Consideration of RoHS issues and Tin Whiskers Evaluation

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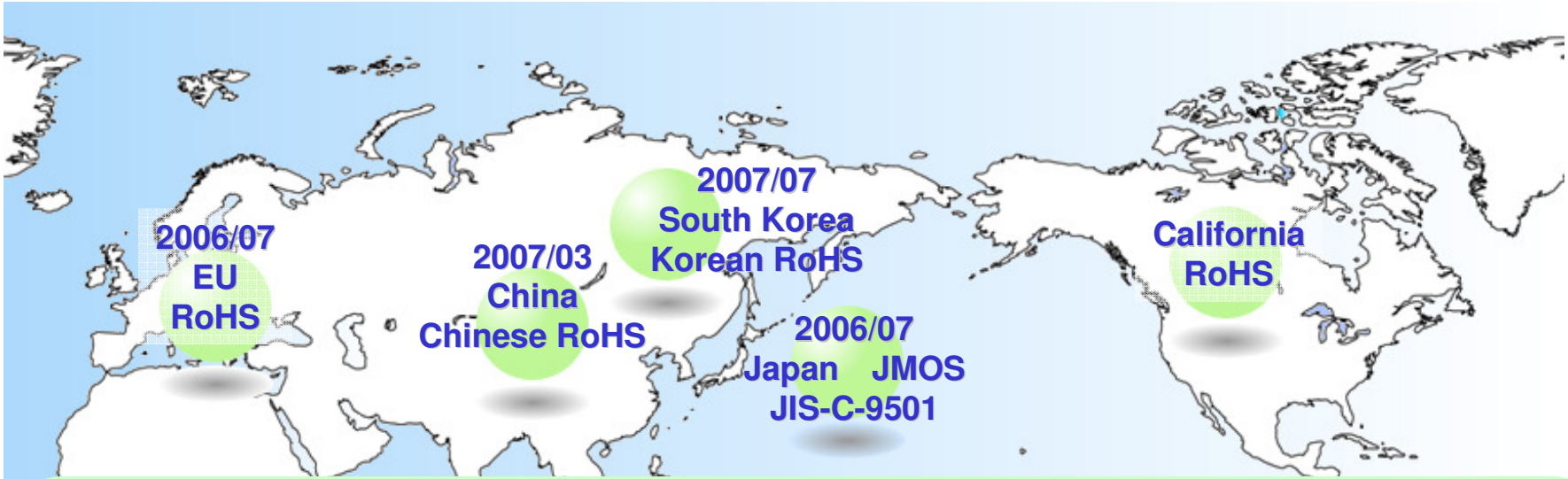
1 . Background

The EU has enacted two directives, RoHS and WEEE, that prohibit the use of Pb, Cd, Cr^{6+}, Hg, PBB and PBDE in products for the EU consumer market since July 2006. One of the key elements in these directives is Pb, which had been widely used in electric components such as solder and parts terminations. Although these regulations only affect products for sale in the EU, many manufacturers in the world have shifted to lead-free products.

1. JAXA continues to use parts containing Pb for space applications.
2. Purchase of the parts and materials that contain lead is becoming difficult.
3. Reliability problems of lead-free parts and materials surface in space applications.

***1:RoHS(Restriction of the use of certain Hazardous Substance in electrical and electronic equipment)** :
http://europa.eu.int/eur-lex/pri/en/oj/dat/2003/l_037/l_03720030213en00190023.pdf
WEEE(Waste Electrical and Electronic Equipment) :
http://europa.eu.int/eur-lex/pri/en/oj/dat/2003/l_037/l_03720030213en00240038.pdf

2.Effects of RoHS in The Consumer Market



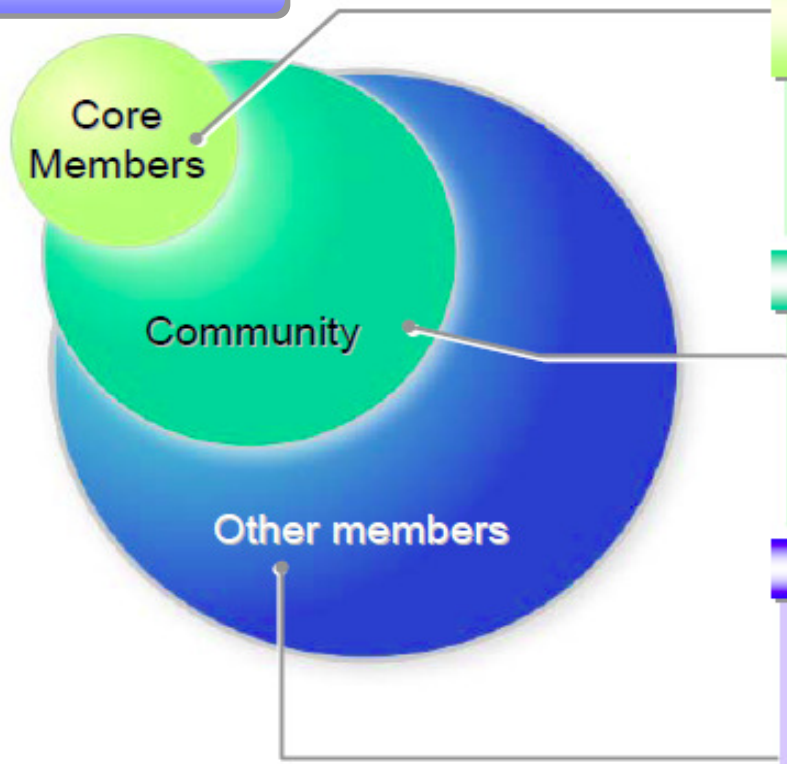
- RoHS & WEEE directives prohibit the use of lead in consumer products in EU after July 2006.
- In several states in the U.S., a similar "green" law has enacted.
- In China and Korea, a similar directive to RoHS was enacted in March 2007.
- Many parts manufacturers in the world have shifted to lead-free products.
- In Japan, "JIS C 0950; J-MOSS" that is <u>not similar</u> to RoHS was enacted in Dec. 2005.
- J-MOSS does not prohibit the use of lead, but requires to indicate the usage of lead.
- Many Japanese parts manufacturers also shifted to lead-free products.

3. The community to Discuss RoHS Issues

Purpose

- Sharing information and subjects about RoHS issues
- Investigation and examine for prohibit material in RoHS
- Propose guide line to the Space Parts Committee

Members



JAXA, Satellite and Rockets system companies

- IHI
- IHIAerospace
- KHI
- JAXA
- MHI
- Melco
- NEC(NEC/TOSHIBA Space)
- HIREC (secretariat)

University and Associations

- Hokkaido University
- Nihon University
- Osaka University
- Gunma University
- Japan Electronics and Information Technology Industries Association (JEITA)
- Society of Japanese Aerospace Companies (SJAC)

Parts and other manufacturers

- HIREC
- muRata
- Hitachi-Chemical
- NEC Electronics
- Nippon Avionics
- JAE
- MPC
- MEISEI
- SHINKO
- OKI
- EEE parts subcommittee member

3.1 Working Group of the Community

Community

- **WG- A** — **Mixed Assemble Technology Discussion**
  Pb-free device, SnPb solder, SnPb PWB assembly reliability evaluation
- **WG- B** — **Pb-free Trend Survey and Lead Technology Discussion**
  - B1 — Trend survey of Pb-free parts and material
  - B2 — Hot Solder Dip method evaluation
- **WG- C** — **Pb-Free Assemble Technology Discussion**
  Pb-free parts, material, assembly techniques
- **WG- D** — **Whiskers Mechanism and Mitigation Technology Evaluation**
  Whiskers mechanism, evaluation method, accelerated test method
- **Sub-WG-E** — **Other Prohibited Material**
  Lead, Cadmium, Chromium

4. Basic Evaluation Test in JAXA

【Background of the test】

- SnPb Hot Solder Dip (HSD) mitigates Sn whiskers growth.
- Generally said, Sn oxide formation is one of the root cause of the whisker growth.
- On the orbit satellite, electrical components is installed in a satellite and exposed to vacuum.
- Mixed assemble tech. (i.e. SnPb solder&lead free parts) will be required in near future.

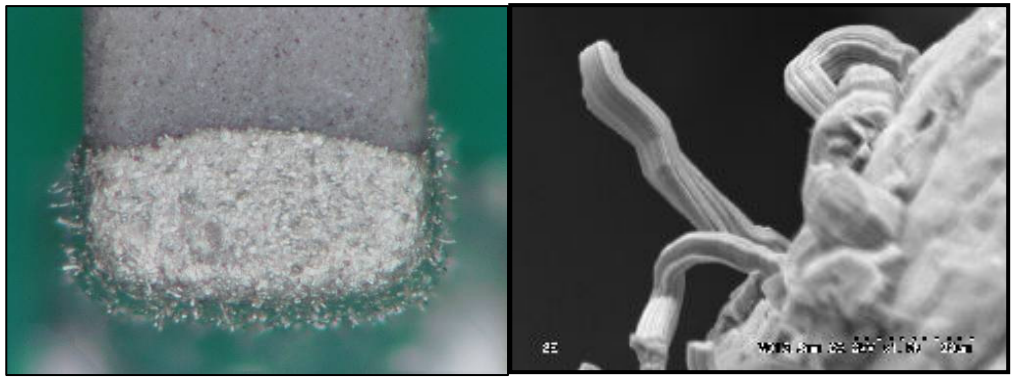


Fig. 1 Whiskers on lead free chip capacitor

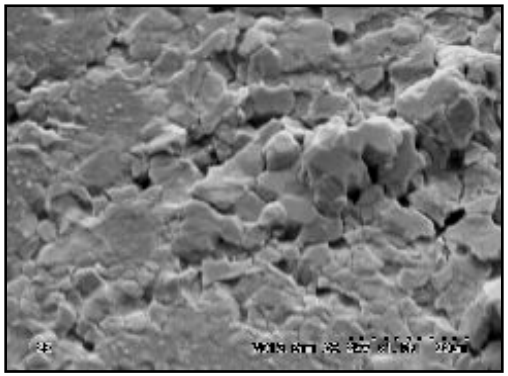


Fig.2 No whiskers was observed on HSD sample

【Purpose of the evaluation test】

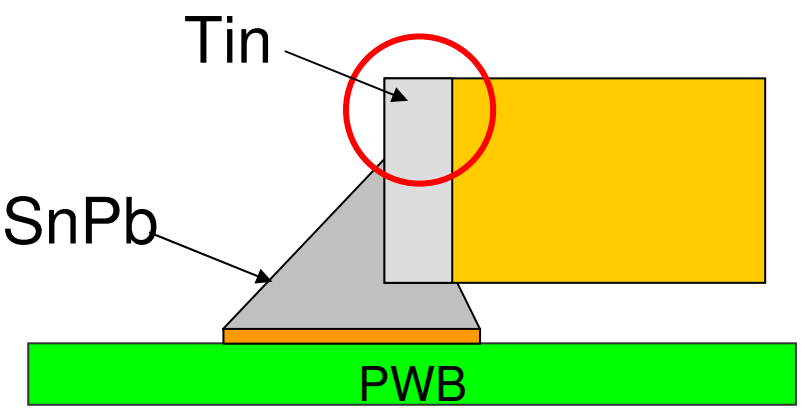
- To evaluate mixed assemble risk about whiskers.
- To evaluate vacuum condition mitigates whiskers growth.

4.1 Mixed Assembly Technology Evaluation

Test condition

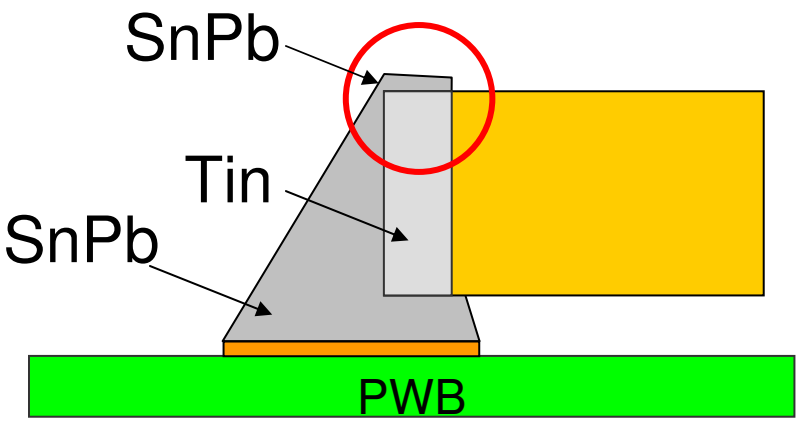
1. Two different manufactures LF chip capacitor sample
2. Reflow and Manual soldering (SnPb solder)
3. Thermal shock cycle test up to 2,000cyc
   (Range:-40 <=> +125, soak: 15 min.)

①Reflow soldering



Top of the chip capacitor is not covered with SnPb solder

②Manual soldering



Top of the chip capacitor is covered with SnPb solder

4.2 Mixed Assembly Test Result of Whiskers

Type	HSD condition	Method	Tin whisker			
			0cyc	500cyc	1000cyc	2000cyc
Type A (Sn/Ni/Ag: Sn=3.8μm)	non-HSD	reflow	non	yes	yes	yes
		manual	non	non	yes	yes
	HSD	reflow	non	non	non	non
		manual	non	non	non	non
Type B (Sn/Ni/Ag: Sn=8.0μm)	non-HSD	reflow	non	yes	yes	yes
		manual	non	non	yes	yes
	HSD	reflow	non	non	non	non
		manual	non	non	non	non

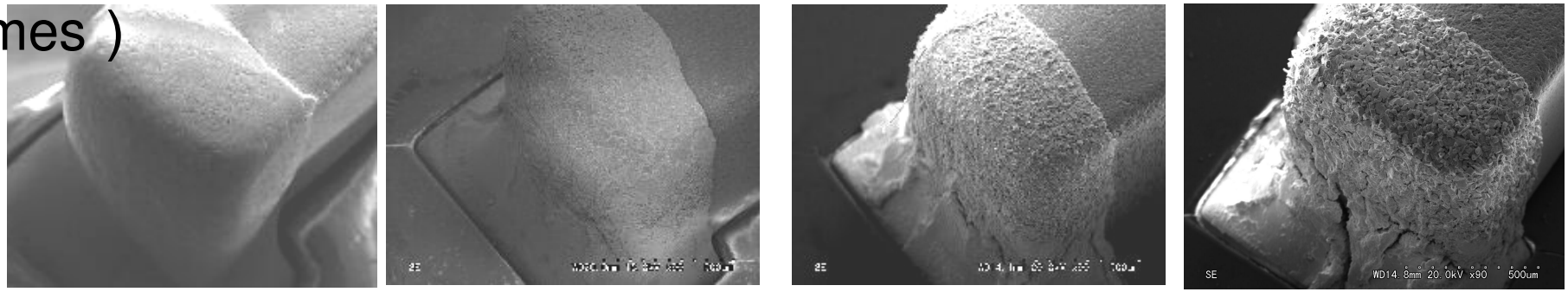
non : Tin whisker growth is not observed, yes : Tin whisker growth was observed

: Short Tin whisker was observed, : Long Tin whisker was observed

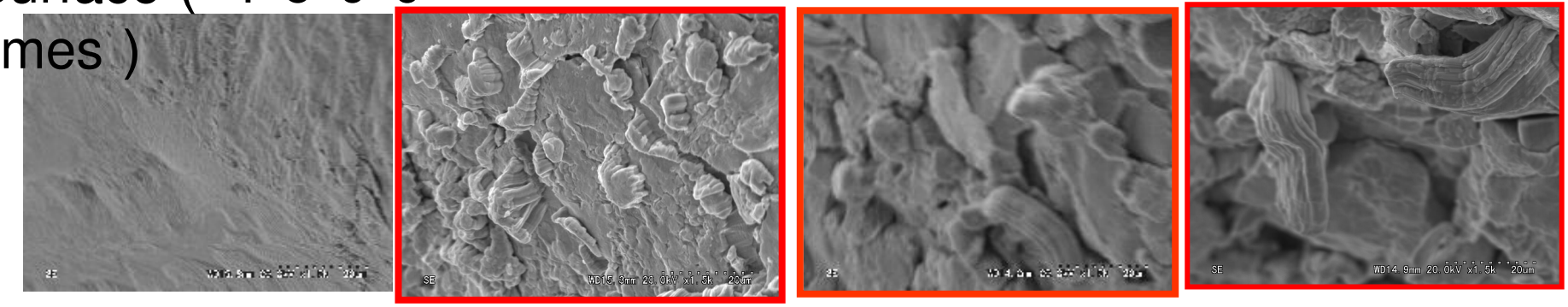
4.3 Thermal Shock Test Result of Whiskers(1/3)

- **Reflow soldering method,**
  Type B capacitor (Sn/Ni/Ag, Sn=8.0um), non-HSD

Electrode (9 0 times)



Surface (1 5 0 0 times)

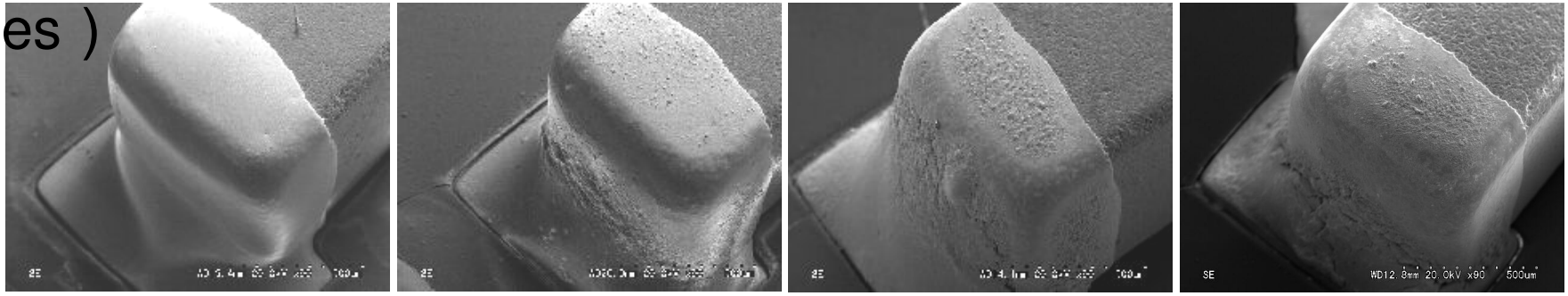


0 cyc 500 cyc 1000 cyc 2000 cyc

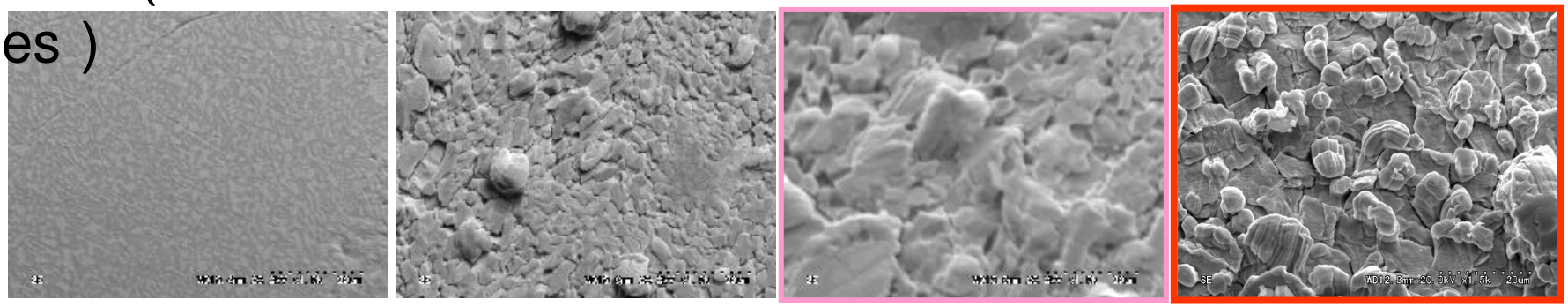
4.3 Thermal Shock Test Result of Whiskers(2/3)

- **Manual soldering method,**
  Type B capacitor (Sn/Ni/Ag, Sn=8.0um), non-HSD

Electrode (9 0 times)



Surface (1 5 0 0 times)

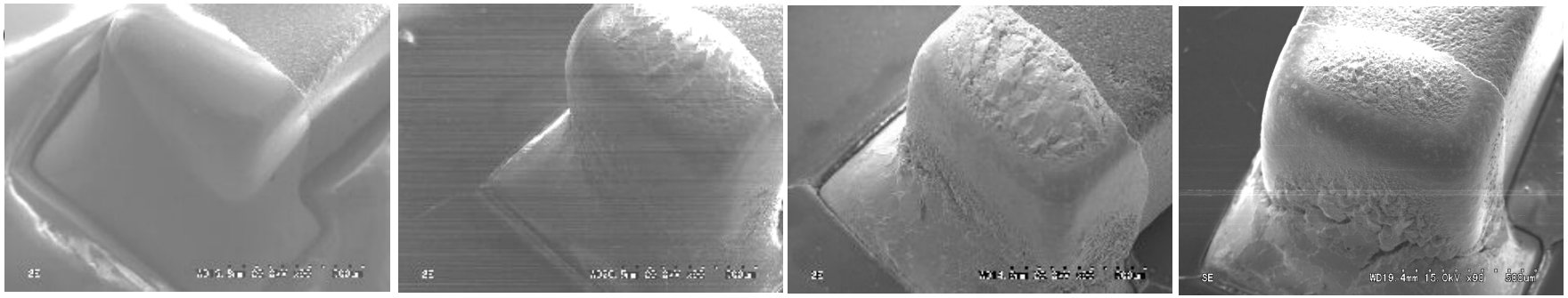


0 cyc　500 cyc　1000 cyc　2000 cyc

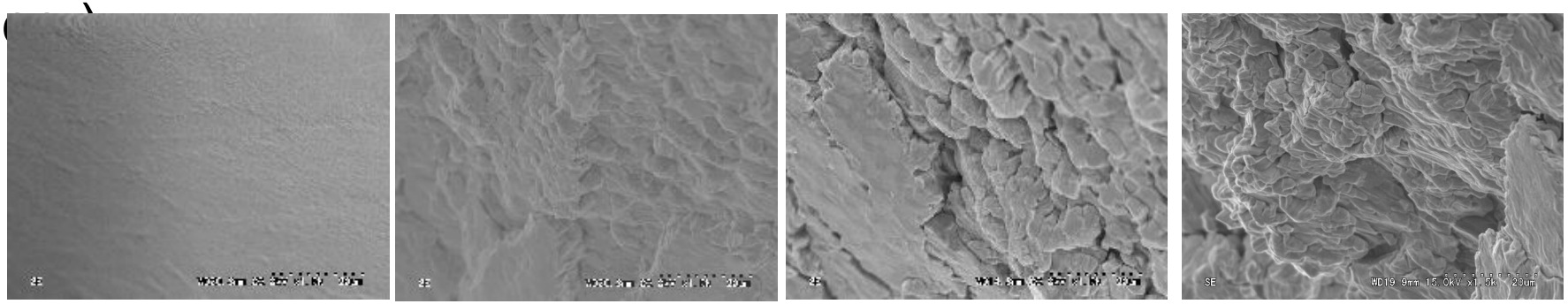
4.3 Thermal Shock Test Result of Whiskers(3/3)

- **Reflow soldering method,**
  Type B capacitor (Sn/Ni/Ag, Sn=8.0um), HSD

Electrode (9 0 tim



Surface (1 5 0 0 tim



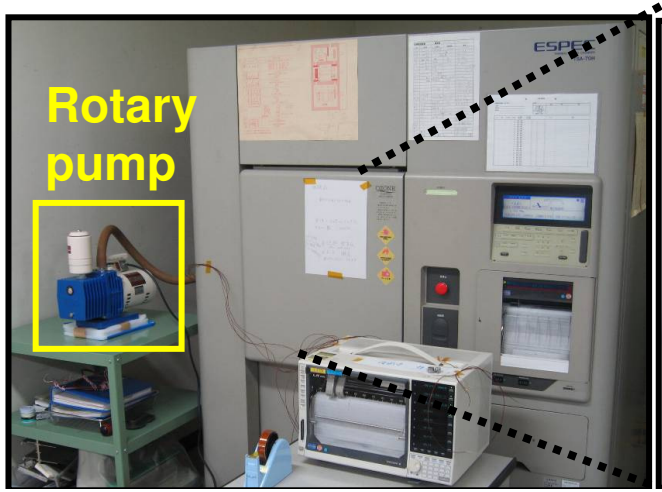
0 cyc 500 cyc 1000 cyc 2000 cyc

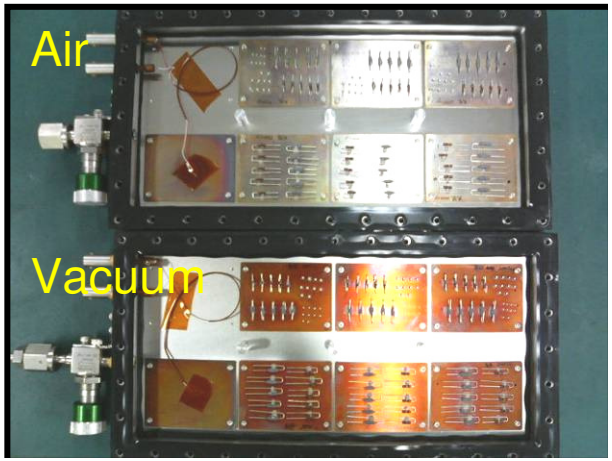
4.4 Vacuum Condition Evaluation test

Test condition

Test method	: Thermal shock cycling
Temperature cycling	: up to 2,000 cycle
Temperature range	: -40 to +125 deg. C
Soak time	: 60 minutes
Atmosphere	: Vacuum (3Pa), Air
Sample	: 2 type chip ceramic capacitor (Electrode is pure Tin)

Test Equipment





4.5 Summary of Vacuum and Air Condition Test

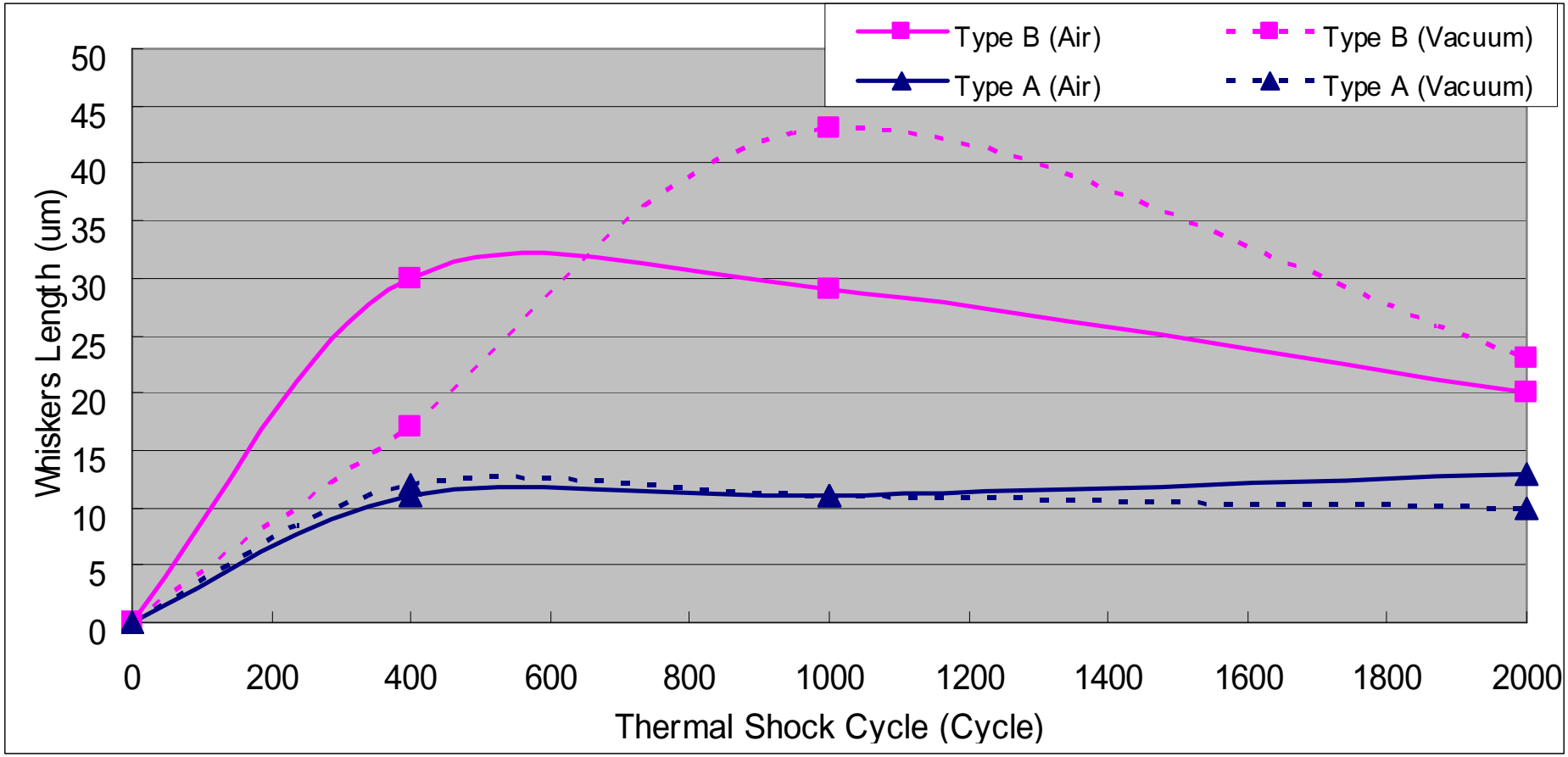
Visual and SEM inspection results

Type	Condition	Thermal shock cycle				
		0cyc	147cyc	420cyc	1040cyc	2000cyc
Type A (Sn/Ni/Ag: Sn=3.8μm)	Vacuumed	no	yes	yes	yes	yes
	Air	no	yes	yes	yes	yes
Type B (Sn/Ni/Ag: Sn=8.0μm)	Vacuumed	no	yes	yes	yes	yes
	Air	no	yes	yes	yes	yes

no : Tin whisker was not observed, yes : Tin whisker was observed

4.6 Whisker Length of Vacuum and Air Condition Test

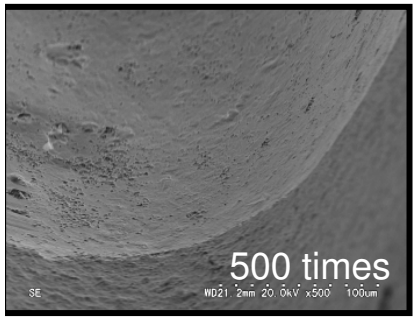
Whiskers Length Result

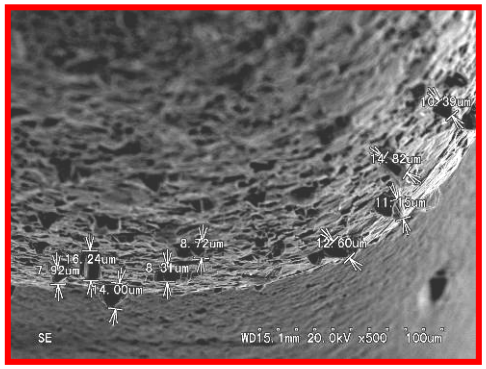


4.7 SEM Inspection Result (1/2)

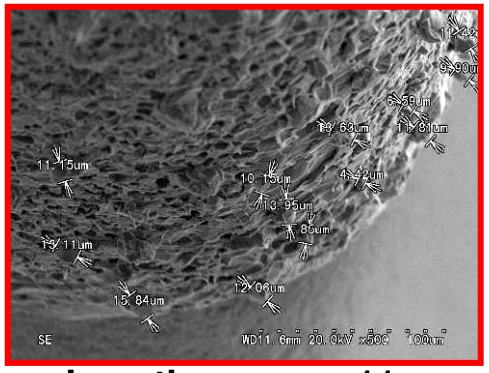
Type A

Vacuum

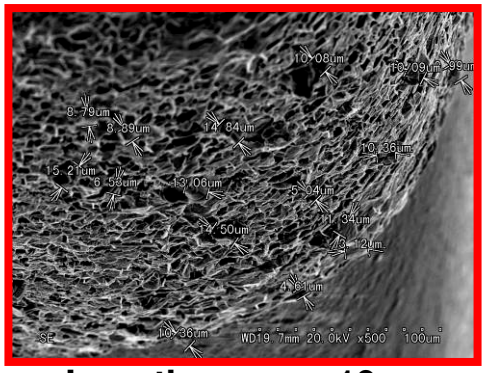




Length : ave. 12um
: max. 16.24um



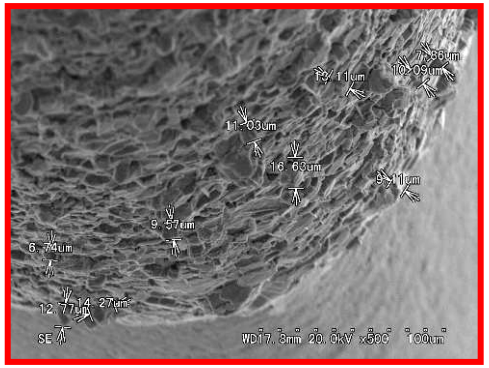
Length : ave. 11um
: max. 15.84um



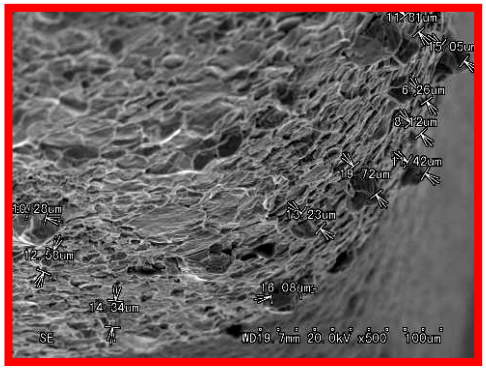
Length : ave. 10um
: max. 15.21um

Air

Length : ave. 11um
: max. 13.06um



Length : ave. 11um
: max. 16.63um



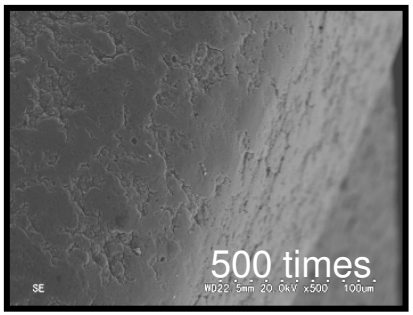
Length : ave. 13um
: max. 19.72um

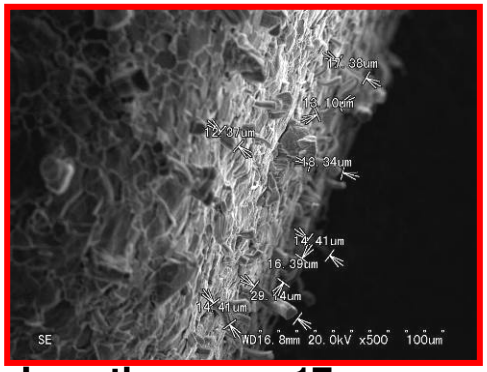
0 cycle | 420 cycle | 1,040 cycle | 2,000 cycle

4.7 SEM Inspection Result (2/2)

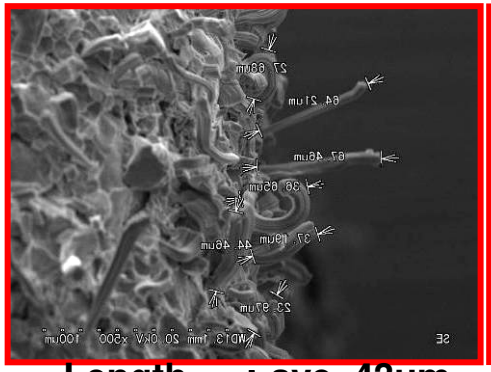
Type B

Vacuum

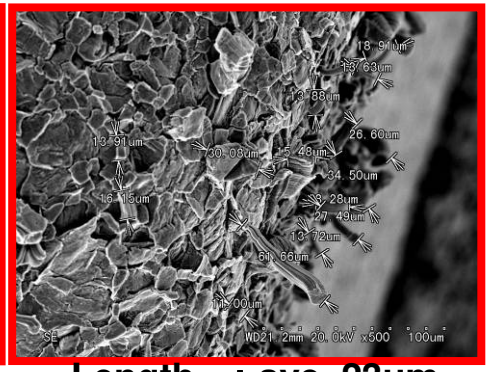




Length : ave. 17um
: max. 29.14um

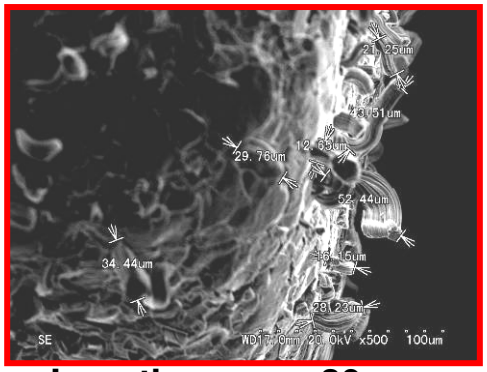


Length : ave. 43um
: max. 67.46um

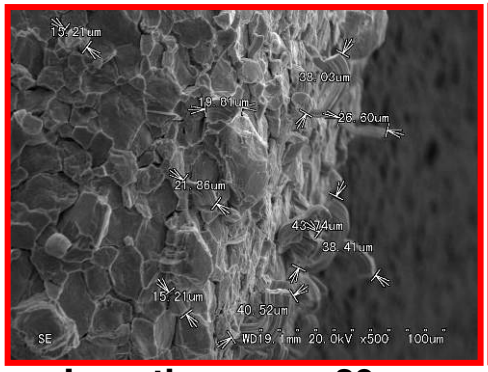


Length : ave. 23um
: max. 61.66um

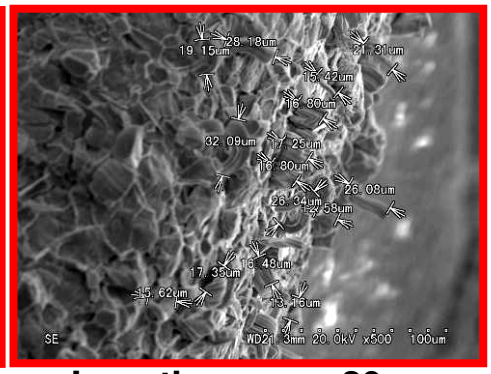
Air



Length : ave. 30um
: max. 52.44um



Length : ave. 29um
: max. 43.74um



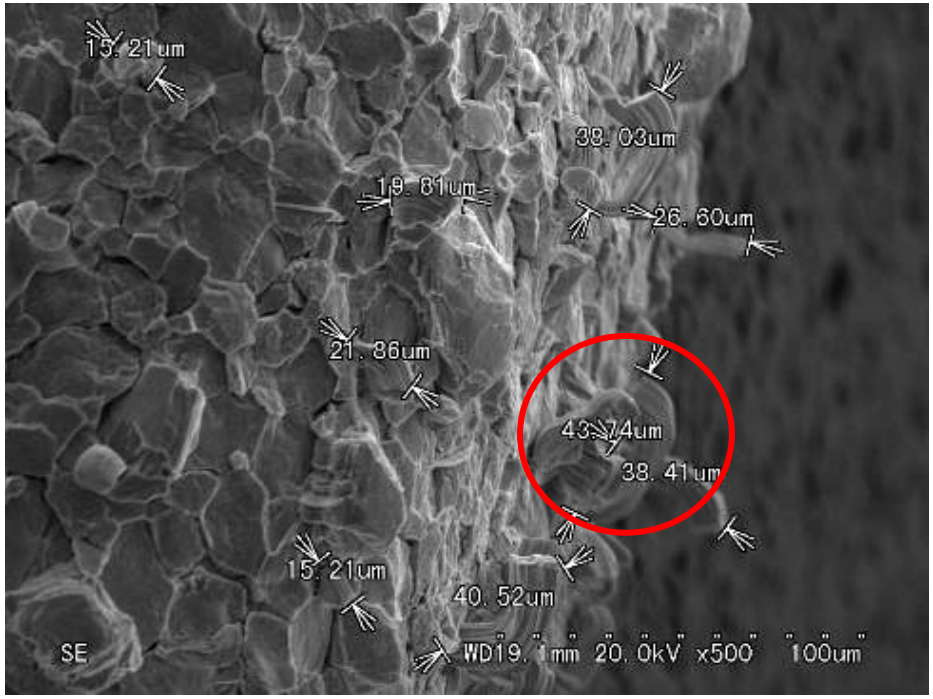
Length : ave. 20um
: max. 32.09um

0 cycle | 420 cycle | 1,040 cycle | 2,000 cycle

4.8 Comparison of Whiskers Shape

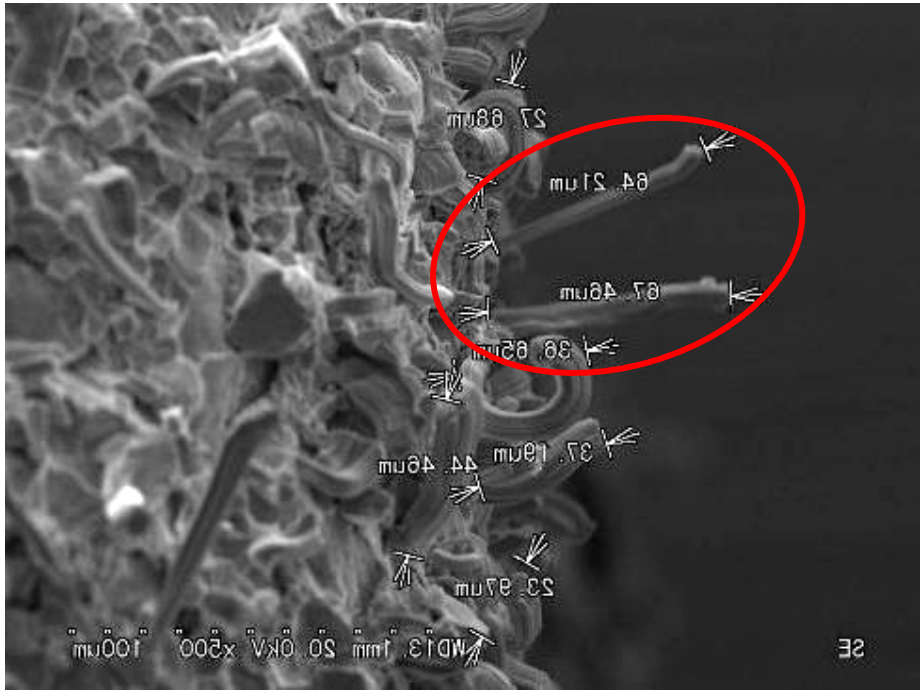
Type B at 1,040 cycle

500 times



Air Condition test result

Length : ave. 29um
: max. 43.74um

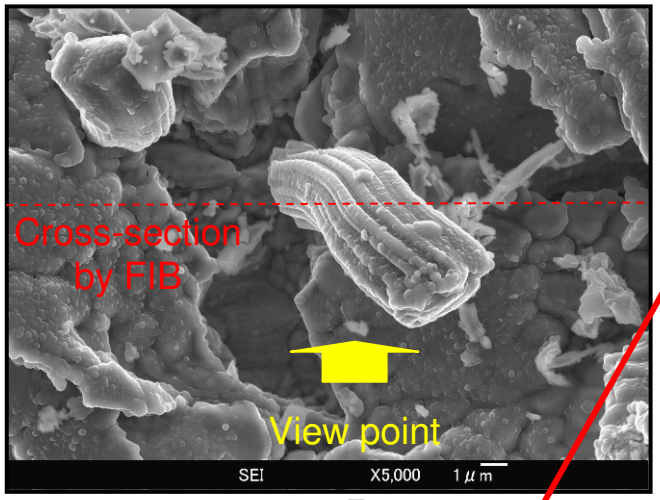


Vacuumed condition test result

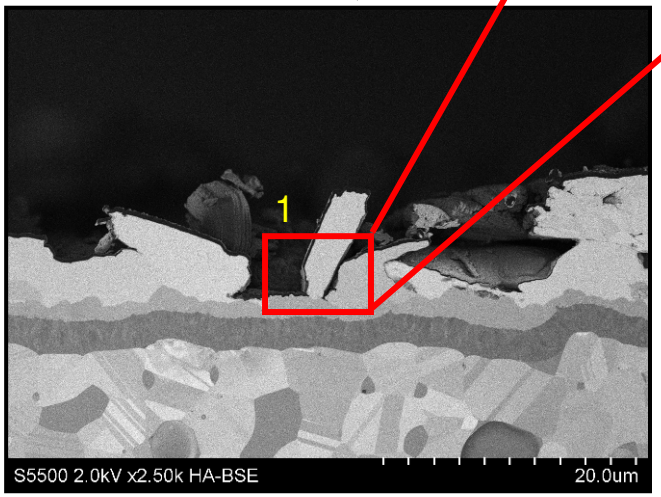
Length : ave. 43um
: max. 67.46um

4.9 Whisker Cross-Section

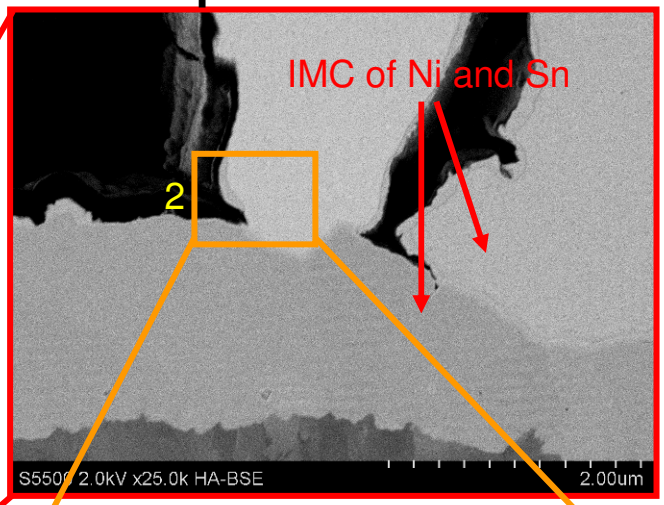
Whisker cross-section（type B, Air condition, after 1,040 cycle）



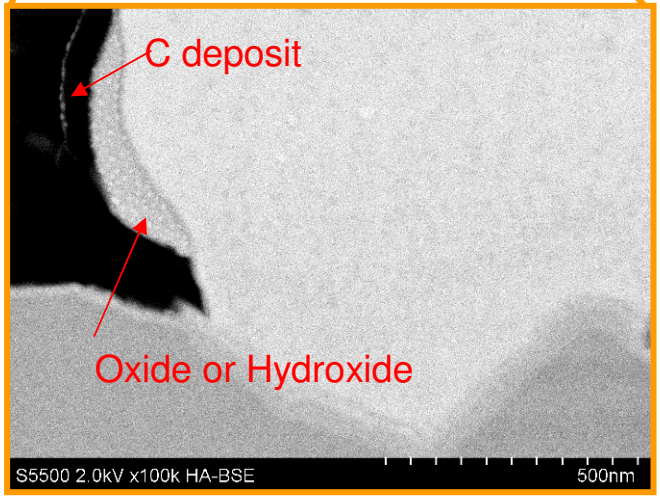
Cross-section



Close-up of #1 area

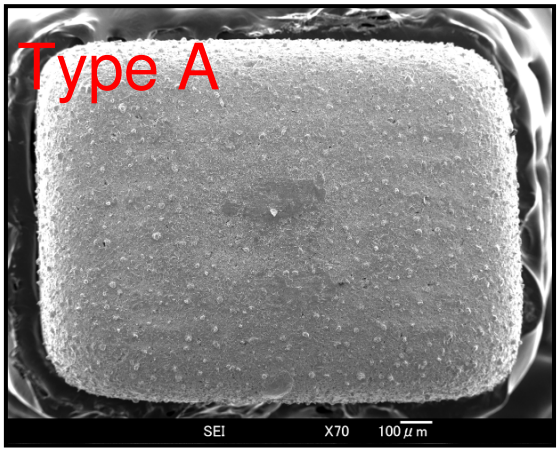


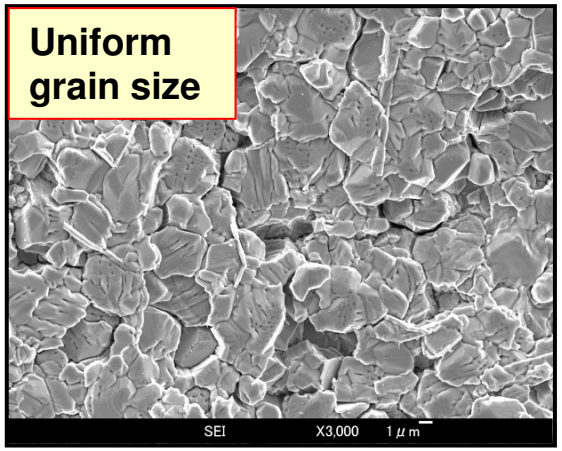
Close-up of #2 area

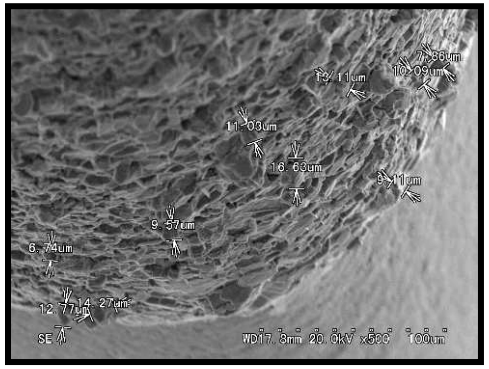


4.10 Comparison of Electrode Condition

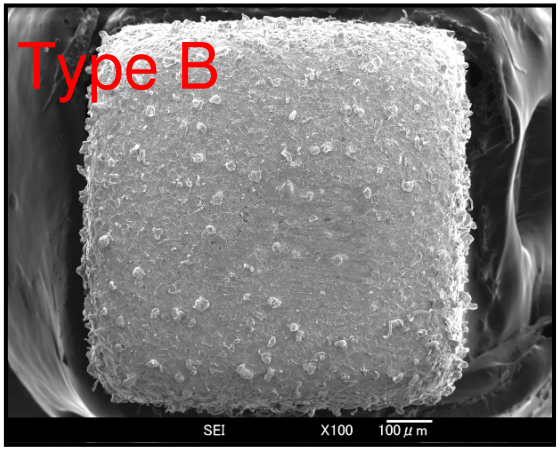
SEM image (after 1,040cycle thermal shock, Air condition)

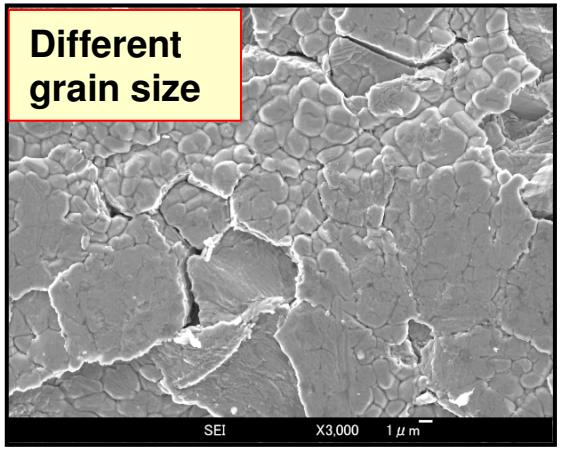


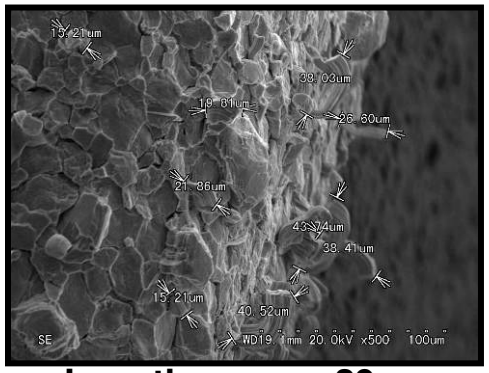




Length : ave. 11um
: max. 16.63um







Length : ave. 29um
: max. 43.74um

5. Summary

EU enacted RoHS and WEEE directives, that restrict the use of Pb et.al. for EU consumer products after July 2006.

1. Purchase of the parts and materials that contain lead will be becoming difficult even for space parts.
2. JAXA established the community to discuss RoHS issue.
3. Tin whiskers characteristics is slight different in vacuum and air condition. Thus tin whiskers evaluation test method for space application may evaluate in RoHS community.
4. Mixed assemble risks such as whiskers and strength will be evaluate this year in RoHS community.

Thank you for your attention!!