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La QUALITÀ nell'AEROSPACE

Le sfide e i risultati

4-5 MAGGIO 2023
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Number of cycles in space equipment thermal testing: state of the art and proposal for optimization

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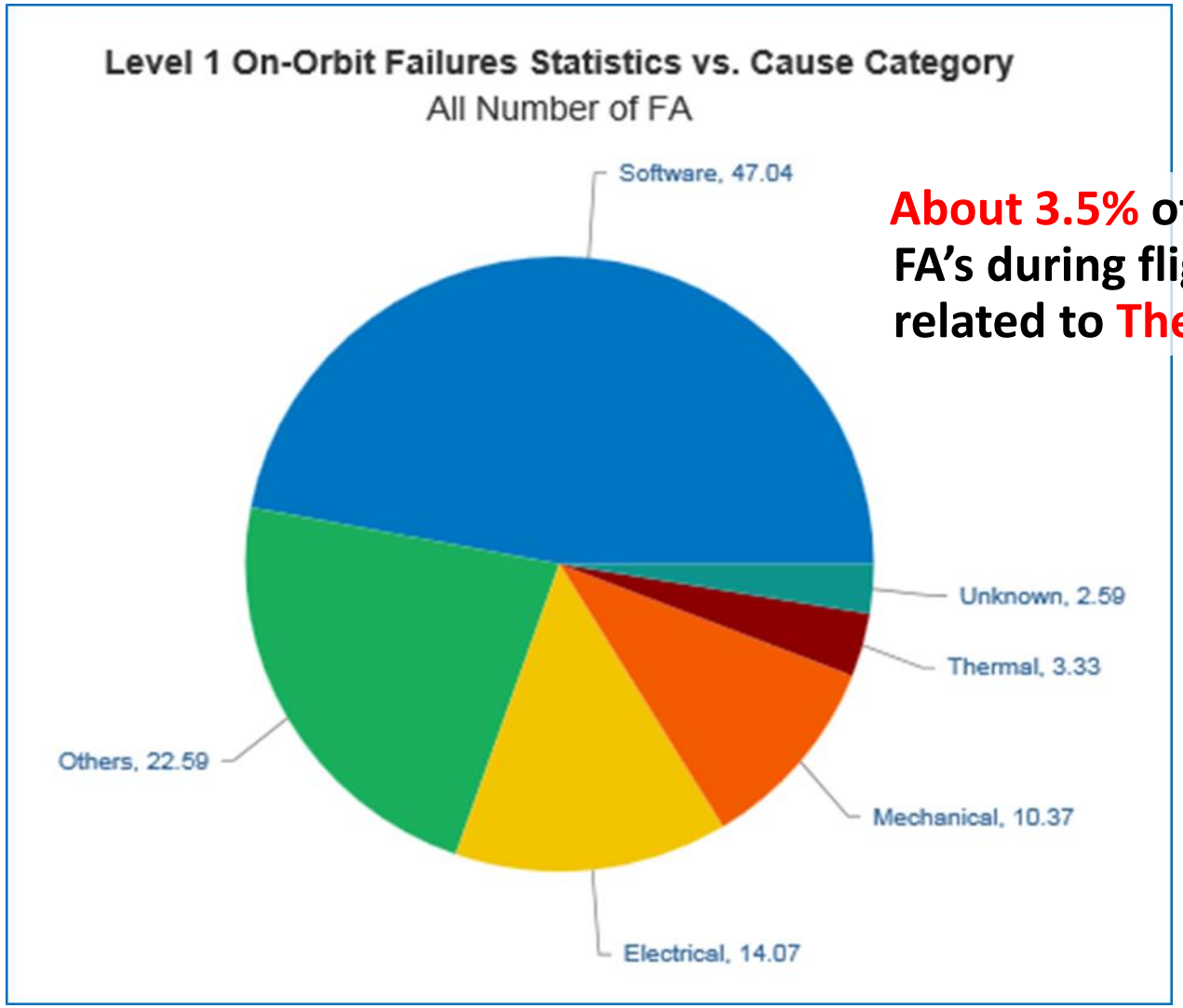
MATED by TAS-I/PoliTO – 6th Int. WS on Verification and Testing of Space Systems

The Model And Test Effectiveness Database (MATED) is European repository of information on verification, test and flight data of space projects.

Objective is to improve the effectiveness of the selected assembly, integration test and verification approaches for new projects, performing investigations on space project plan and AIV/AIT activities and relate them to anomalies (NCRs) experienced during the AIT campaign and to flight anomalies (FAs) encountered during flight operations.

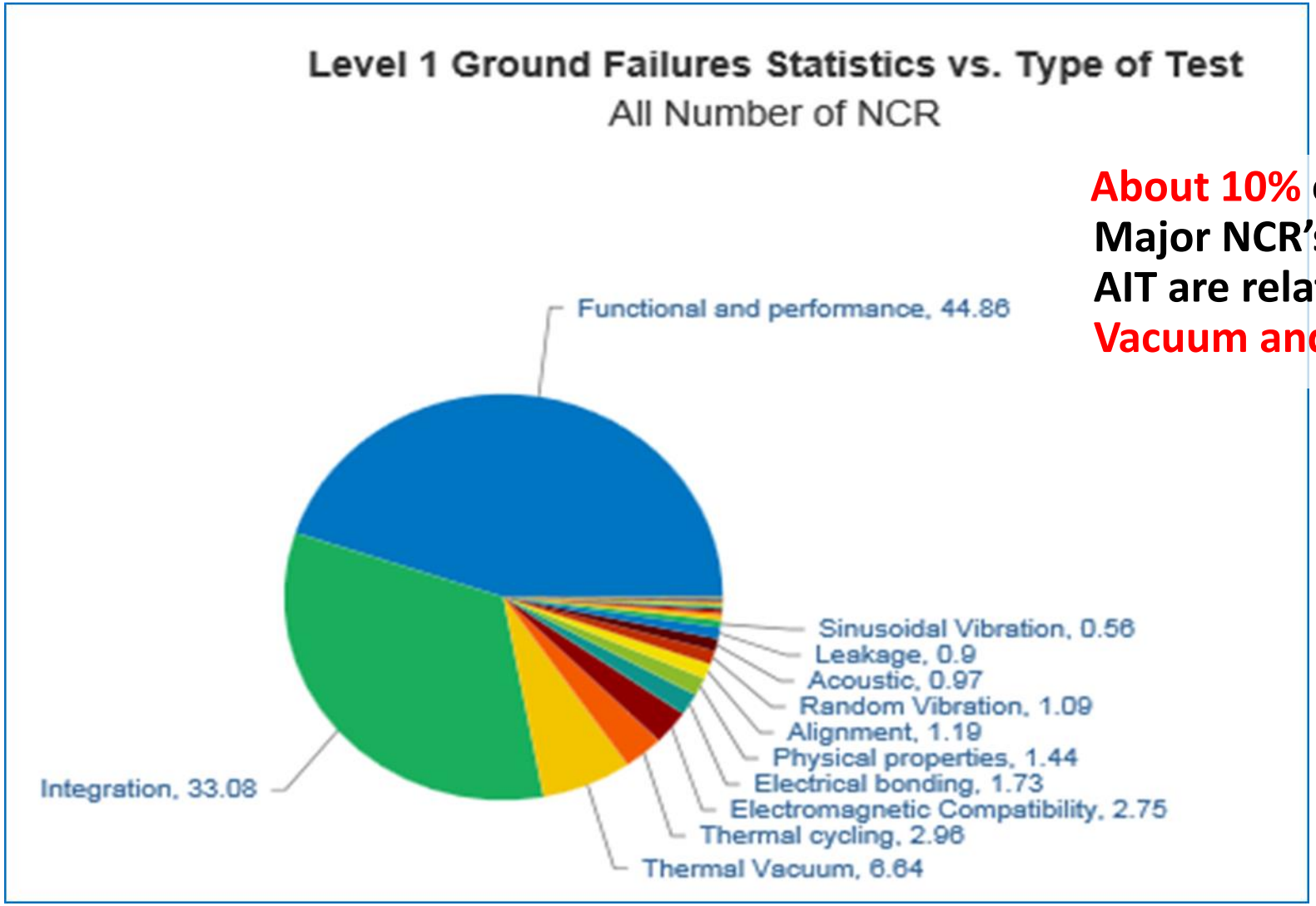
Data from 30 Projects have been collected, with more than 100 FM's and more than 4300 AIT related NCRs and 329 related FA's

MATED by TAS-I/PoliTO: FA's statistics



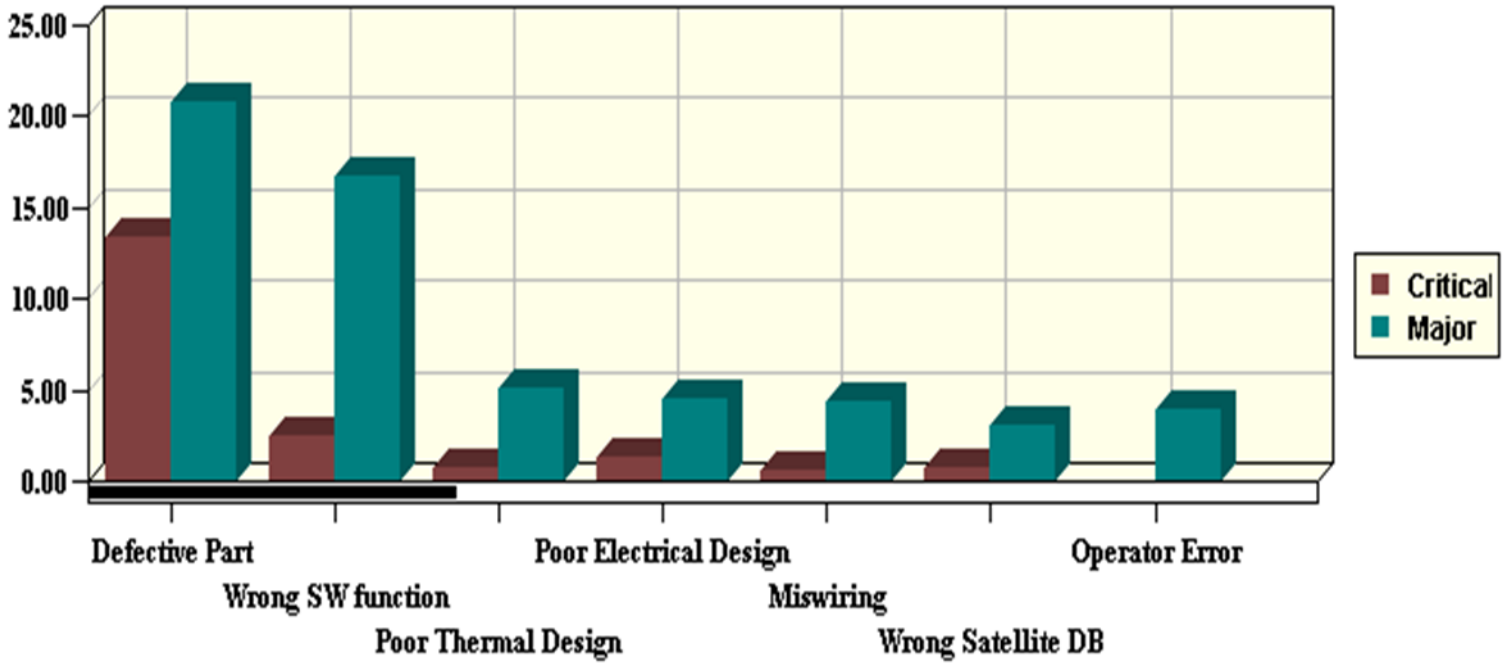
About 3.5% of Critical and Major FA's during flight operations are related to **Thermal Causes**

MATED by TAS-I/PoliTO: NCR's statistics



About 10% of Critical and Major NCR's during project AIT are related to **Thermal Vacuum and Cycling Test**

MATED by TAS-I/PoliTO: NCR's statistics



In average ground anomalies (Critical and Major) issued during the Thermal Vacuum Test in Acceptance or PFM at System Level are 5 per satellite

The most important detailed cause is: "Defective Part"

Similar investigations made by Aerospace (2002) show 4.1 mission degrading failures per satellite, where the first vehicle in the build cycle presents 6 critical anomalies per satellite.

Test Standards for TV/Cycling Testing

- U.S. Department of Defense (MIL-STD-1540 and SMC-S-016)
- European Space Agency (ECSS-E-ST-10-03A and 03C)
- NASA Goddard Space Flight Center (GEVS)
- JAXA (JERG-2-130A)

Hardware	Test Level	Test Margins (°C)				Test Durations (cycles)			
		DoD	ESA	GEVS	JAXA	DoD	ESA	GEVS	JAXA
Vehicle	Qualification	10	5	10	5	8	4	4	4
	Protoflight	5	5	10	5	4	4	4	4
	Acceptance	0	0	5	0	4	4	4	4
Unit	Qualification	10	5	10	5	**27**	**4**	**8**	**8**
	Protoflight	5	5	10	5	**20**	**4**	**8**	**8**
	Acceptance	0	5	5	0	**14**	**4**	**8**	**8**

Considerations:

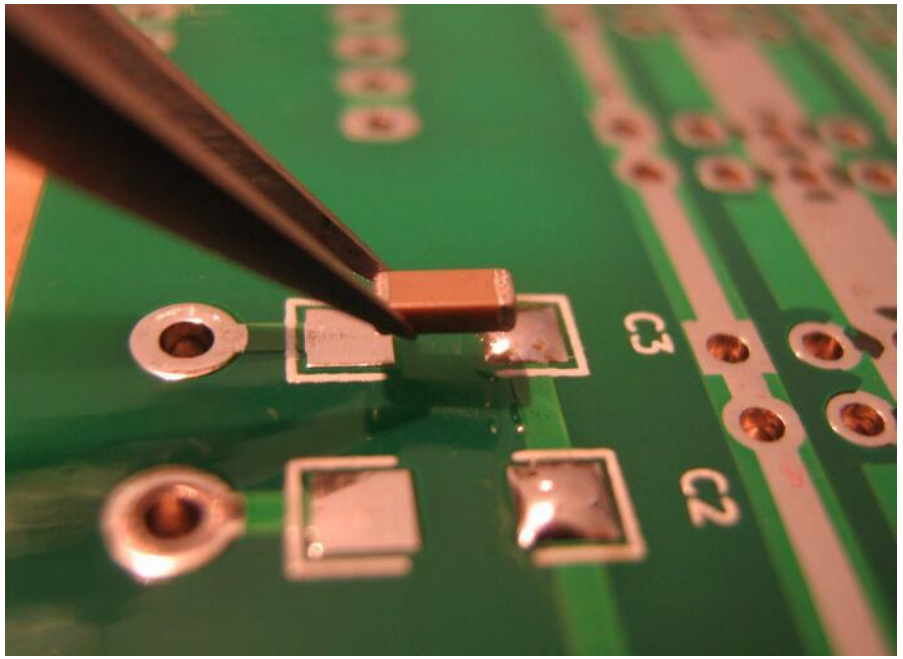
Limited number of FA's in orbit linked to thermal causes, significant number of NCR's discovered in System TV/Cycling testing, very similar independently by the big differences in the number of cycles applied at equipment level….

Question:

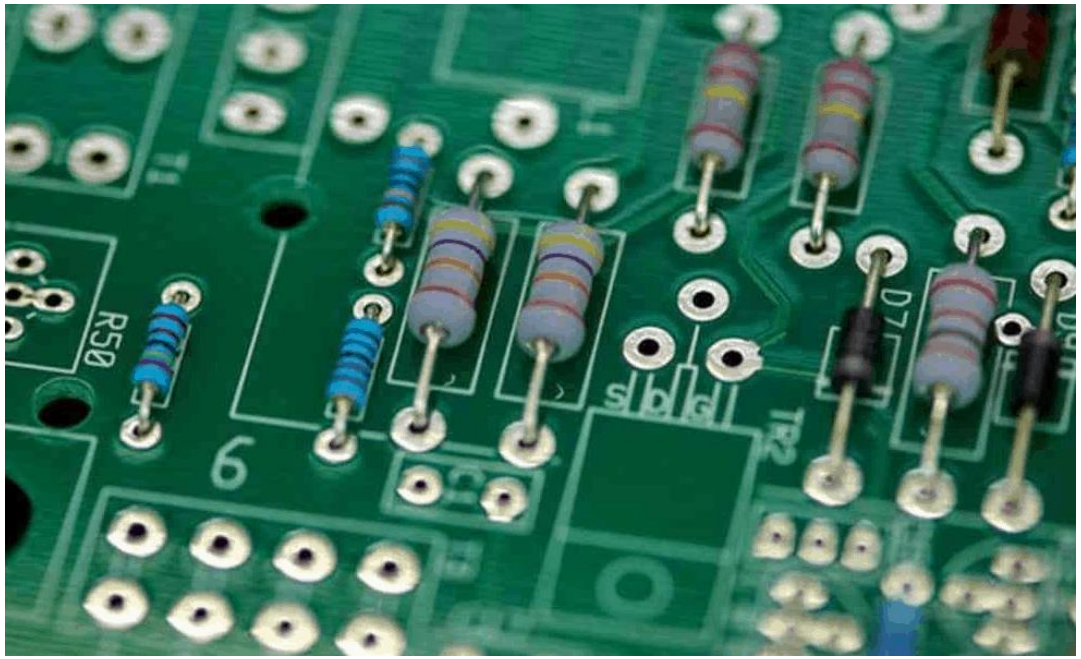
What is the optimum number of thermal cycles at equipment level?

Comparison between SMD and SMT technology

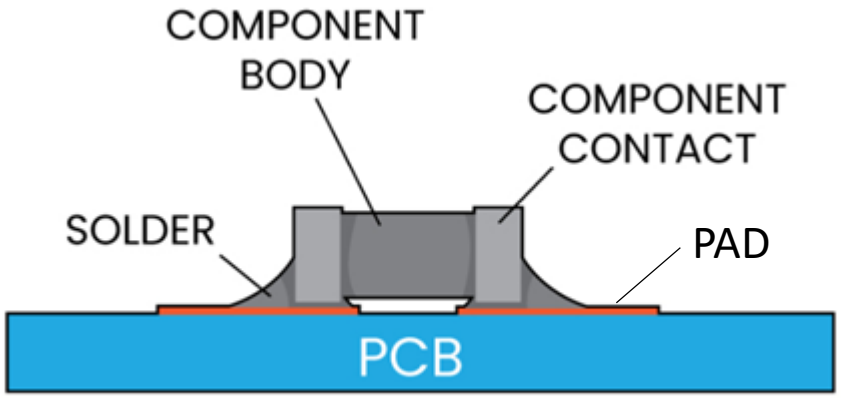
SMD - SURFACE MOUNTING DEVICE

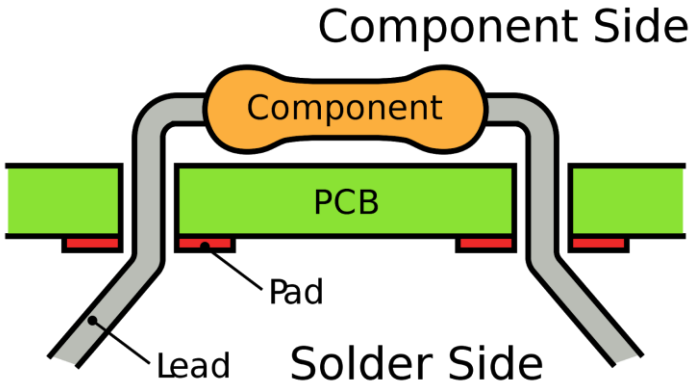


SMT - SURFACE MOUNT TECHNOLOGY

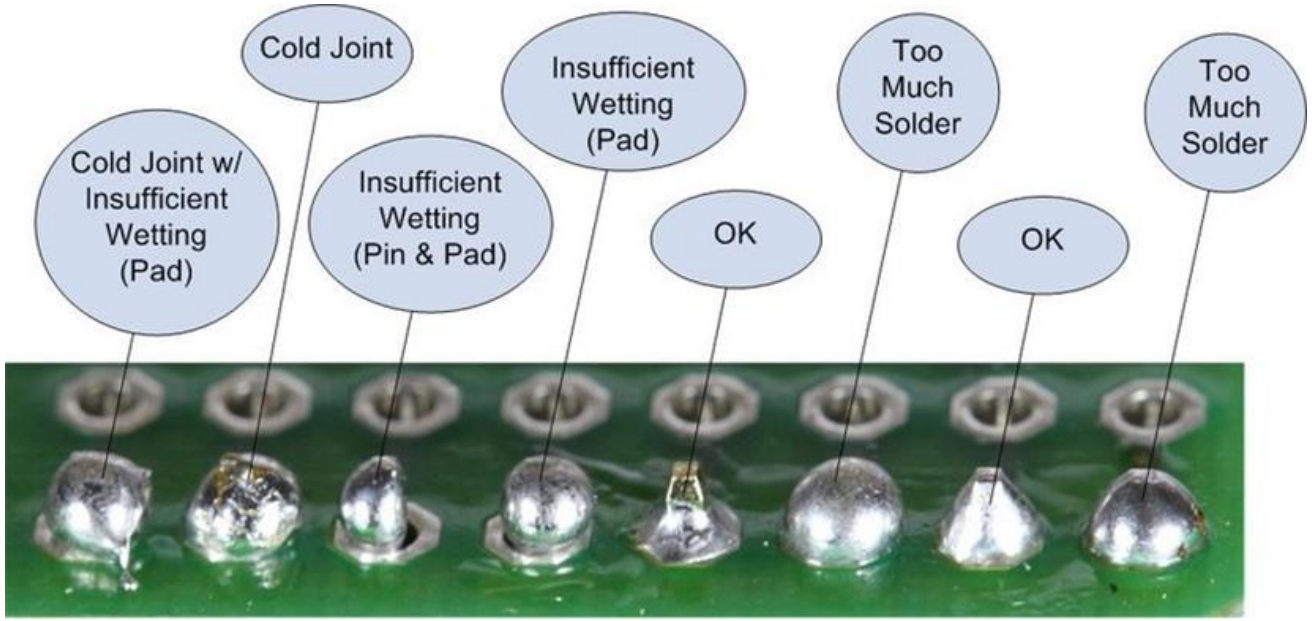


Comparison between SMD and SMT technology

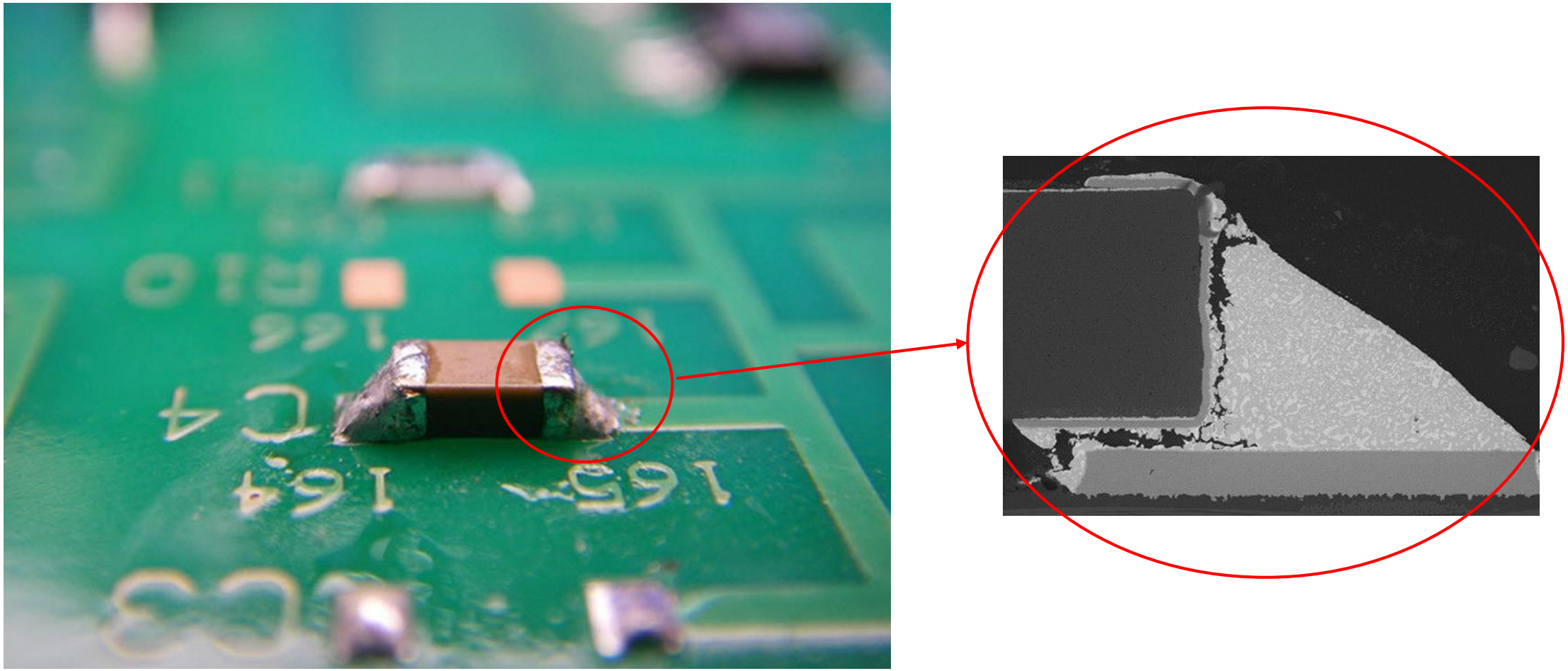




SMT soldering joint defects

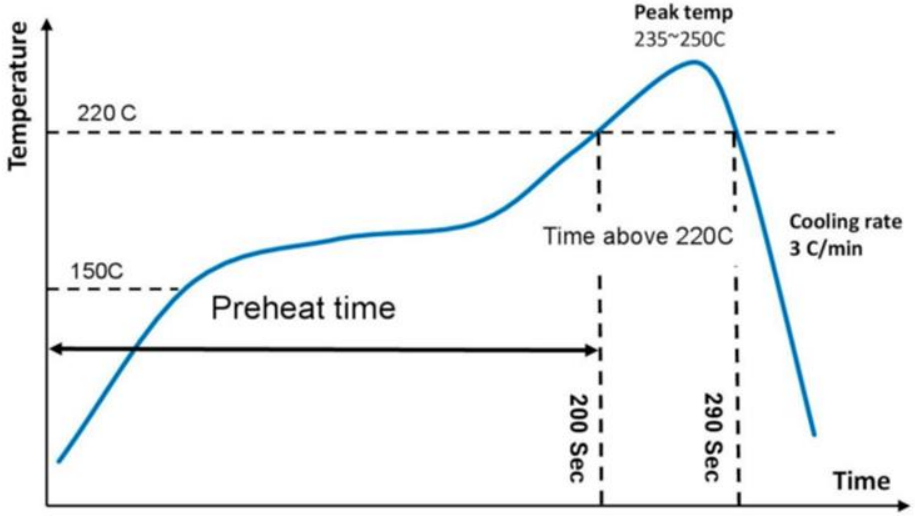


Defect on a SMD soldering joint



Schematic figure of Reflow oven and temperature profile

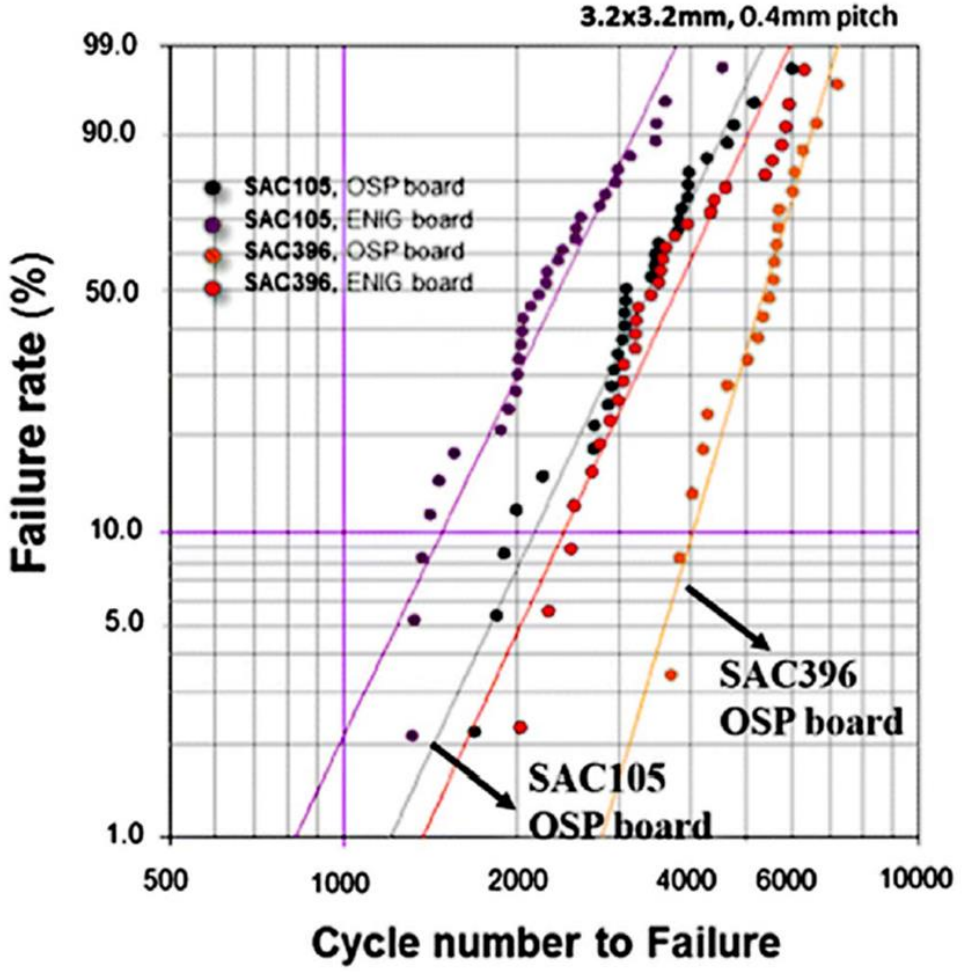
(a)



(b)

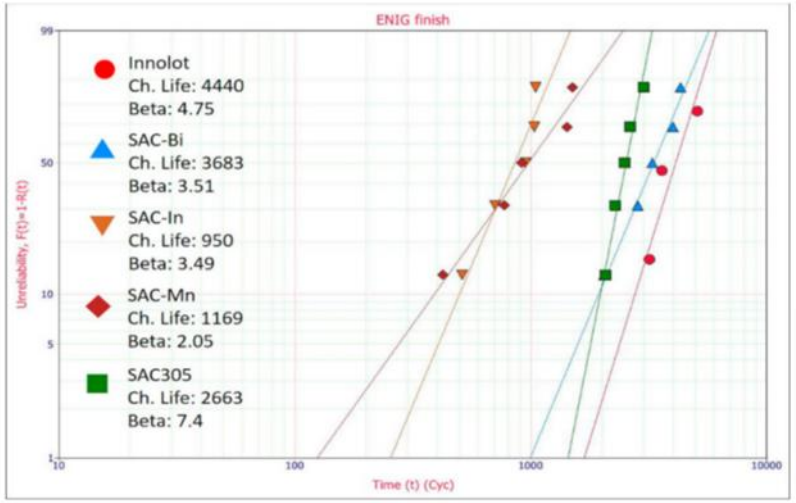
Weibull plots of thermal cycling results for SnAgCu/OSP and SnAgCu/ENIG joints

organic solderability preservative (OSP)
electroless nickel/immersion gold (ENIG)

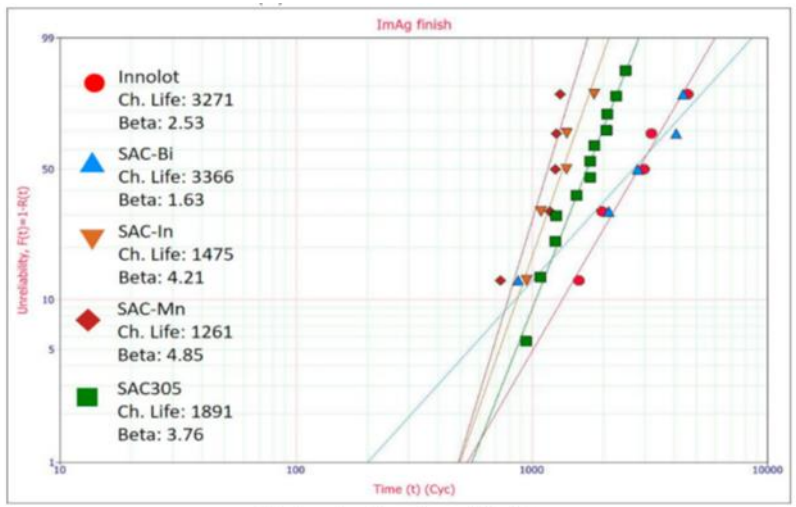


C.J. Lee, W.-Y. Chen, T.-T. Chou, T.-K. Lee, Y.-C. Wu, T.-C. Chang, J.-G. Duh, J. Mater. Sci.: Mater. Electron. 26, 10055 (2015)

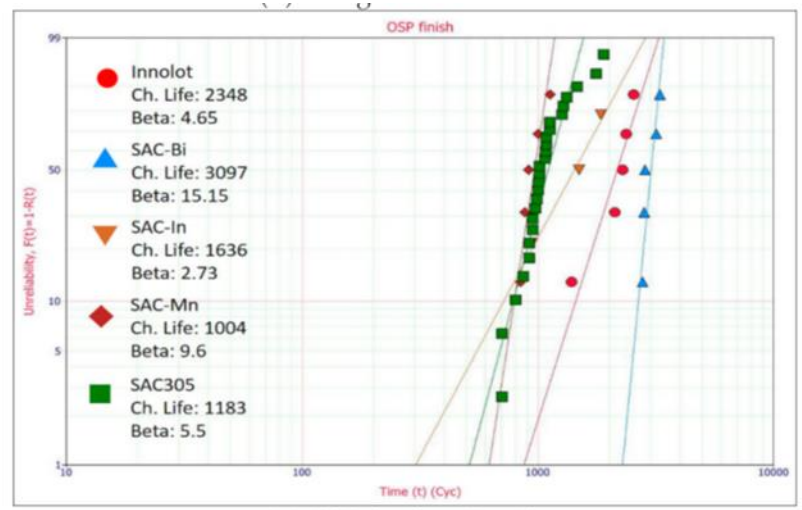
Weibull plots of thermal cycling results for ENIG, ImAg, and OSP joints



(a) ENIG Surface Finish



(b) ImAg Surface Finish



(c) OSP Surface Finish

Akkara, F.J.; Hamasha, S.; Alahmer, A.; Evans, J.; Belhadi, M.E.A.; Wei, X. The Effect of Micro-Alloying and Surface Finishes on the Thermal Cycling Reliability of Doped SAC Solder Alloys. Materials 2022, 15, 6759. https://doi.org/10.3390/ma15196759

Proposed approach for experiments

Simulation of cold solder joints:
- On Silicon
- On PCBs

The cold joints defects can be simulated by introducing a thin film (<100nm) of a non adhering material (oxide, nitride)

Thin films are deposited by Physical Vapour Deposition (e.g. Sputtering). Equipment available at PoliTO

The "entity" of the cold joints can be gradually simulated proportionally by depositing the non-adhering materials in patterns over a controlled area (entity will scale with the covered area)

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