9th International Symposium on Tin Whiskers
Essen, Germany
October 13, 2015

Tin Whiskers: Contact Shorting Risk

Subset of Tin Whisker Short Course

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About the Presenter:

Michael Osterman (Ph.D., University of Maryland, 1991) is a Senior Research Scientist and the director of the CALCE Electronic Products and System Consortium at the University of Maryland. Dr. Osterman served as a subject matter expert on phase I and II of the Lead-free Manhattan Project sponsored by Office of Naval Research in conjunction with the Joint Defense Manufacturing Technical Panel (JDMTP). He has consulted with several companies in the transition to lead-free materials and has developed fatigue models for several lead-free solders. He has lead CALCE in the study of tin whiskers since 2002 and has authored several articles related to the tin whisker phenomenon. He has written eight book chapters and over eighty articles, including the Best Session Paper Award in 41st International Symposium on Microelectronics, IMAPS 2008 and the Best Paper-Maurice Simpson Technical Editors Award in the Inst of Environmental Sciences, 2008. In 2008, a PhD. student working under Dr. Osterman won the co-sponsored SMTA and Circuits Assembly Charles Hutchins Educational Grant for work on BGA reballing. He has conducted multiple experiments on temperature cycling, vibration, and mechanical bend of electronic assemblies. He is a member of ASME, IEEE, IMAPS and SMTA.

What is CALCE?

http://www.calce.umd.edu

Center for Advanced Life Cycle Engineering (founded 1987) is dedicated to providing a knowledge and resource base to support the development and sustainment of competitive electronic components, products and systems. Focus areas:

- Physics of Failure
- Design of Reliability
- Accelerated Qualification
- Supply-chain Management
- Obsolescence
- Prognostics

Center Organization

16 research faculty
5 technical staff
40+ PhD students
20+ MS students
11 visiting scholars

CALCE

Center for Advanced Life Cycle Engineering for Electronic Products and Systems

Education

- MS and PhD programs
- International visitors
- Web seminars
- Short courses for industry

Electronic Products and Systems Consortium

- Risk assessment, management, and mitigation for electronics

Prognostics and Health Management Consortium

- Techniques based on data trending, physics-of-failure, and fusion

Research Contracts

- Large scale programs
- Medium to long-term durations
- Contractual agreements
- Examples:
  Software development,
  testing,
  training programs

Lab Services

- Small to medium scale
- Rapid response
- Examples:
  Failure analysis,
  measurement,
  design review,
  supplier assessment

Standards

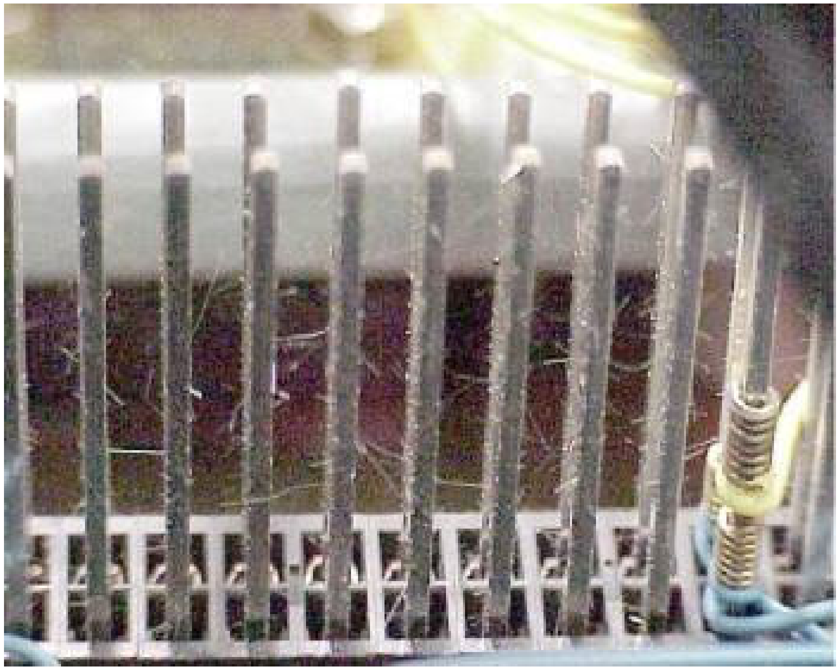
- Putting CALCE research to work for industry
- Examples:
  IEEE
  GEIA
  IPC
  JEDEC
  IEC

Failure Risks from Tin Whiskers

- Major failure modes and mechanism of tin whiskers are:
  - Electrical short: permanent (typically <10mA), intermittent (typically >10mA)
  - Metal vapor (plasma) arcing in vacuum and low pressure
  - Contamination

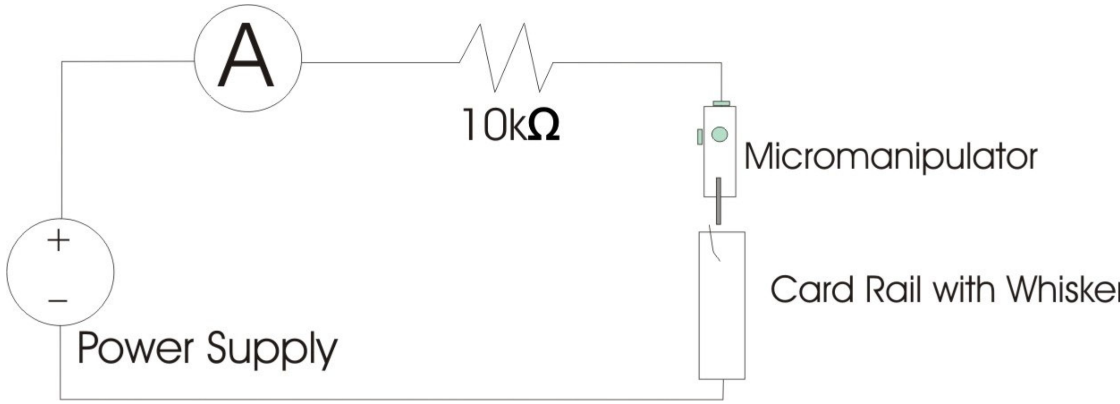
- Various sectors of the electronics industry, including military, medical, telecommunications and commercial applications, have experienced field failures induced by tin whiskers.

Pure tin plated connector pins

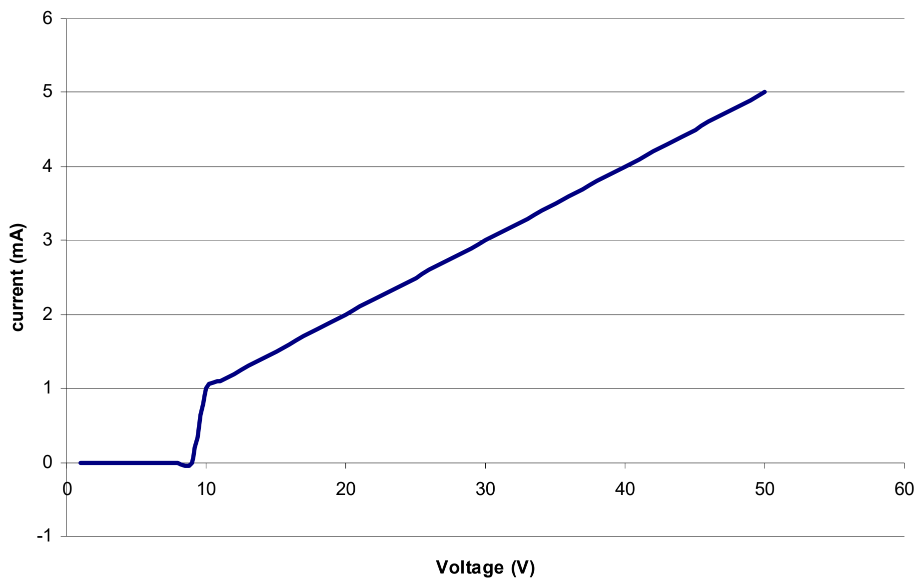


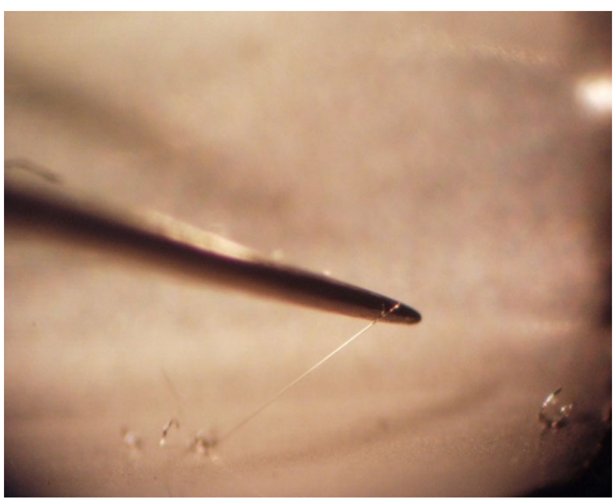
10 years in the field (reported in 2000)
[Courtesy of NASA Goddard]

Elevated Voltage Required For Current Flow



Physical contact does not necessarily create an electric circuit. Oxide film on whisker and on contact surface provides an insulation barrier. Voltage potential above the oxide breakdown voltage is required.

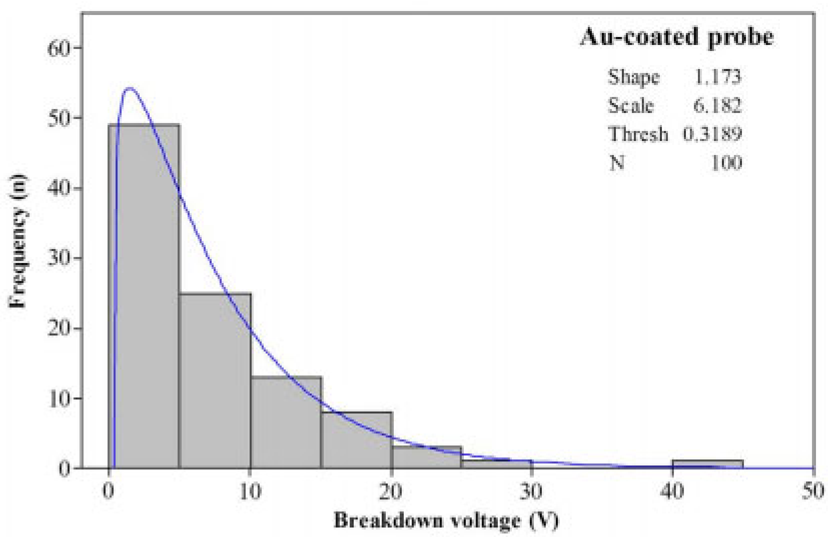




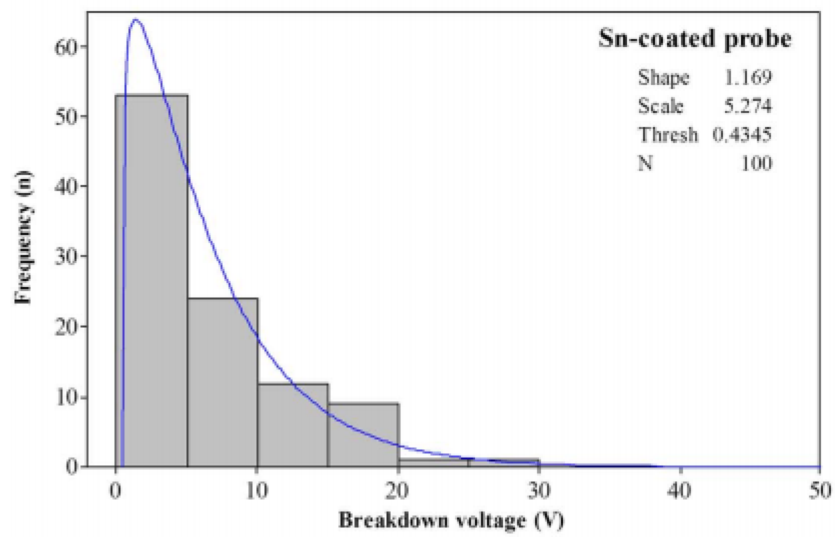
Example of Breakdown Voltage for Tin Whisker and Tungsten probe

Examination of Breakdown Voltage for Tin Whisker Induced Electrical Shorts

- Two parameter Weibull found to provide best fit.
- Kruskal-Wallis shows that there is no significant statistical difference in breakdown voltage between the Au-coated probe and Sn-coated probe



(a)



(b)

KRUSKAL–WALLIS TEST ON BREAKDOWN VOLTAGE DEPENDING ON PROBE TYPES

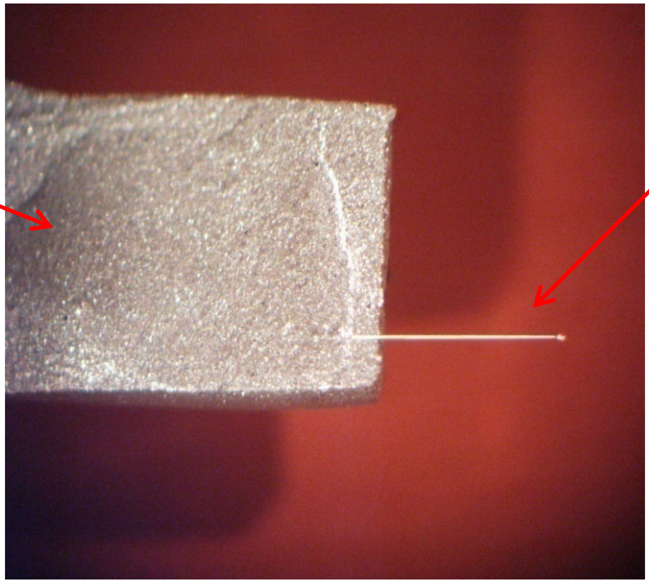
Types of probe	N	Median	Ave Rank	Z
Au-coated	100	5.300	104.1	0.88
Sn-coated	100	4.775	96.9	-0.88
H=0.77 DF=1 P=0.379				
H=0.77 DF=1 P=0.379 (adjusted for ties)				

Electrical Shorting Propensity of Tin Whiskers, S. Han, M. Osterman and M. Pecht, *IEEE Transactions on Electronics Packaging Manufacturing*, Vol. 33, No. 3, July 2010.

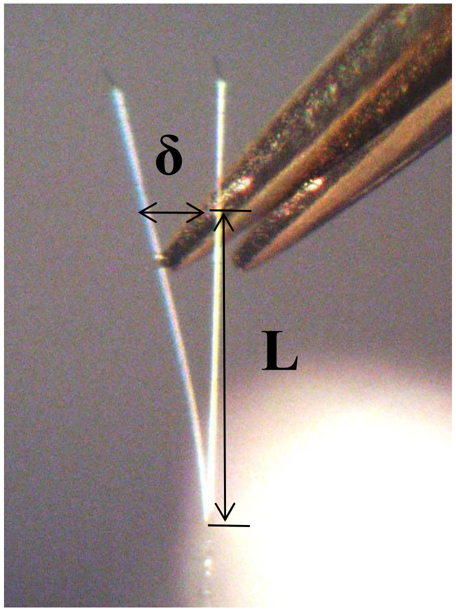
Contact Force Measurement - Specimen

- A whisker on the card-rail was cut off and attached on the Cu plate using the silver paste
- The whisker specimen was contacted with a Au-coated probe and deflection of the whisker was measured.
- At each measured deflection, the voltage sweep was conducted.

Silver paste on Cu plate

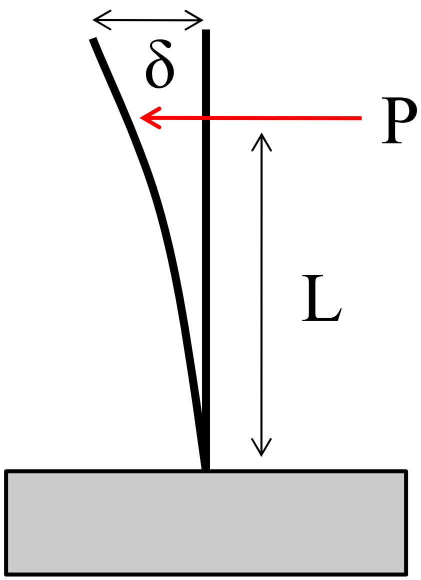


Whisker



Contact Force Measurement – Cantilever Beam Model

- The contact force applied by probe calculated using cantilever beam model
- The deflection (δ) and distance from the base of whisker (L) obtained from the captured image and the radius of whisker (r) measured using SEM



$$P = \frac{3EI\delta}{L^3} \qquad I = \frac{\pi r^4}{4}$$

P - Force

E - Young's Modulus of tin (41.4GPa)

I - Moment of inertia

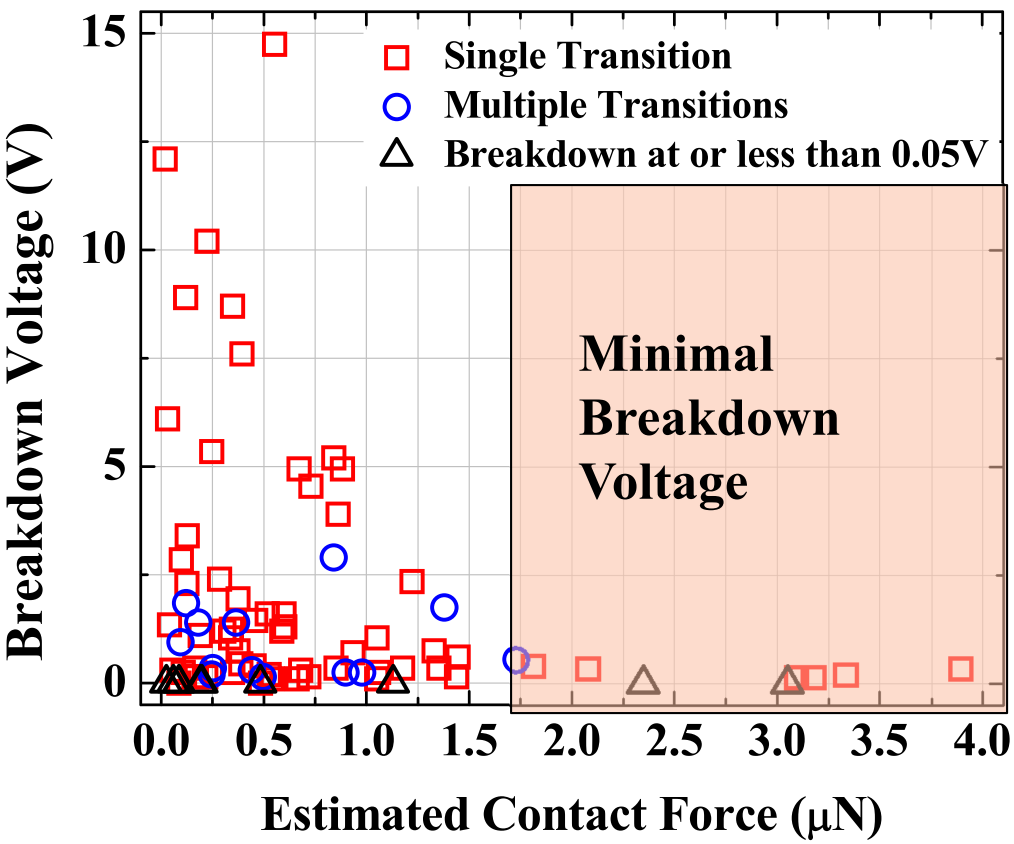
L- Distance from the base of the whisker

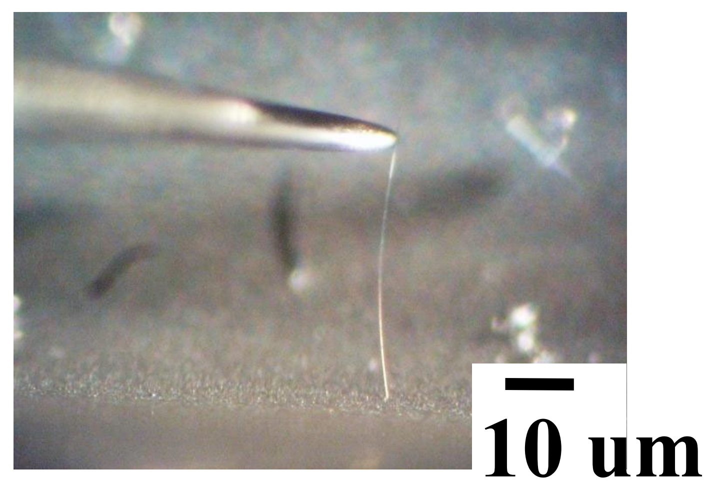
δ - Whisker deflection

r – Radius of whisker

Effects of Contact Force on Breakdown Voltage

- The both single and multiple transitions occurred at breakdown voltages between 0 to 15 V, when the estimated contact force was less than 1.5 μN. While, the breakdown voltage was less than 0.5 V when the estimated contact force exceed 1.5 μN.



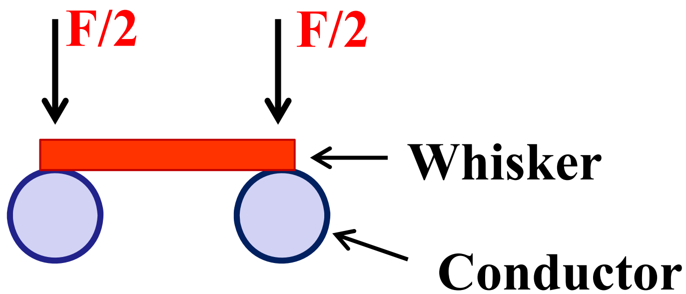


Estimated contact force
: 0.048 ~ 0.78 μN

Estimated Contact Force Between Tin Whiskers and Conductors

- The range of contact force between tin whisker and conductors was estimated based on the possible situations that can cause the electrical failures.

- **Force of gravity by tin whisker [36]**

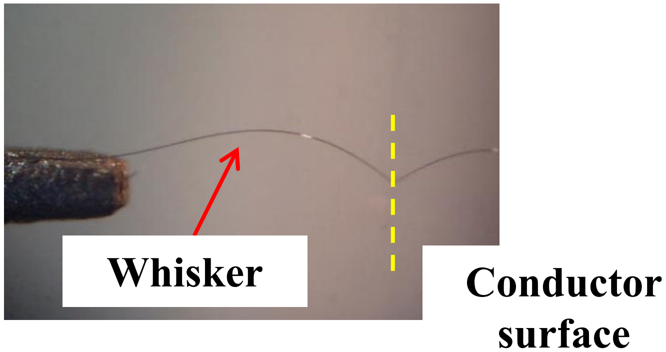


$$F_{Gravity} = 9.8 V_{Whisker} \rho_{Sn}$$

$$V_{Whisker} = L_{Whisker} \pi \left(R_{Whisker} \right)^2$$

$F_{Gravity}$ = Force of gravity by tin whisker
$V_{Whisker}$ = Volume of whisker
ρ_{Sn} = Density of tin (7310 kg/m^3)
$L_{Whisker}$ = Length of whisker
$R_{Whisker}$ = Radius of whisker

- **Buckling force by tin whisker [37]**

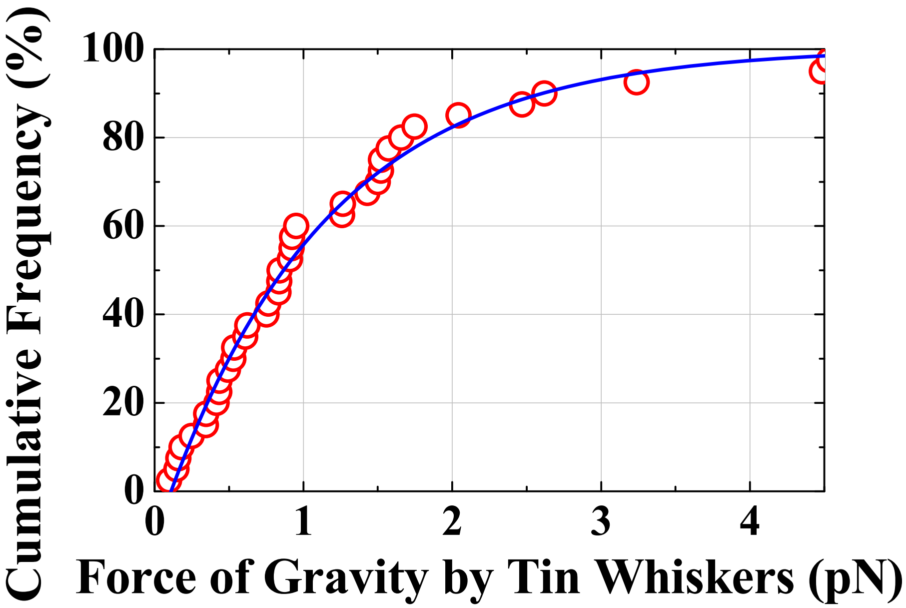


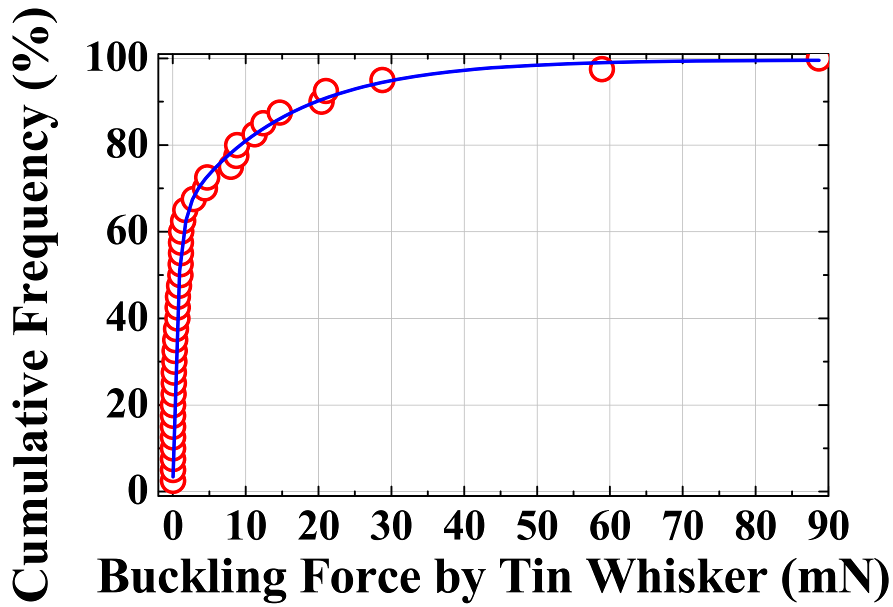
$$F_{Bucking} \approx \frac{\pi^3 E_{Whisker} d^4}{32 L^2}$$

$E_{whisker}$ = Elastic modulus of tin (**41.4GPa)**
d = Diameter of whisker
L = length of whisker

Estimated Contact Force Between Tin Whiskers and Conductors

- Tin whiskers whose length is more than 50 μm† are selected from CALCE whisker data
- The estimated buckling force by tin whisker is the range between 0.01 ~ 88.7 mN that is much higher than 1.5 μN.
- It implies that a bridging whisker that exhibits buckling may occur the breakdown with the voltage of less than 0.5 V.





† Maximum allowable whisker length proposed by JESD201