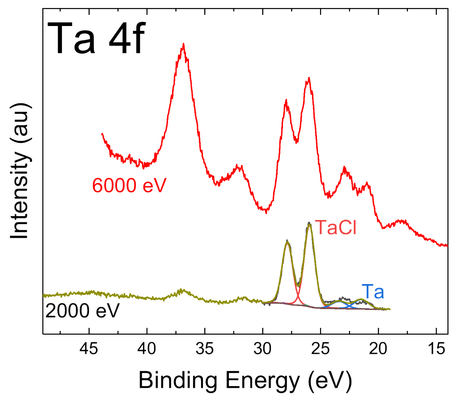
SEM of the corroded diode samples exposed to 5% NaCl solution fog.

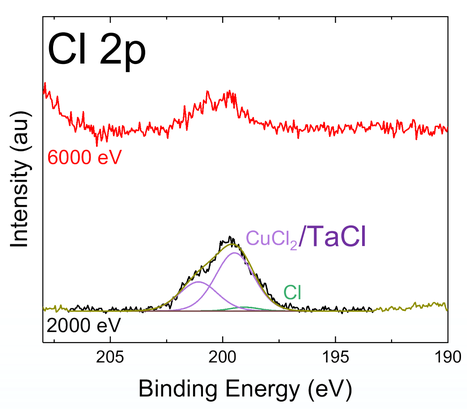


SEM of the corroded diode samples exposed to pure water fog.

HAXPES Analysis of Capacitors







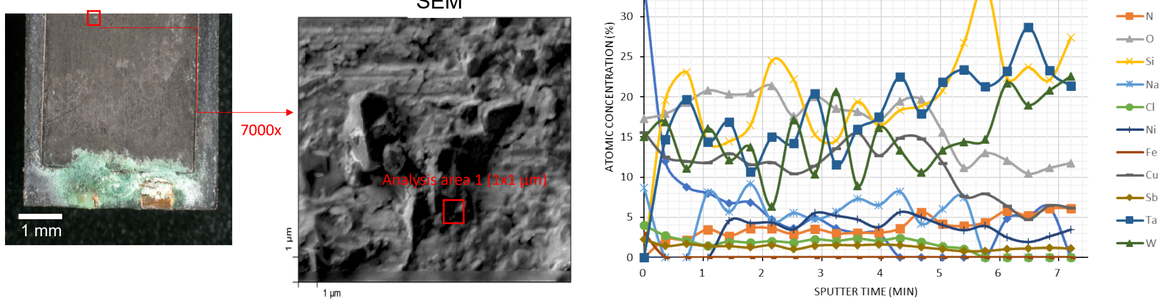
HAXPES was performed at 2000eV and 6000eV on several capacitor samples prepared according to the panels above (sectioned then 5% NaCl salt fog exposure at 50°C for 100 hours).

At 2000eV all expected peaks are seen, Na, Cl, Cu, C, Ta and O. At 6000eV Na and Cl are present as well, suggesting that the NaCl has penetrated through the surface of the capacitor. High resolution spectra shows the Cl is present as $CuCl_2$ and TaCl.

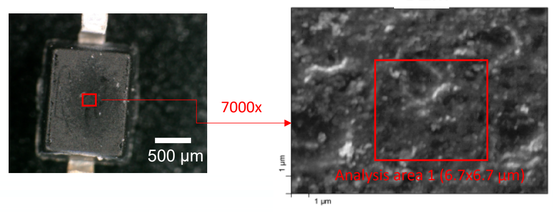
Capacitor sample formed a bubble after being exposed to X-rays and UHV.

*Diodes were too small for HAXPES analysis at this time

Auger Analysis of Capacitors & Diodes



Capacitors exposed to salt fog show corrosion on the surface (green/white area on SEM), as well as Na & Cl on the depth profile.



Sputter time (min)	C1	N1	O1	Si1	Cr1	Fe1	Ni1	Sn1	Ta2
0	24.12	9.46	4.08	28.52	3.4	0	0	5.19	25.22
0.36	44.16	6.22	10.9	16.46	0	5.38	0	2.42	14.48
0.72	34.5	5.69	6.12	22.55	2.24	8.68	5.16	2.02	13.04
1.08	36.05	6.43	8.27	18.4	3.83	8.26	0	1.31	17.46
1.62	33.99	7.13	6.7	17.77	3.48	9.95	0	1.81	19.16
2.62	30.61	5.73	6.72	22.87	3.92	9.54	0	2.16	18.45
3.62	35.64	6.64	7.13	21.99	0	7.65	0	2.43	18.52

Diodes exposed to salt fog show no corrosion on the surface or through depth profiling, indicating that the epoxy used may be the key to corrosion abatement.

U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC,
a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.
SAND2022-XXXX C
SAND No. _____

Sandia National Laboratories

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.