The 13th Annual NEPP Program's ETW

On-orbit validation to mitigate tin whisker growth (3rd year)

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Agenda

1. Background
2. Mission objectives
3. Overall plan of our Mission
4. Experimental samples
5. Analytical evaluation(Non-coating)
6. Analytical evaluation(Conformal coating)
7. Summary

1. Background

The use of COTS is expanding now due to various mission requirements, and tin-plated lead-free parts are expected to be used for satellites in the future.

On the other hand, there is concern about tin Whiskers on tin-plated lead-free parts. Tin whiskers originate and grow from the plated surface of pure tin on lead-free parts. This may cause electrical short circuits and failures.

JAXA S&MA department have been considering this countermeasure for many years.

Past evaluation results

Test condition : Non-coating, air/vacuum(1×10^{-4}Pa) environment, ground, non-energized, thermal cycling test, -40℃～+85℃, after 500cycle

- Differences in shape were observed between air and vacuum environment.
- Long and straight tin whiskers were observed in vacuum environment.

From these results, we decided to conduct experiments for tin whiskers in the actual on-orbit environment.

2. Mission objectives

Mission objective 1)

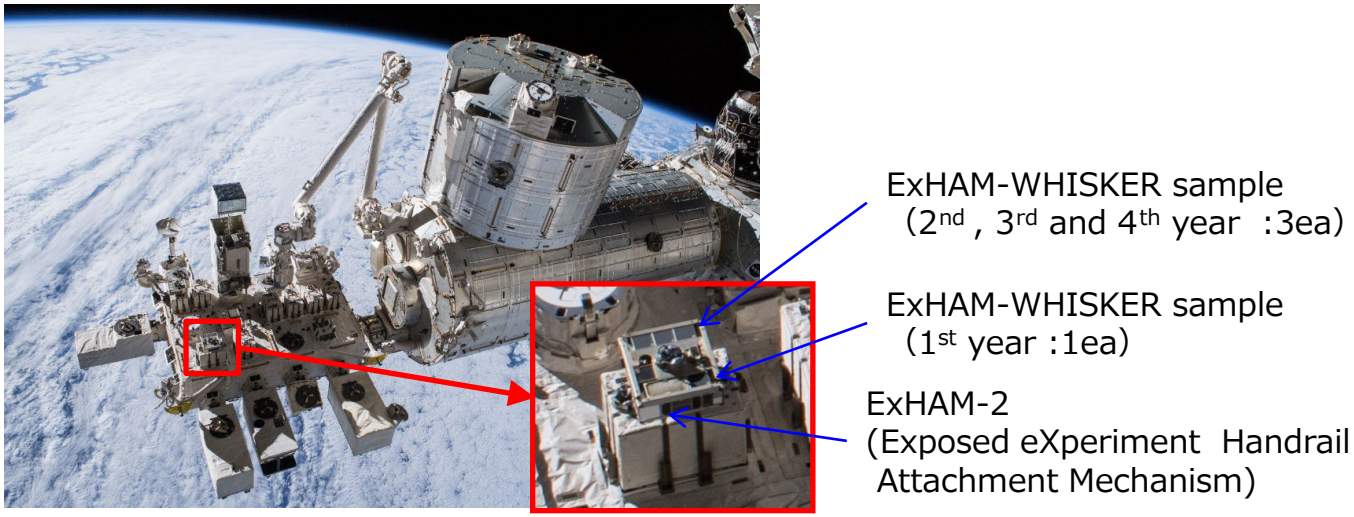
To compare differences in whisker growth characteristics between air(on ground) and on-orbit environment

The difference in length and shape, the difference in saturation characteristics etc.

Mission objective 2)

To evaluate the effectiveness of conformal coatings which may mitigate whisker growth

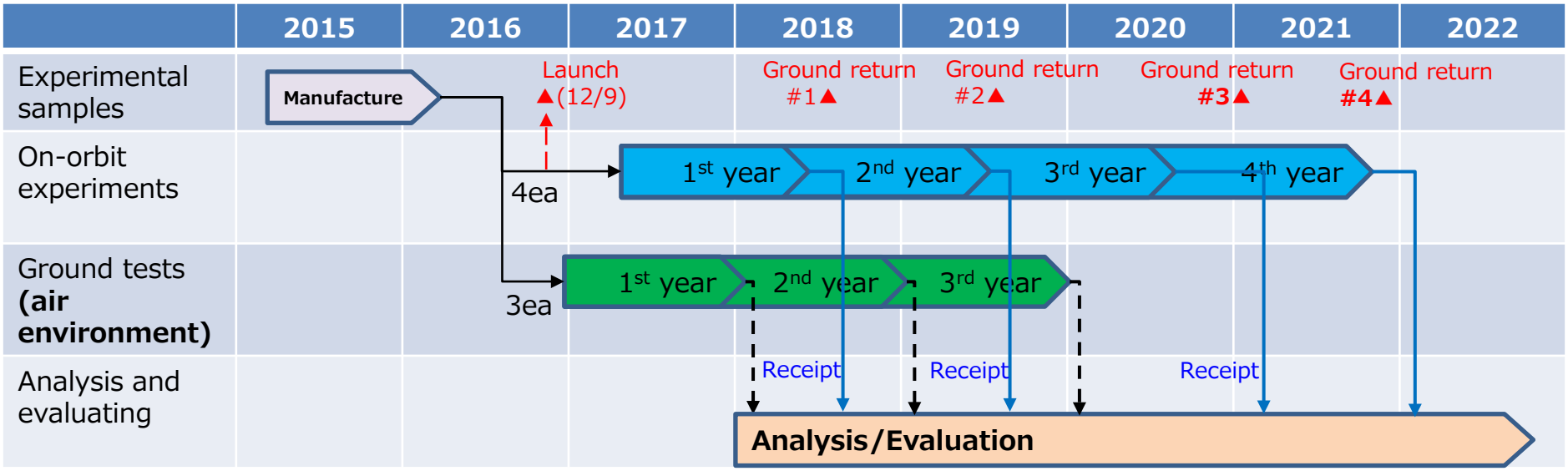
We have a finding from past experiment that Para-xylene coating can mitigate whisker growth. We will demonstrate this result in the actual on-orbit environment.

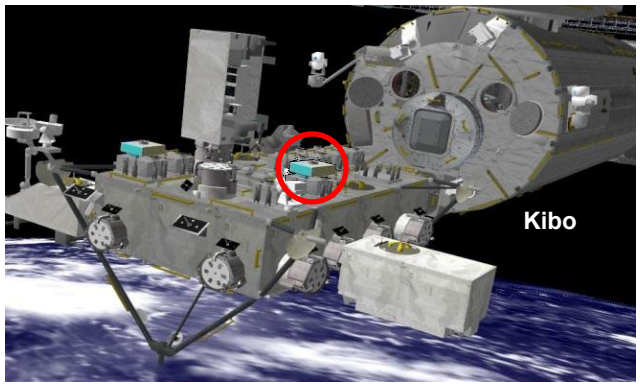


3. Overall plan of our Mission

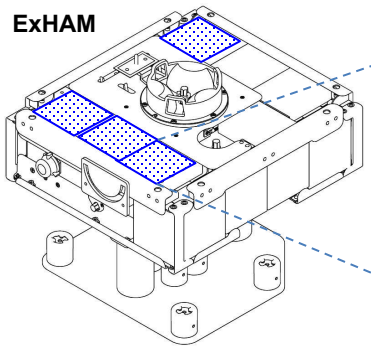
On-orbit experiments have been performed for total 4 years at ExHAM on "Kibo" outboard platform. In addition, ground tests have been conducted for 3 years.

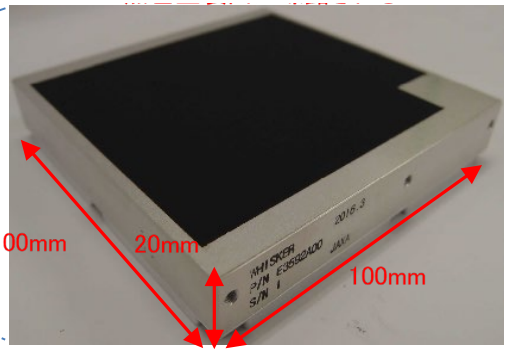
We have been retrieving the samples every year, analyzing and evaluating it.





ExHAM(Exposed Experiment Handrail Attachment Mechanism)

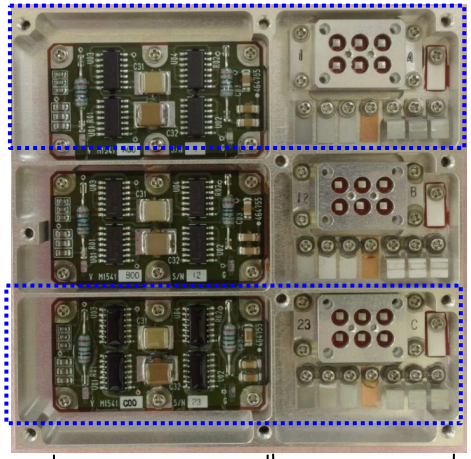


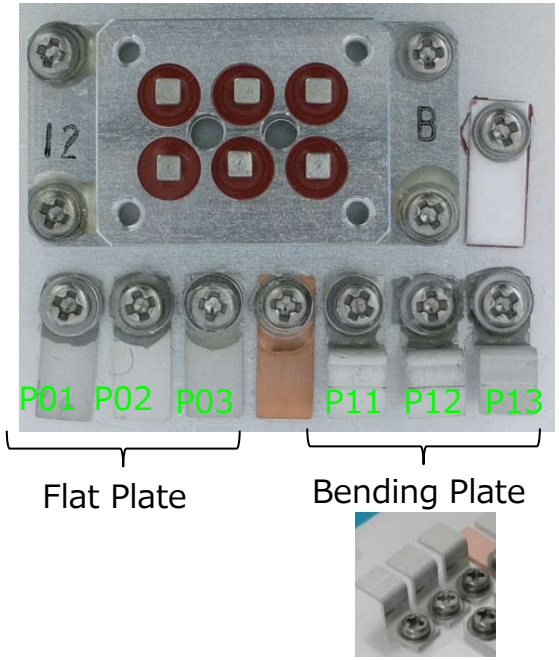


ExHAM-WHISKER Experimental samples

4. Experimental samples

PWB and test piece block were prepared as experimental samples. On-orbit experimental samples and ground test experimental samples are the same configuration.





Test piece P01 / Test piece P11
Base :Cu, Underplating :Ni=2μm, tin plating=3μm
(Plating **hard** to grow whiskers)

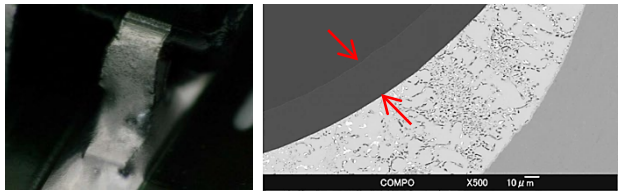
Test piece P02 / Test piece P12
Base :Cu, Underplating :Ni=2μm, tin plating=8μm
(Plating **easy** to grow whiskers)

Test piece P03 / Test piece P13
Base :42alloy, Underplating :None, tin plating=8μm
(Plating **easy** to grow whiskers)

Tin plating
Underplating
Base material

[Initial analysis data : cross section SEM of SOP IC on PWB]

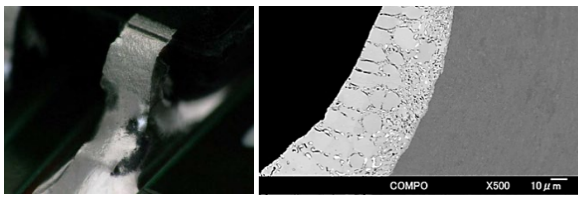
para-xylene coating



vacuum deposition

Thickness: About 25μm
(Almost constant thickness)

Non-coating



Urethane coating

applied with brush

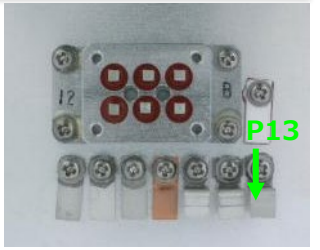
Thickness: About 30μm
(Uneven thickness)

5. Analytical evaluation(Non-coating)

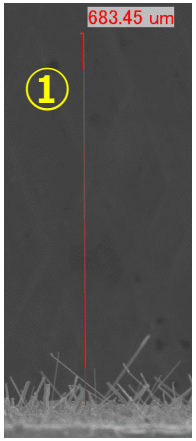
Whisker on-orbit

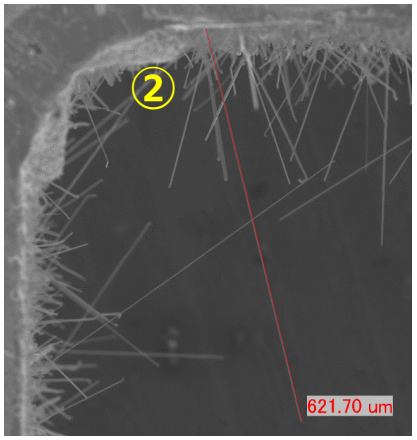
We observed many long whiskers on Test piece Block (P13).

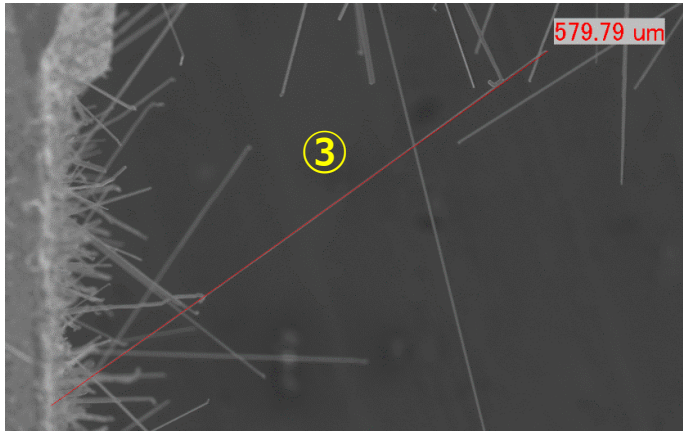
Test piece(Bending plate) P13	
	Base :42alloy, Underplating :None, tin plating=8μm (Plating **easy** to grow whiskers)

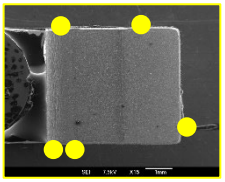


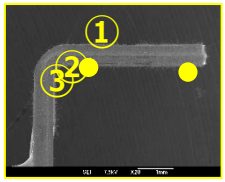
On-orbit 2nd year





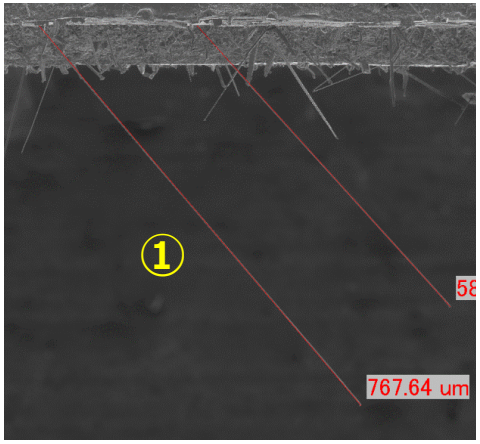


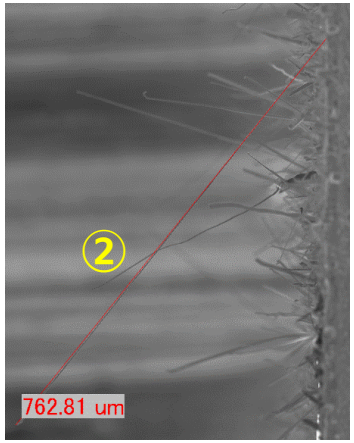


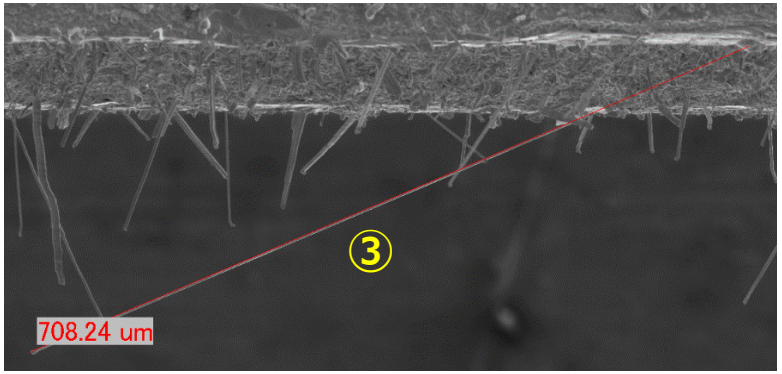


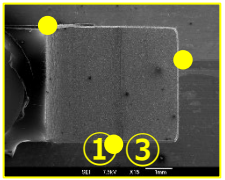
On-orbit 3rd year

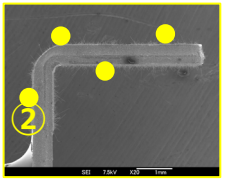
※Each Scale is different.









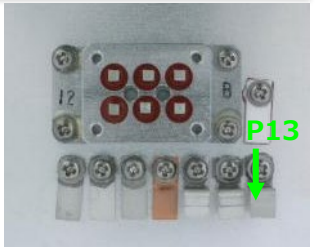


5. Analytical evaluation(Non-coating)

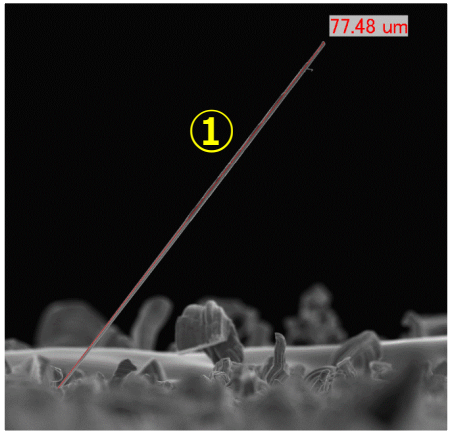
Whisker on ground

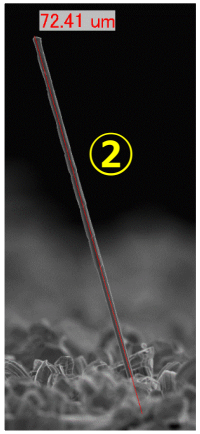
We observed short whiskers on Test piece Block (P13).

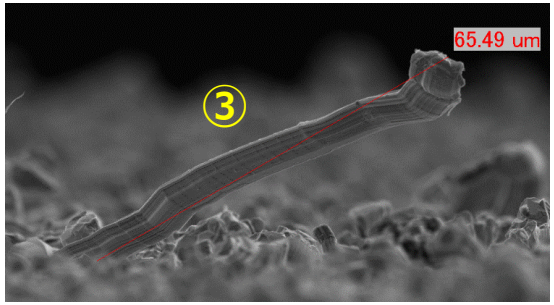
Test piece(Bending plate) P13	
	Base :42alloy, Underplating :None, tin plating=8μm (Plating **easy** to grow whiskers)

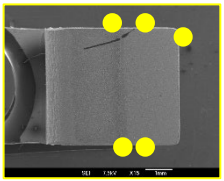


Ground 2nd year



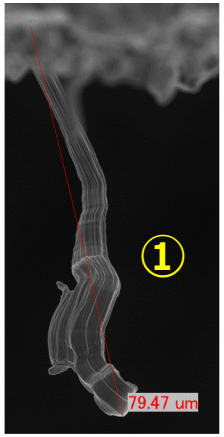


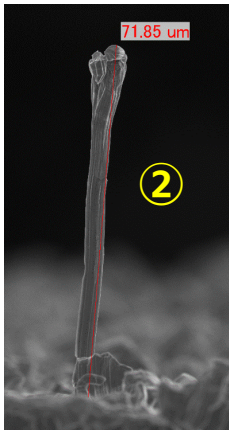


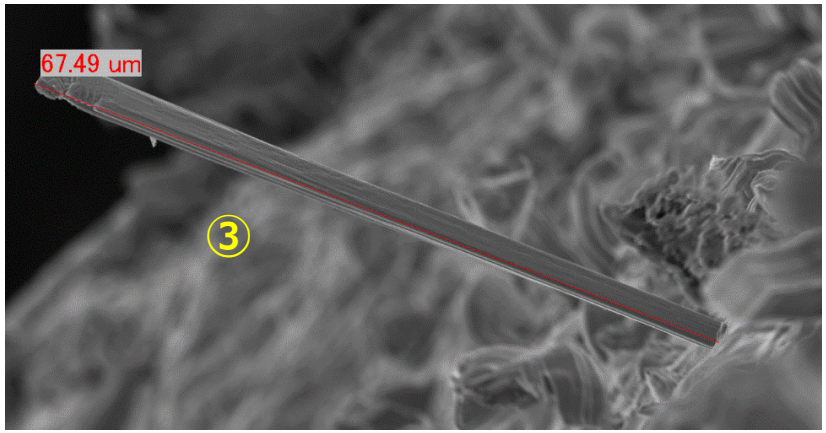


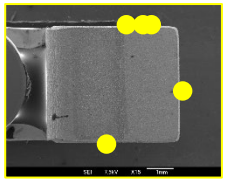
Ground 3rd year

※Each Scale is different.



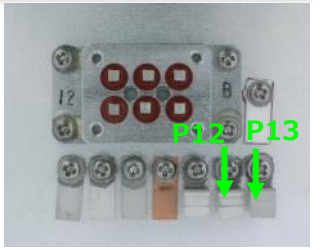






5. Analytical evaluation(Non-coating)

Change in tin whisker length in 3 years



- On-orbit: Length of 3rd year whisker on-orbit is still increasing. Mean length shows saturation trend, but with large variance. Judgement of saturation will be made based on the results of the fourth year.
- Ground: The length of whiskers are obviously saturated.

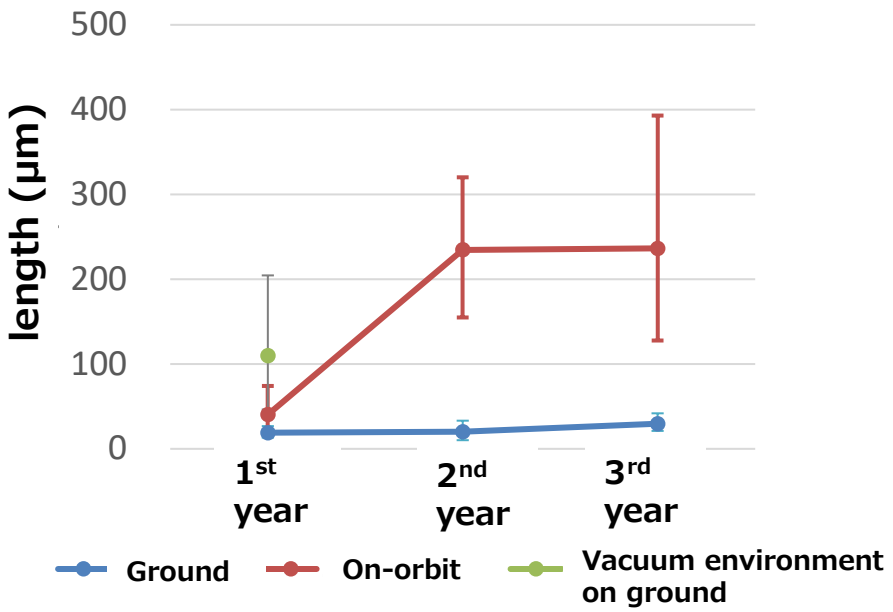
Test piece(Bending plate) P12

Base Material :Cu,
Underplating :Ni=2μm,
Tin plating=8μm
(Plating easy to grow)

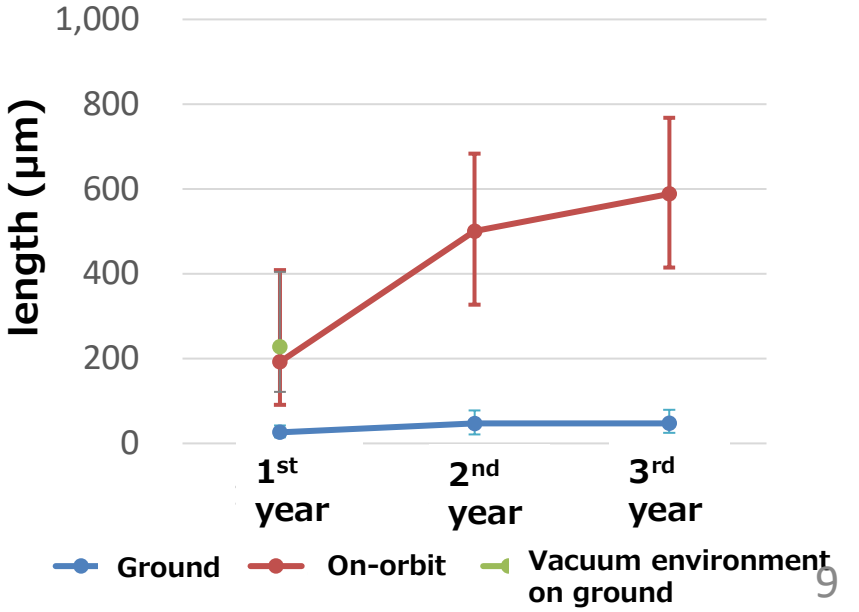
Test piece(Bending plate) P13

Base Material :42alloy,
Underplating :None,
Tin plating=8μm
(Plating easy to grow)

Average of Top 10 (P12)

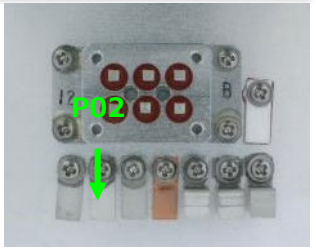


Average of Top 10 (P13)



5. Analytical evaluation(Non-coating)

the grain boundaries

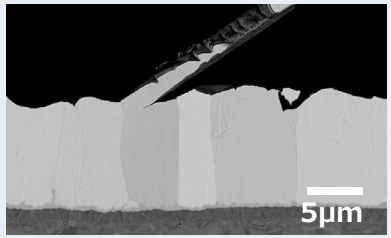
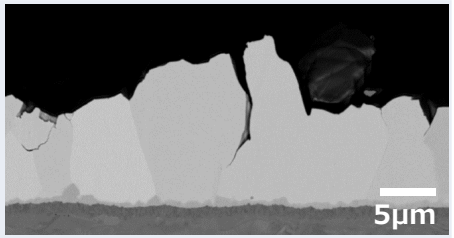
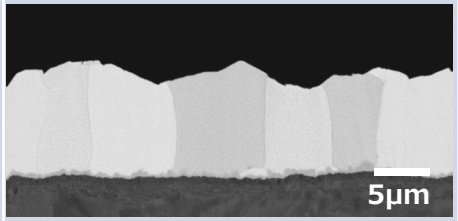
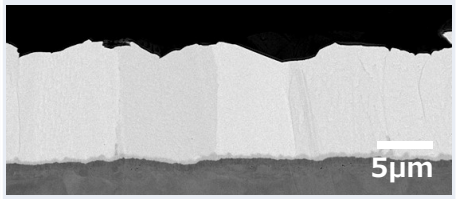
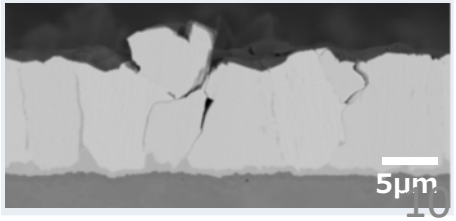


- On-orbit: We could observe the sound contacts at the grain boundaries.
- Ground: Due to the surface of grain boundaries oxidized and IMC (Intermetallic Compound ; Ni_xSn_x), there were not the sound contacts at the grain boundaries.

Tin whisker were formed to relieve compressive stress, so Sn atom diffused in tin plating.

- On-orbit: The sound contacts at the grain boundary secured the Sn diffusion path toward the whisker.
- Ground: IMC; Ni_xSn_x grains blocked this path and prevented Sn atom Diffusion which caused tin whisker growth.

Test piece(Flat plate) P02	
	Base Material :Cu, Underplating :Ni=2μm, Tin plating=8μm (Plating easy to grow)

	Test piece2 (Flat plate) P02	
	On-orbit	Ground
1st year		
2nd year		
3rd year		

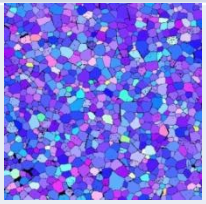
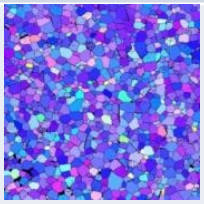
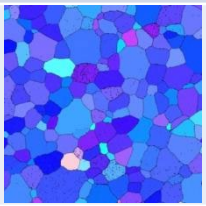
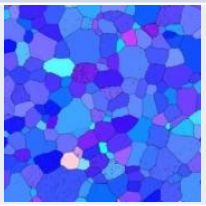
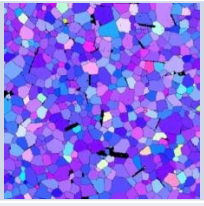
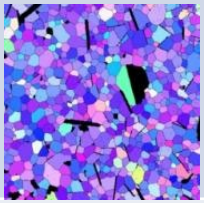
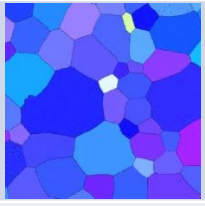
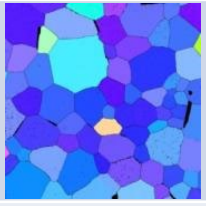
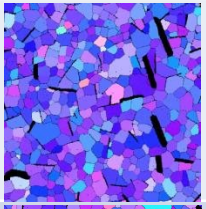
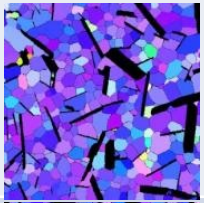
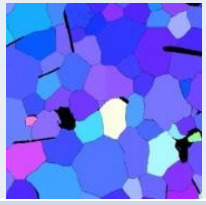
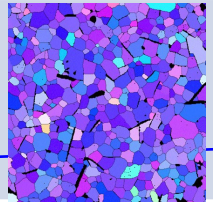
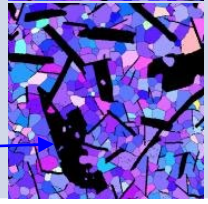
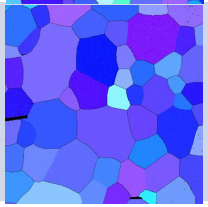
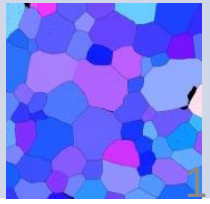
5. Analytical evaluation(Non-coating)

The surface of grain

●Ground: We observed IMC(Intermetallic Compound ; Ni_xSn_x). These IMC were remarkably growing as time proceeds.

The size of tin grain was increasing both on-orbit and ground, because tin grains recrystallized to relieve compressive stress by thermal cycling and to be stabilized.

Test piece(Flat plate) P01
 Base Material :Cu, Underplating :Ni=2μm, Tin plating=3μm (Plating hard to grow)
Test piece(Flat plate) P02
 Base Material :Cu, Underplating :Ni=2μm, Tin plating=8μm (Plating easy to grow)

	Test piece1 (Flat plate) P01		Test piece2 (Flat plate) P02	
	On-orbit	Ground	On-orbit	Ground
Initial				
1st year				
2nd year				
3rd year				

Black color is IMC.

5. Analytical evaluation(Non-coating)

The saturation of whisker

Conditions for whisker saturation: The supply path of Sn atoms from Sn plating to whiskers must be blocked.

The following are assumed to be factors that block the supply path of Sn atoms.

1. Collapsed grain boundaries (not sound contacts at the grain boundaries)
2. A lot of IMC (Intermetallic Compound ; Ni_xSn_x) generation
3. A drain on Sn plating

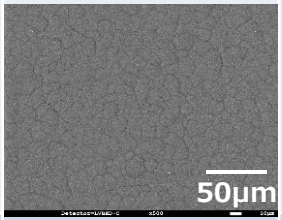
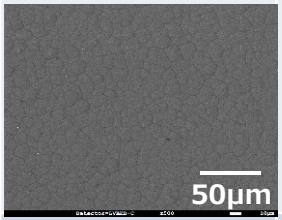
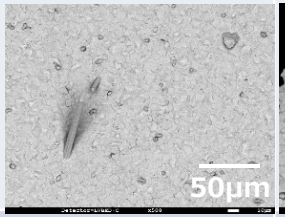
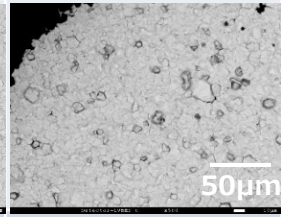
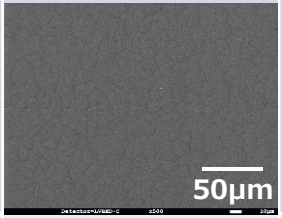
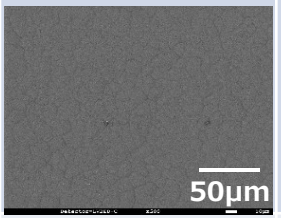
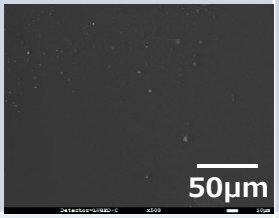
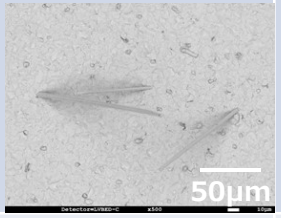
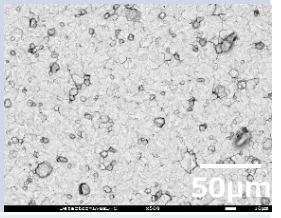
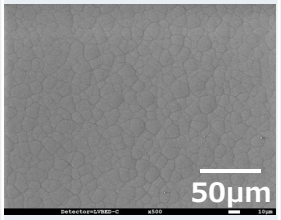
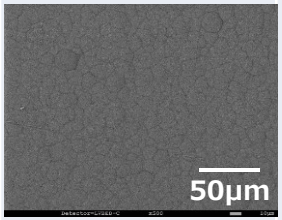
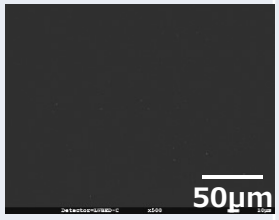
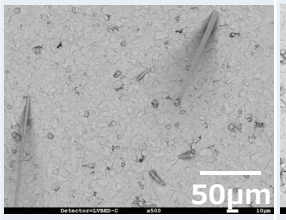
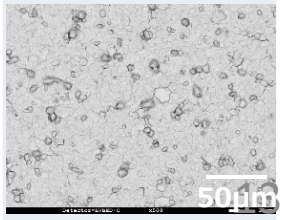
Samples on ground are observed “collapsed grain boundaries” and “IMC”, but samples on-orbit are not.

About Tin plating easy to grow whisker, we think it would be difficult to completely saturate the length of whisker on-obit in a short period of time.

6. Analytical evaluation(Conformal coating)

the effectiveness of conformal coating

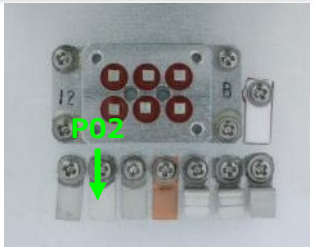
- Para-xylene coating: There was no whisker growth both on–orbit and ground.
- Urethane coating: There was no whisker growth in the thick urethane coating both on–orbit and ground.
- No coating: There were many whiskers both cases.

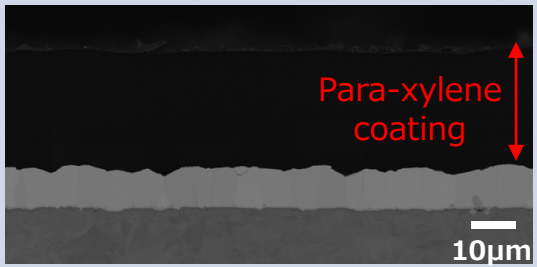
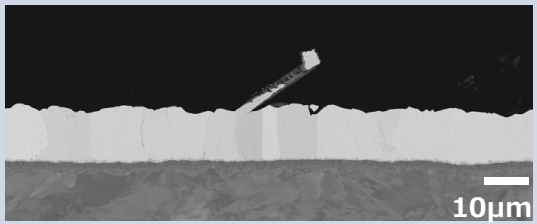
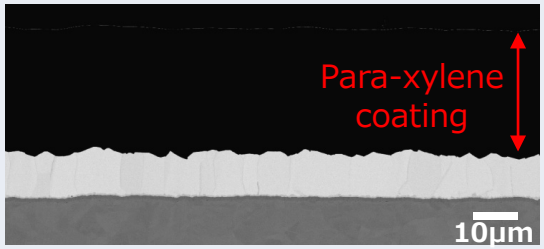
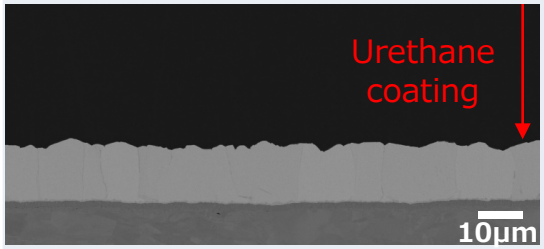
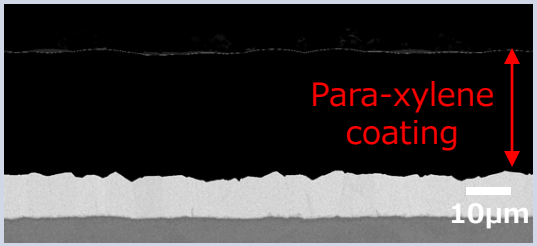
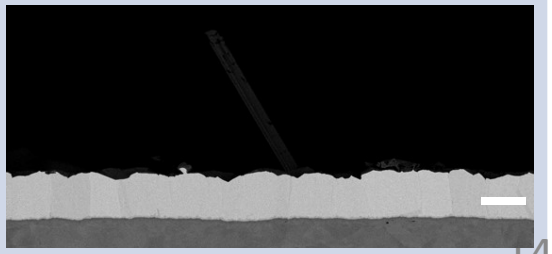
	Para-xylene coating		Urethane coating		Non-coating	
	On-orbit	Ground	On-orbit	Ground	On-orbit	Ground
1st year						
2nd year						
3rd year						

6. Analytical evaluation(Conformal coating)

the effectiveness of conformal coating

It was observed that para-xylene coating and urethane coating prevent whisker growth itself. There were no whiskers under each coating.



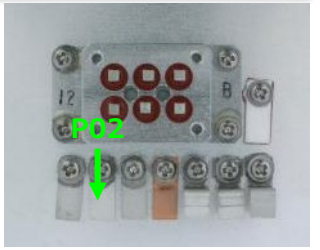
	Para-xylene coating	Urethane coating	Non-coating
On-orbit 1st year			
On-orbit 2nd year			
On-orbit 3rd year			

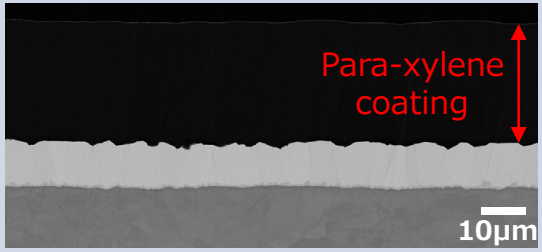
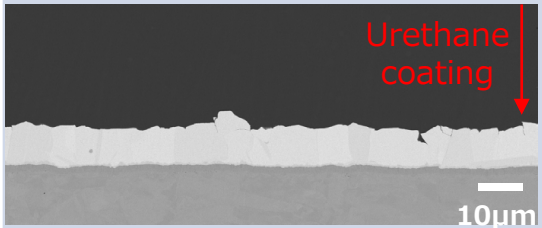
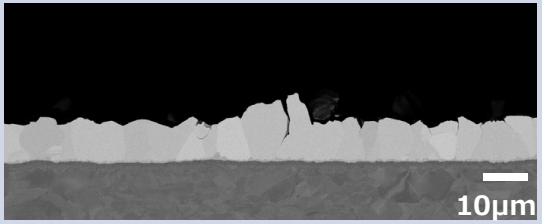
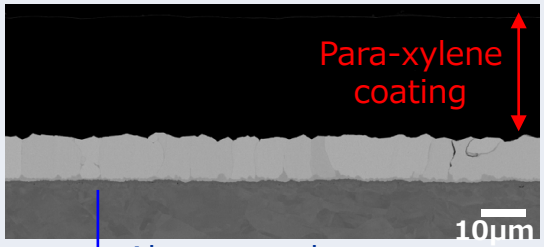
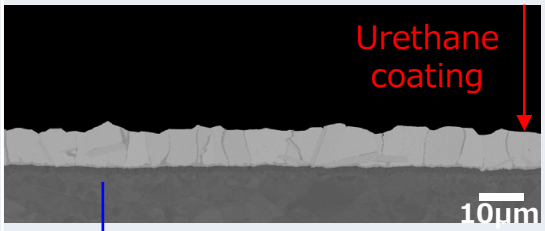
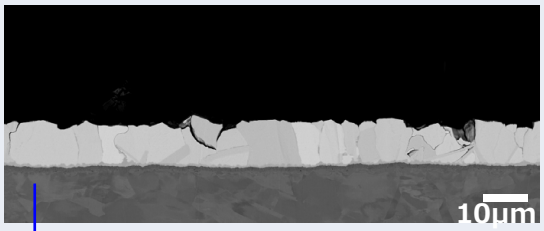
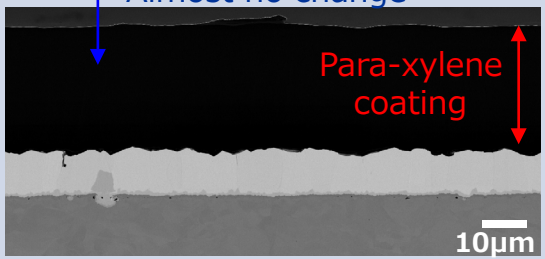
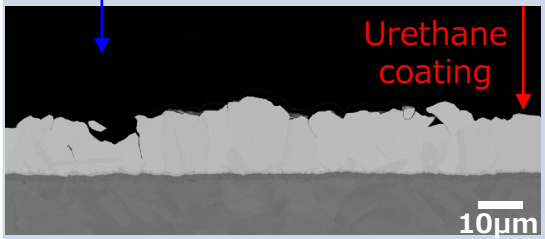
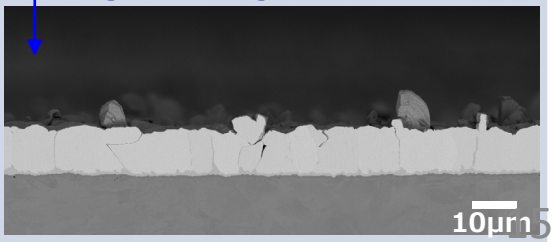
6. Analytical evaluation(Conformal coating)

the surface of tin plating under coating

The surface of tin plating under coating of Urethane became rougher. Whereas Para-xylene coating was almost no changed.

However, both coatings prevent whisker growth itself (no whiskers under each coating) .



	Para-xylene coating	Urethane coating	Non-coating
Ground 1st year			
Ground 2nd year			
Ground 3rd year			

6. Analytical evaluation(Conformal coating)

the surface of Tin plating under coating

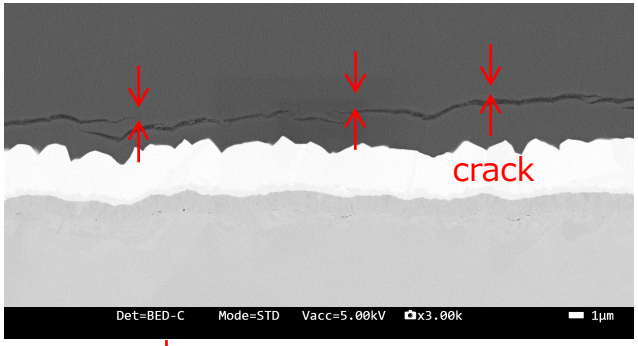
Crack and debonding were observed in part of test piece block in para-xylene coating and urethane coating. We suppose that they were happened due to mismatching co-efficient of thermal expansion between Tin plating and base, or roughness of Tin plating of coating.

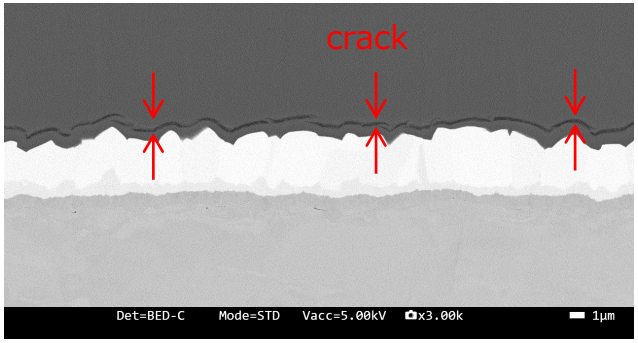
Since the direction of the crack and debonding is horizontal, we do not think that they would penetrate the coating.

On-orbit 3rd year

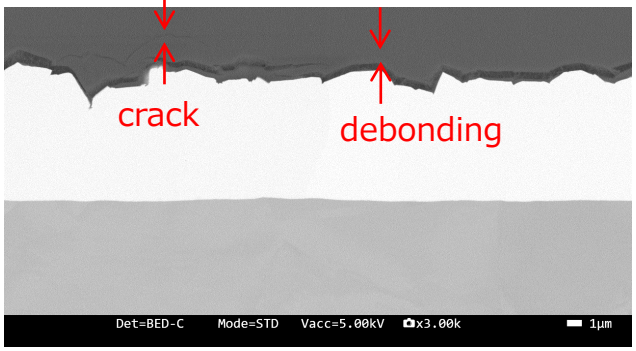
Ground 3rd year

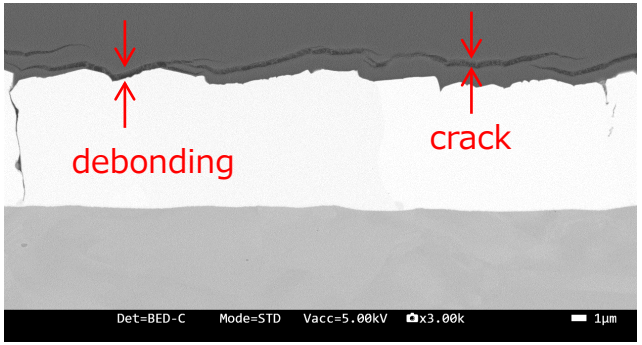
P01





P03





7. Summary

The summary is as follows.

Mission objective 1)

To compare differences in whisker growth characteristics between air and on-orbit environment

- Ground : The length of whiskers are obviously saturated.
- On-orbit : Length of 3rd year whisker on-orbit is still increasing. Mean length shows saturation trend, but with large variance. Judgement of saturation will be made based on the results of the fourth year.

Mission objective 2)

To evaluate the effectiveness of conformal coatings which may mitigate whisker growth

- Para-xylene coating : There was no growth of tin whiskers on ground and on-orbit, and the suppressing effect was confirmed.
- Urethane coating : There was no growth of tin whiskers in the thick coating area, and partial whisker suppression effect was obtained.

Crack and debonding were observed in part of test piece block in para-xylene coating and urethane coating. However, since the direction of the crack and debonding is horizontal, we do not think that they would penetrate the coating.

Thank you for your attention !

Please let us exchange information about tin whisker with you in the future.