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Sn whisker growth in thermal vacuumitions

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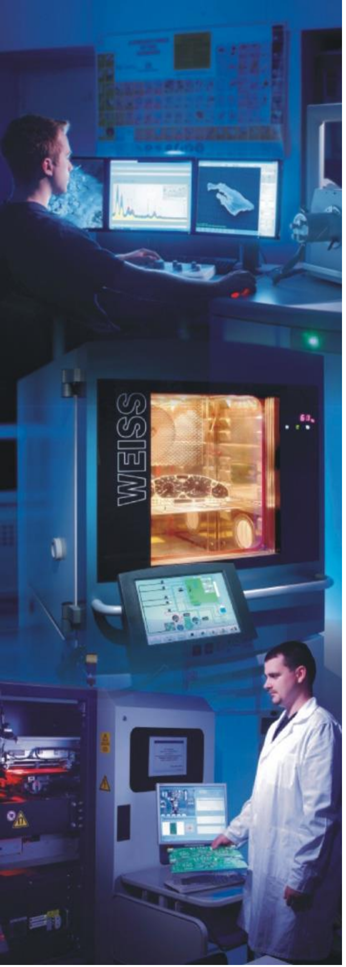

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Located in the heart of Budapest (Hungary)

Activities:

- Computer Aided Design of PCBs
- PWB and SMT prototyping
- Numerical modeling (electrical, mechanical, thermal, and CFD)
- Quality and reliability inspections of electronics
- Failure analysis of electronics assemblies

WHISFUSE PROJECT

Lead free components with Sn solder finishes are widely available in the industry → used in almost all COTS EEE parts (*COTS: Commercial Off The Shelf / EEE: Electrical, Electronic and Electro-Mechanical*).

These components are prone to grow tin whiskers. The demand is increasing for these components in space flight equipment.

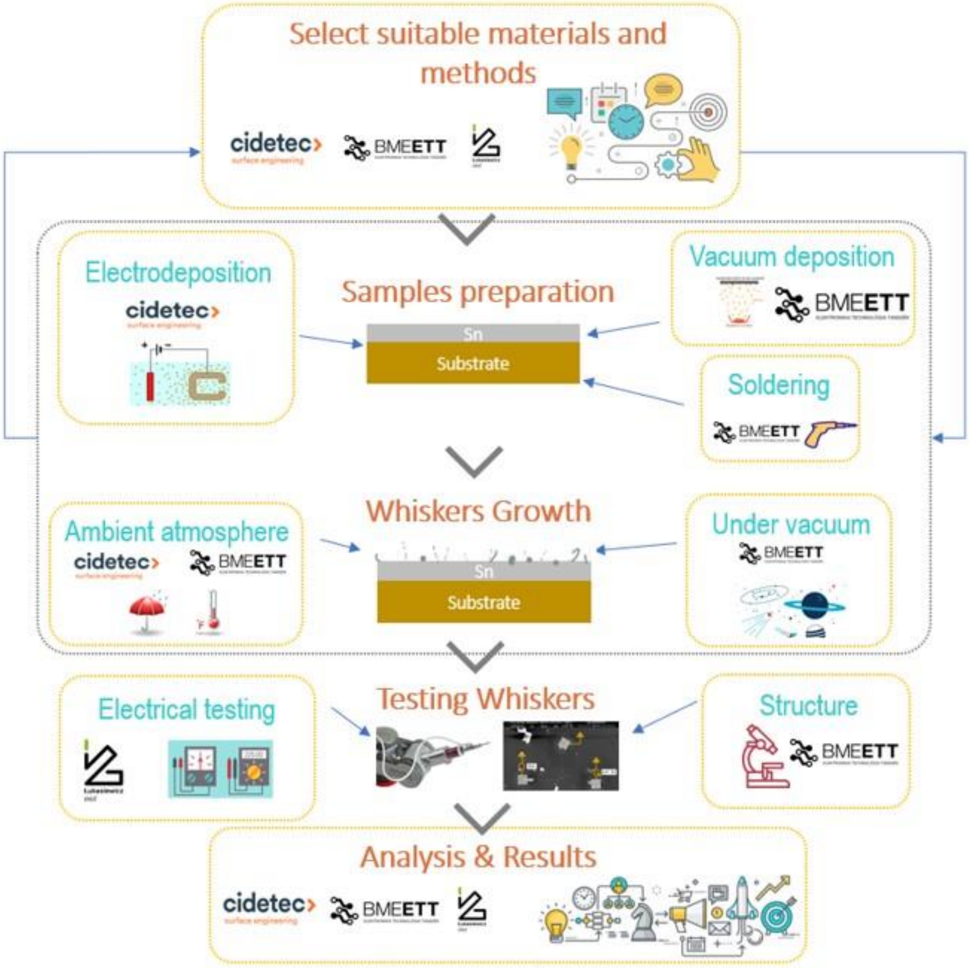
The **WHISFUSE** project studied the **"Current capacity and effects of vacuum of the tin whiskers"**.

Aim: **demonstrate if vacuum has any effect on whisker growth** and identify if there is an increased risk of short circuits to space flight electronics.

Two main technical objectives:

- Determine if vacuum influences and speed of tin whiskers growing.
- Determine the characteristics and current carrying capacity of tin whiskers.

WHISFUSE PROJECT

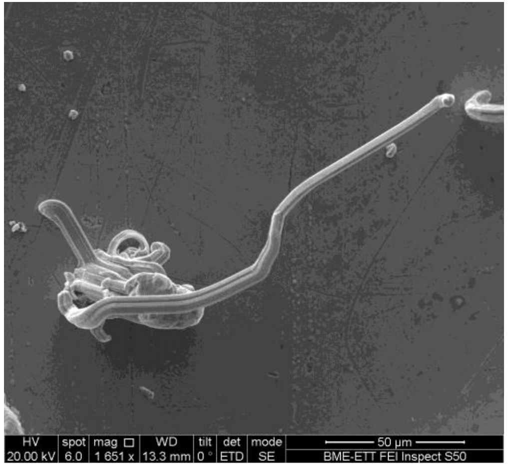


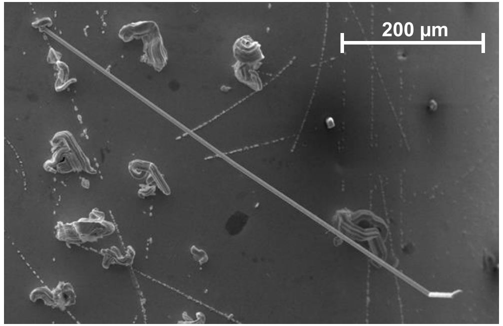
Sn WHISKER ??

- Sn whiskers are a reliability issue
- Conductive whiskers „spontaneously” grow from Sn surfaces

Mechanical stresses cause whiskering:

- residual stress in the Sn layer,
- direct external mechanical load,
- volumetric expansion (by ***intermetallic*** or *oxide growth*),
- thermomechanical effects.





THERMO-VACUUM TESTS

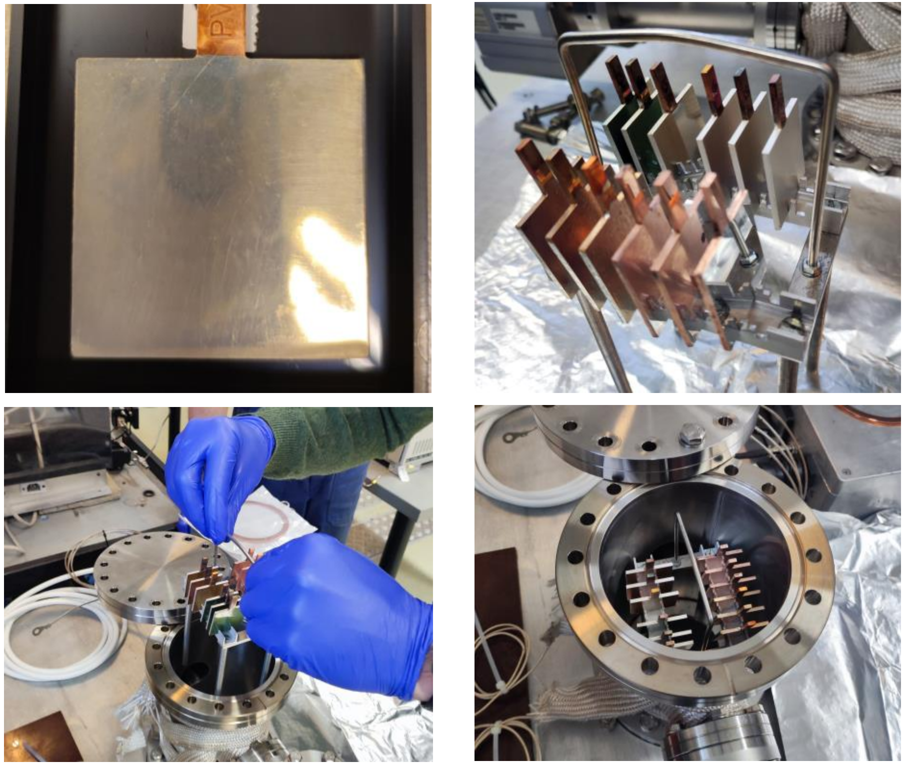
Tests:
V1: constant 50ºC in vacuum for 1000h
V2: 25-125° C cycling in vacuum, 1000 cycles (1000h)
Pressure: 8.3x10^{-6} mbar

Samples:

- PVD Sn,
- Electroplated Sn bright & matt.
- Soldered SnCu0.7 and SAC0307.

Sample evaluation:

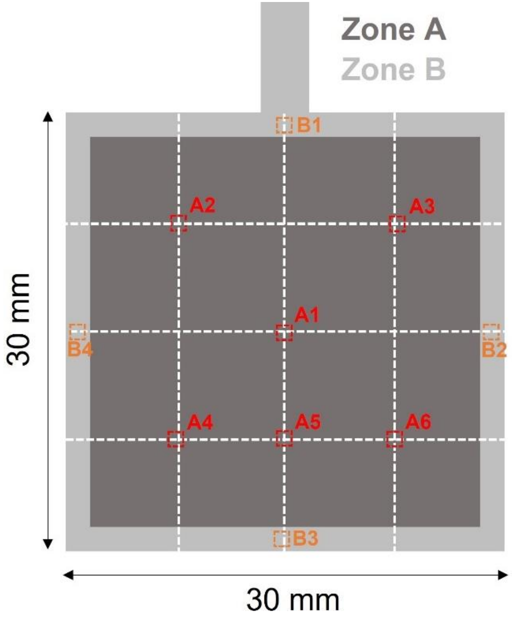
- No return test
- N$_2$ flushing during the sample removal



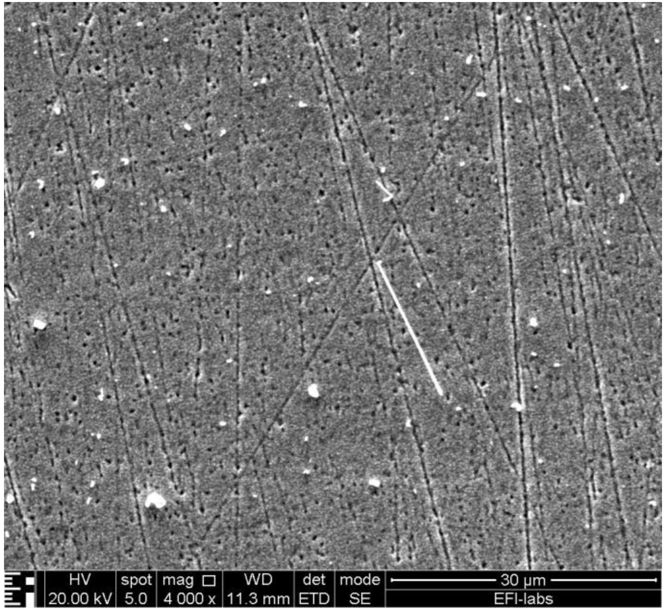
RESULTS OF V1 TEST

Whiskers appeared on PVD Sn samples after 75 hours

Investigation zones



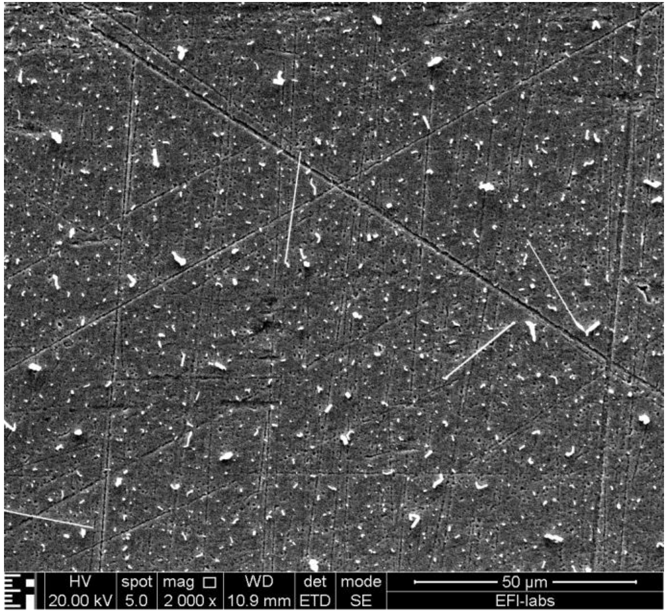
PVD Sn – A1 zone (75 hours)



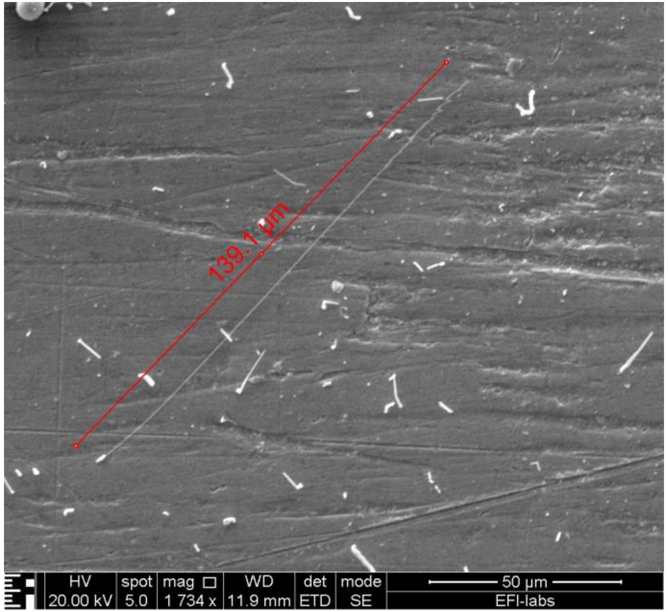
RESULTS OF V1 TEST

***The number and the length of Sn whiskers considerably increased over time*.**

PVD Sn – A2 zone (500 hours)



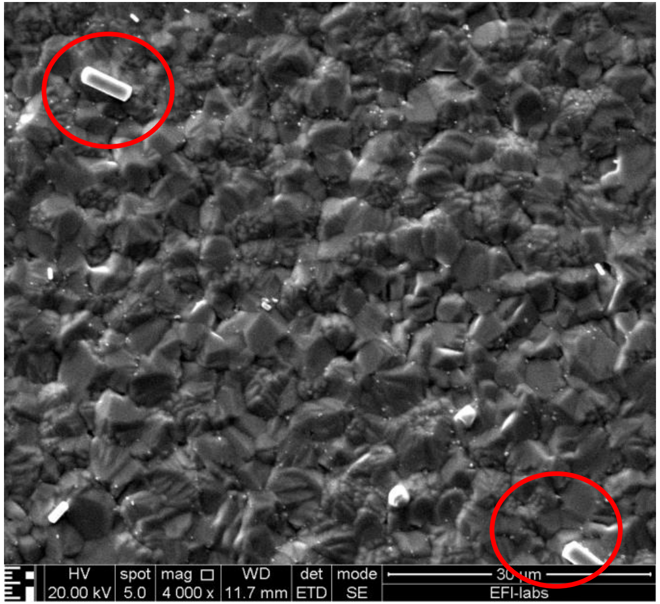
PVD Sn– B1 zone (500 hours)



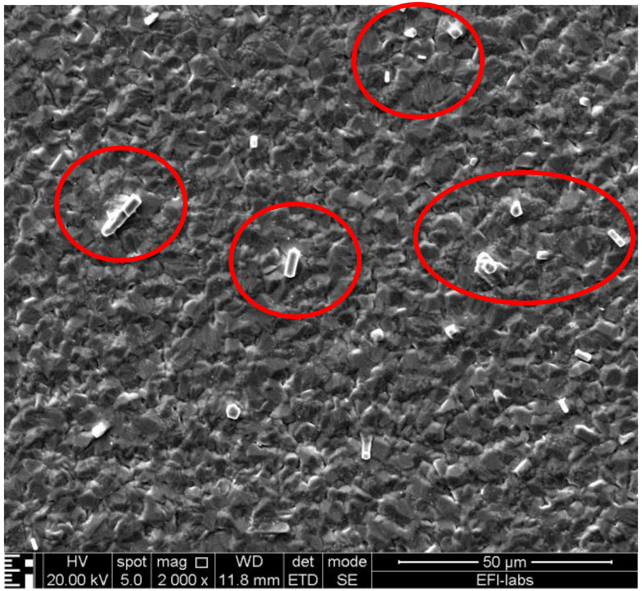
RESULTS OF V1 TEST

Whiskers appeared on electroplated mat Sn samples after 250 hours

Electroplated Matt Sn (250h)



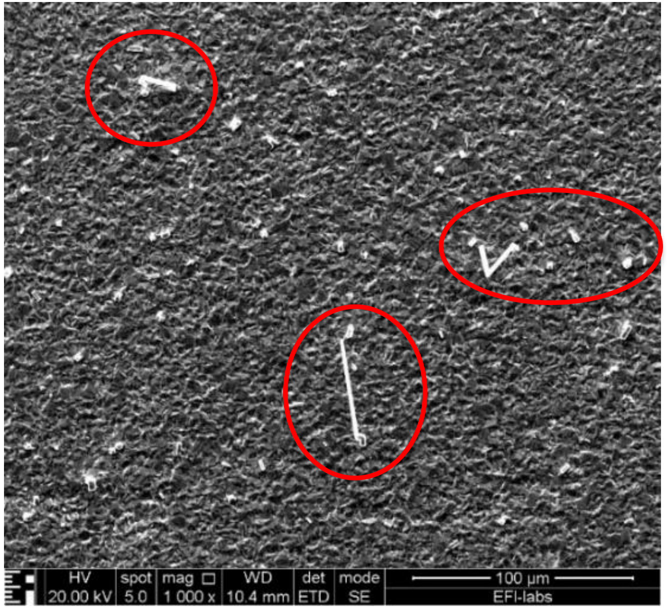
Electroplated Matt Sn (250h)



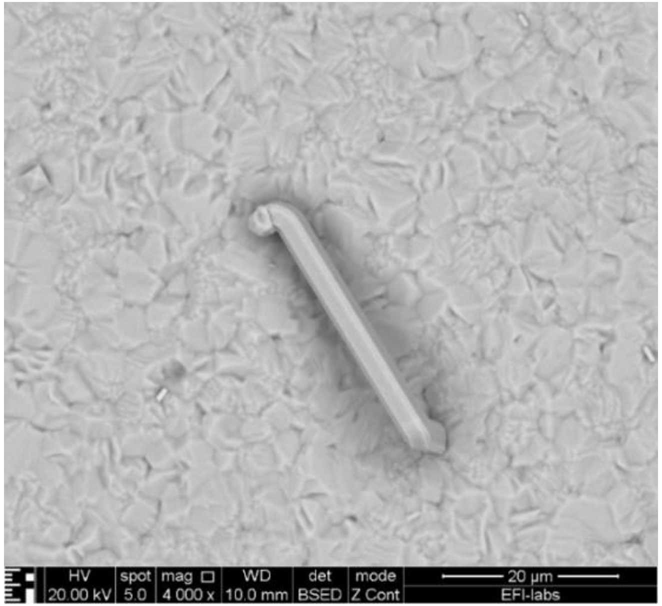
RESULTS OF V1 TEST

- **TASK T2.3.** Whiskers growing in vacuum (M4 – M10)

Electroplated Matt 1 – A2 zone (1000h)



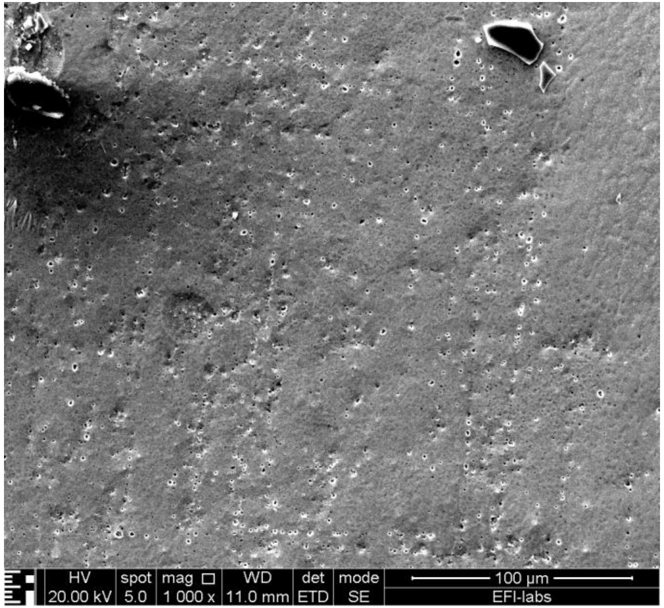
Electroplated Matt 1 – A4 zone (1000h)



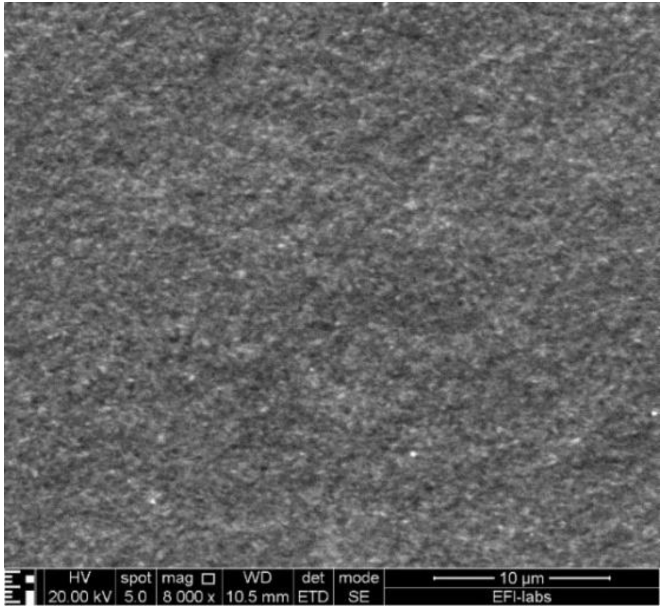
RESULTS OF V1 TEST

No whiskers on the electroplated bright Sn and soldered samples

Soldered SAC0307 – 1000h



Electroplated Bright 1 – 1000h



RESULTS OF V1 TEST

Whiskers have been found on:

- PVD Sn
- *Matt Sn (contradiction!)*

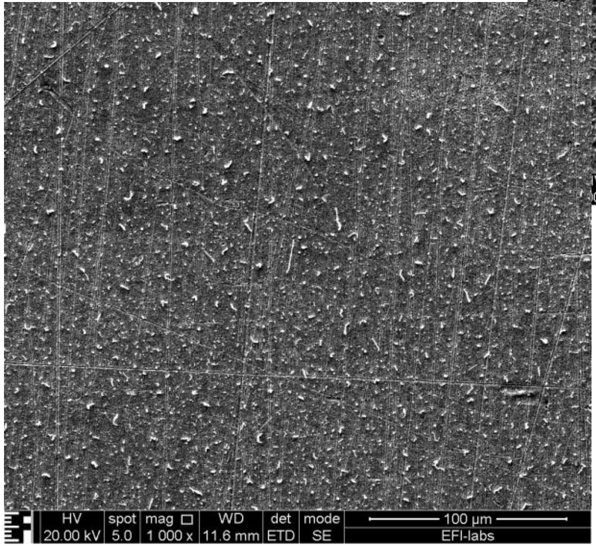
No whiskers:

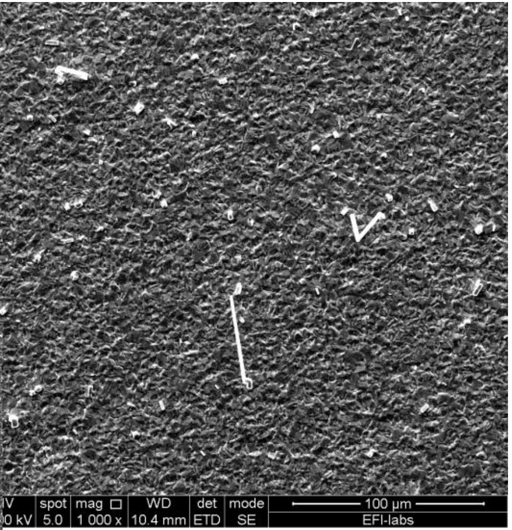
- Solderd samples (Sn0.7Cu, SAC0307)
- *Bright Sn (contradiction!)*

Amount of whiskers:

- PVD very high density
- Matt Sn lower density

PVD Sn (1000h)





Matt Sn (1000h)

RESULTS OF V2 CYCLING TEST

Whiskers have been found on:

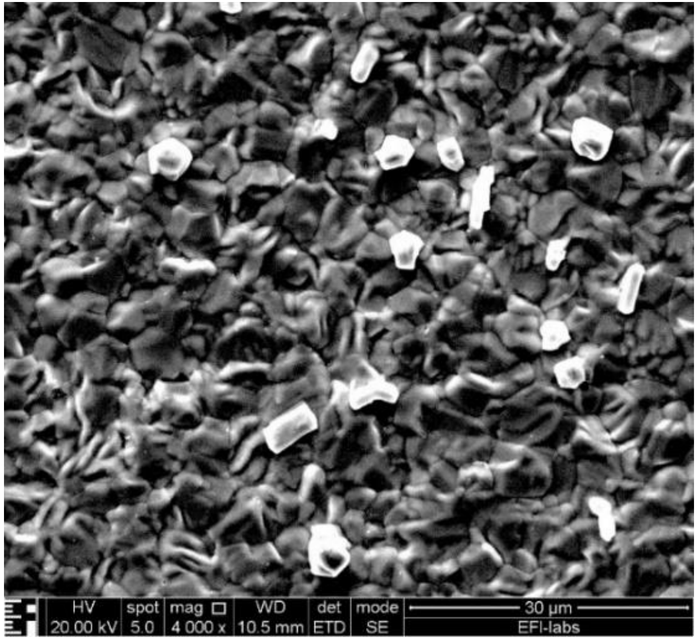
- *Matt Sn (contradiction!)* ⚡

No whiskers:

- PVD Sn
- Solderd samples (Sn0.7Cu, SAC0307)
- *Bright Sn (contradiction!)* ⚡

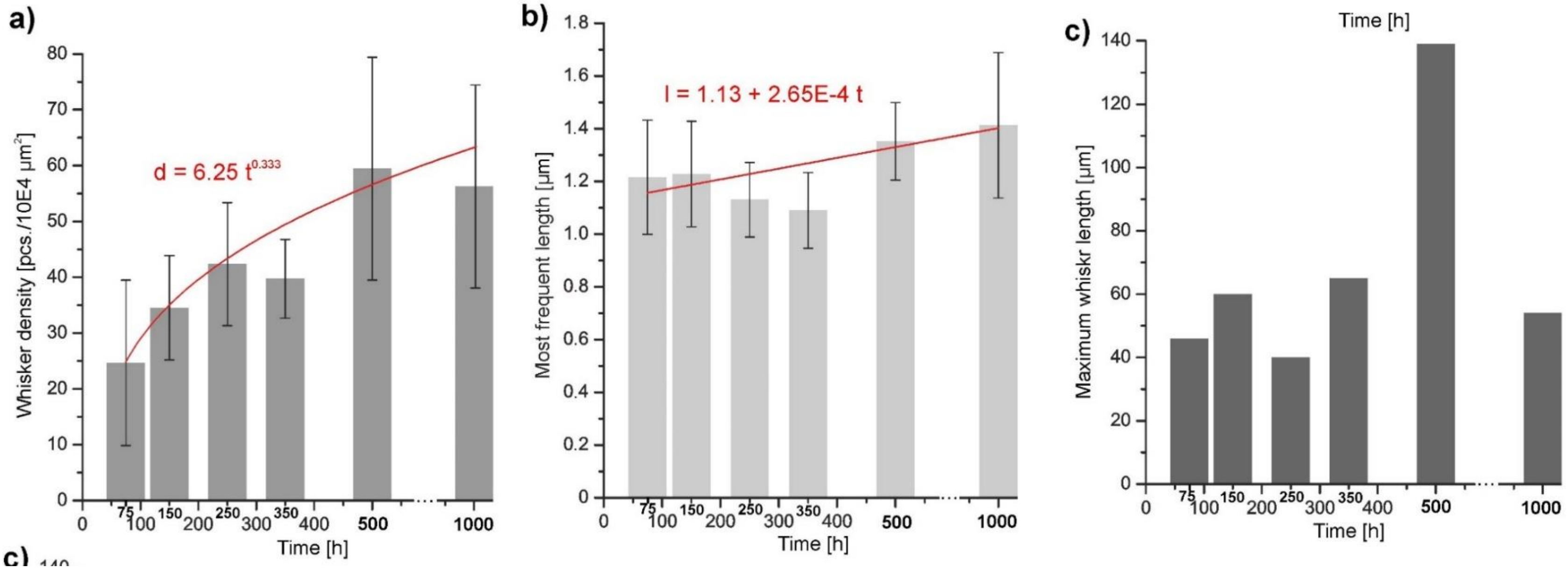
Whisker types:

- Mostly short filament- and hillock-type whiskers have been found.



Matt Sn (1000 cycles)

STATISTICS PVD Sn (V1 test)

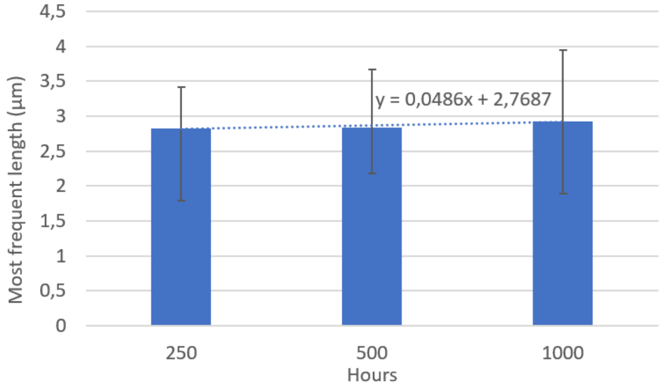


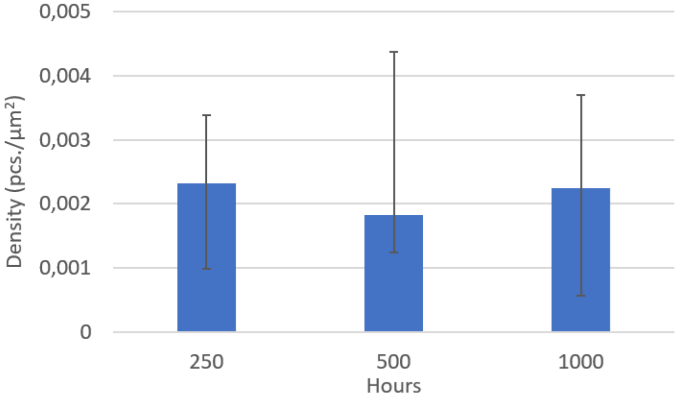
PVD sn a) whisker densities; b) most frequent length; c) maximum length.

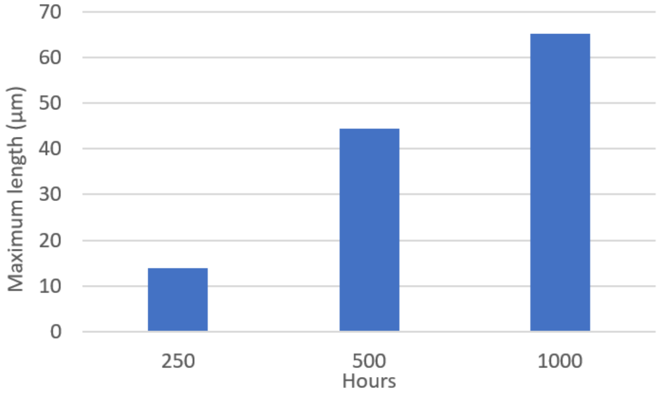
- Cu_6Sn_5 IMC layer growth driven Sn whisker growth.
- ***Twice more but shorter whisker than at room conditions.***

STATISTICS OF MATT Sn (V1)

- **Average density 21-22pcs./10E4/µm^2.**
- **Half the amount of whiskers** than on PVD Sn.
- The **most frequent** lengths was **2.6-2.9µm.**
- The **maximum whisker** lengths were **65µm**.
- The **matt Sn layer** was ~20 times thicker than PVD –> **better relaxation ability**.

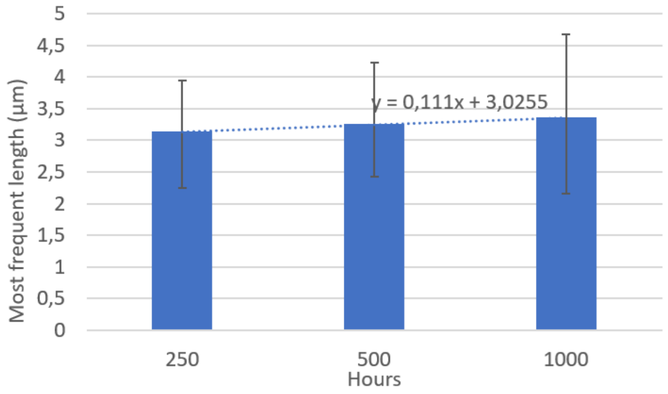


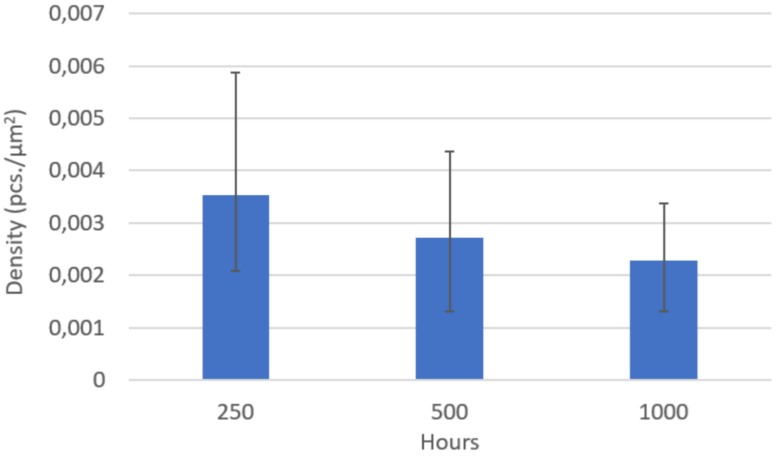


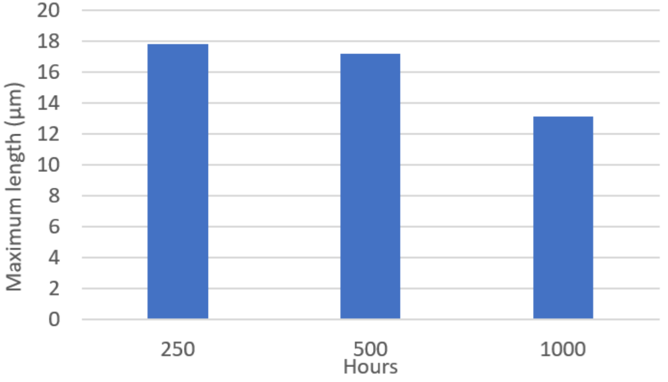


STATISTICS OF MATT Sn (V2)

- The **average density** was ***23-35pcs./ 10E4/ µm^2***; higher than in V1 test; higher average temperature of V2 than V1.
- The **most frequent length** was **3.1-3.4µm**.
- The **maximum whisker length** was ***18µm.***



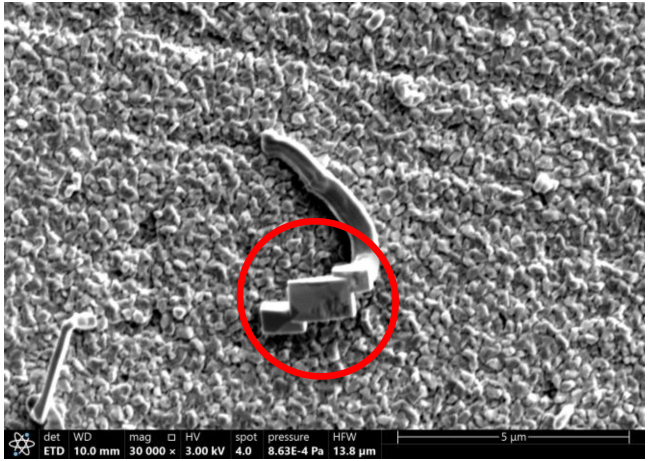


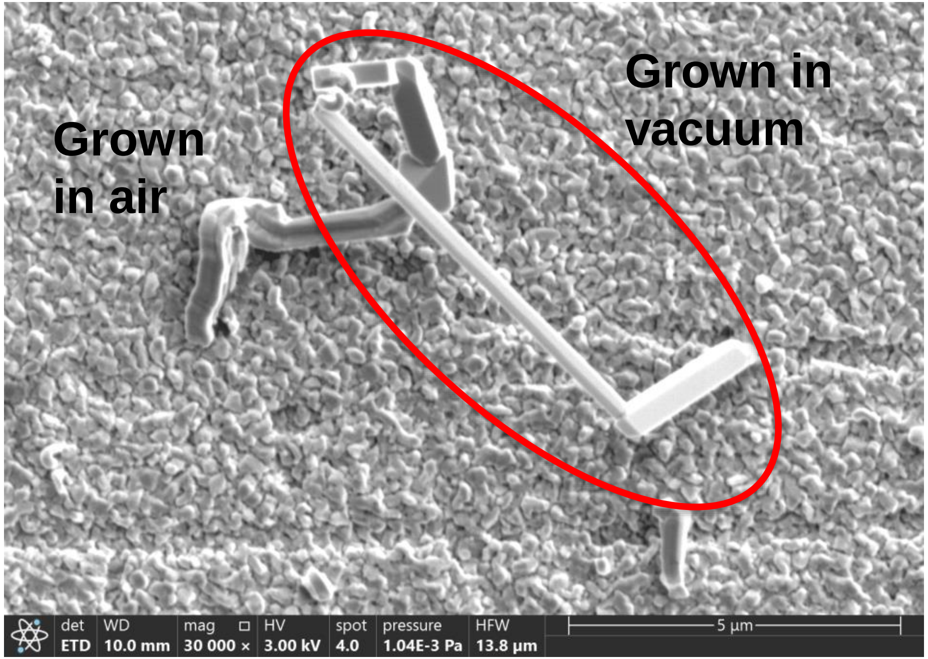


STRUCTURAL PROPERTIES

Unusual whisker growth in vacuum conditions:

- Bolck-like („***Minecraft”***) whiskers grown in a vacuum without grooves
- After the vacuum, growth continued in the usual way, twisted body with grooves.



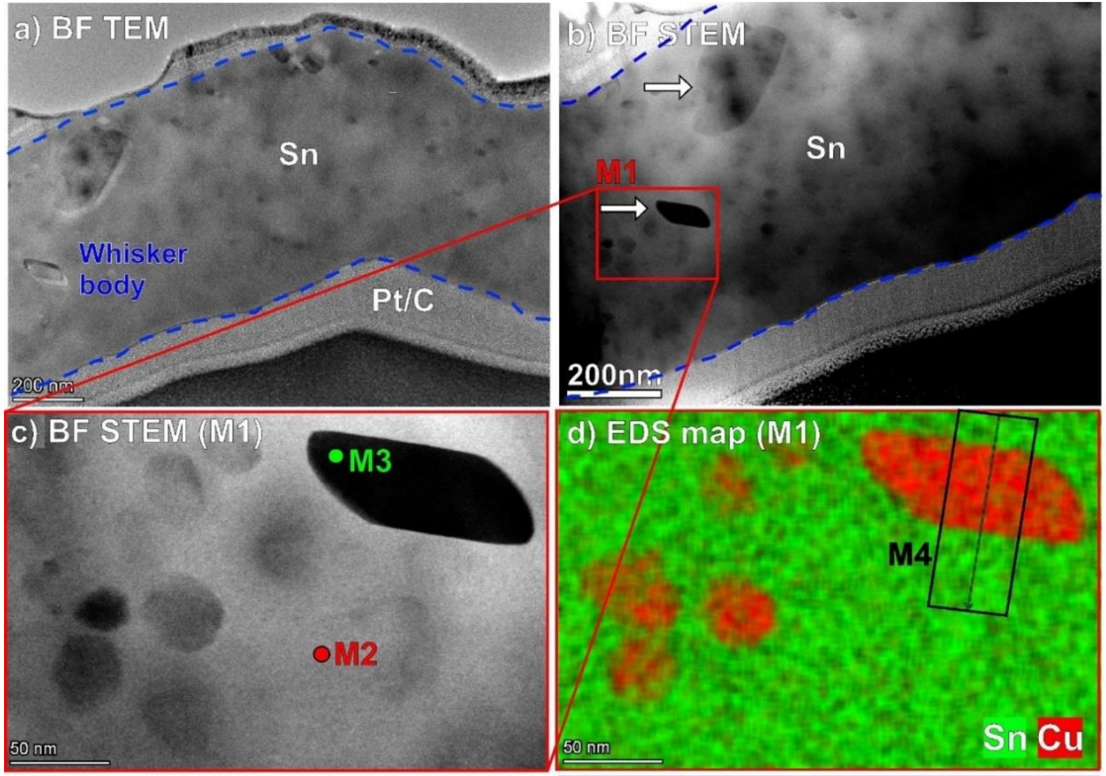

Grown in air

Grown in vacuum

STRUCTURAL PROPERTIES

TEM investigations of the whiskers (twisted part):

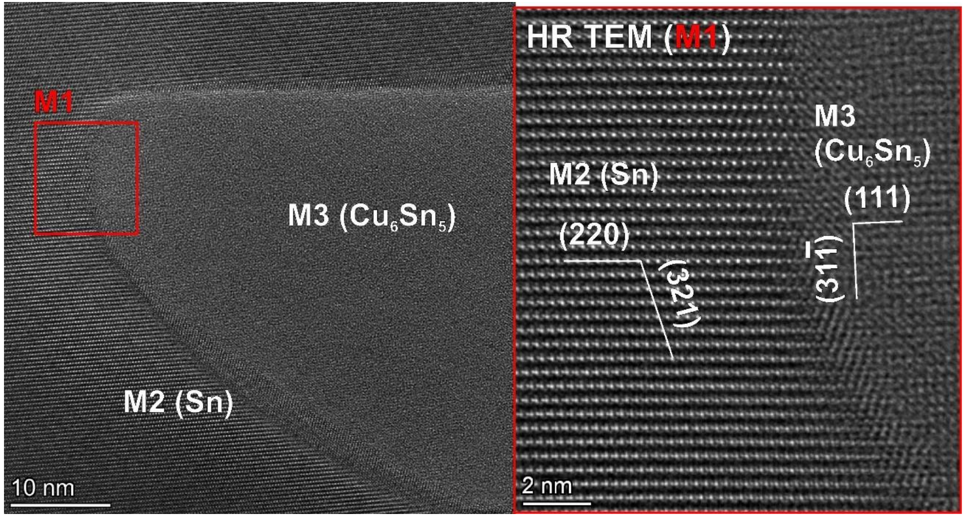
- Lamellae were prepared from the Sn whiskers for TEM by FIB.
- The whisker was placed on a Cu grid.
- The the whisker was covered with an 200 nm thick Pt layer to protect.
- Plenty of inclusions/voids were found in the body of the whisker.

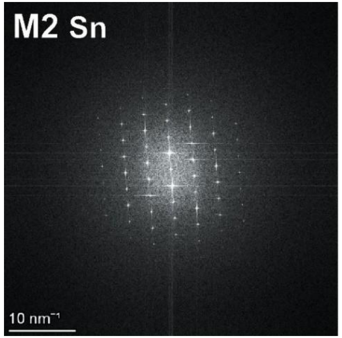


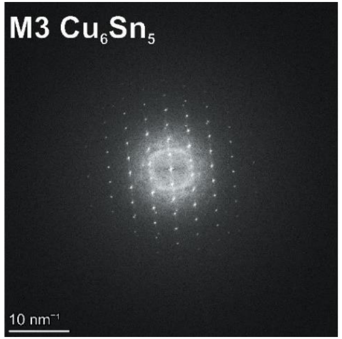
STRUCTURAL PROPERTIES

TEM investigation of the whiskers (twisted part):

- The inclusions are ***Cu_6Sn_5* *(8-12 at%).***
- HR-TEM and SAED analysis showed that both the whisker ((220) and (321)) and the Cu_6Sn_5 inclusions ((111) and (31-1)) are single crystals.



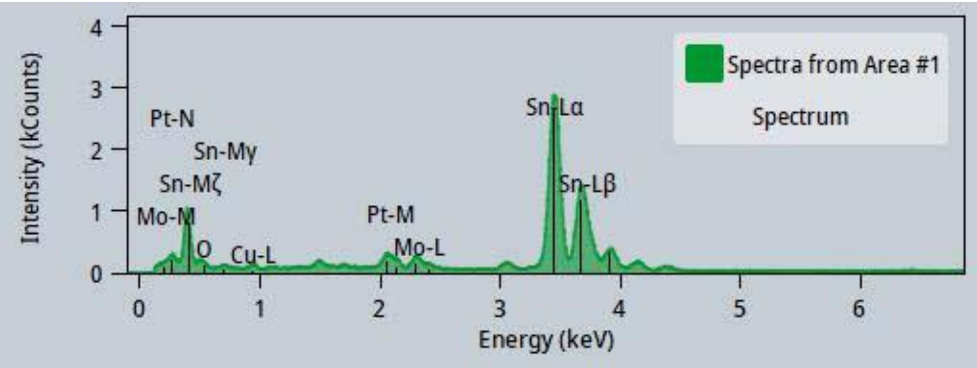


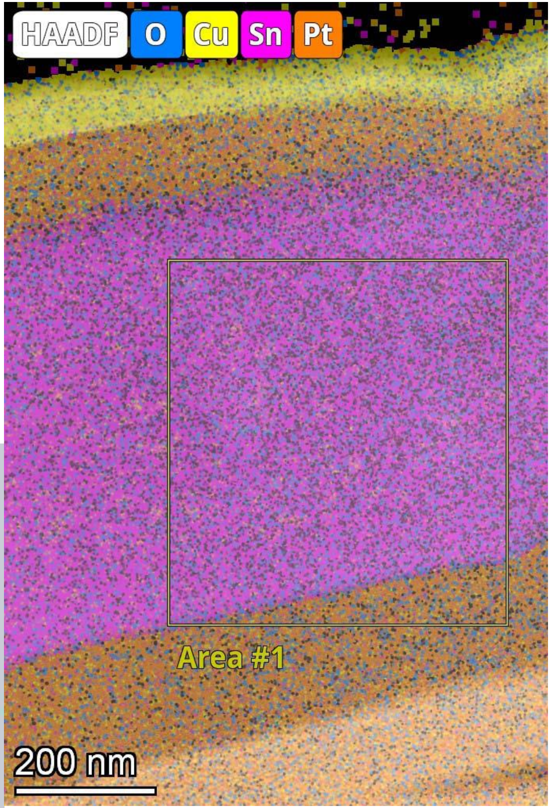


STRUCTURAL PROPERTIES

TEM investigation of whiskers (twisted part):

- Only a small amount of oxide was found on the body of the whisker.
- Contradiction with the literature.

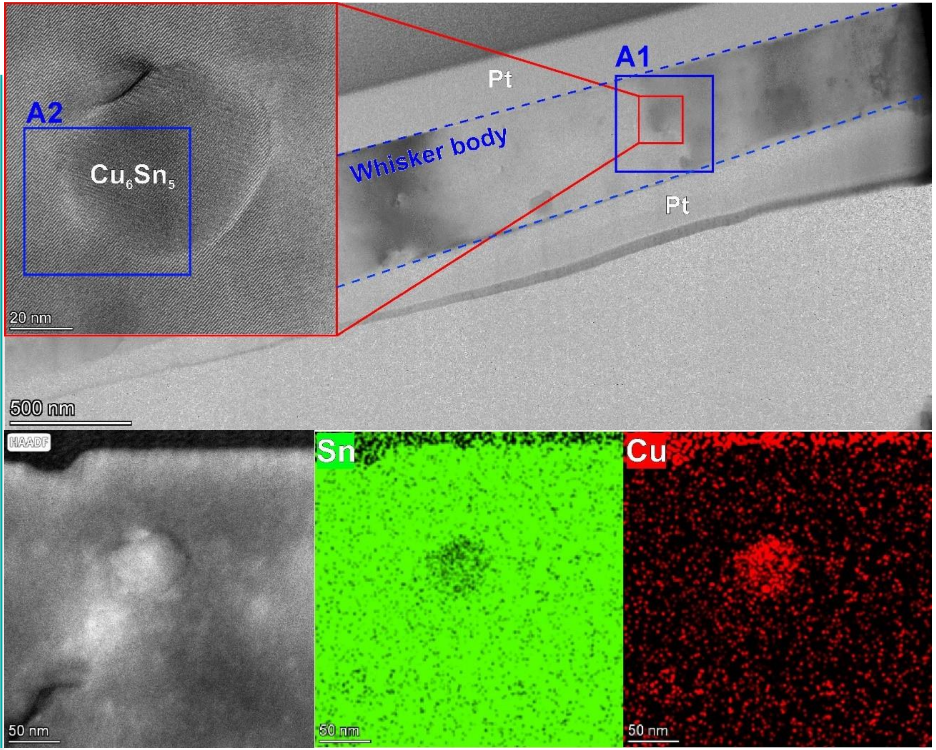




STRUCTURAL PROPERTIES

TEM investigation of the whiskers (block-like):

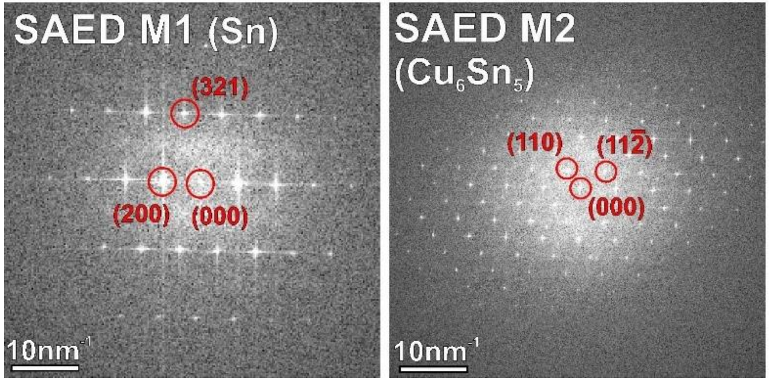
- Lamellae were prepared from the Sn whiskers for TEM by FIB.
- The whisker was placed on a Cu grid.
- The surface of the whisker was covered with an 200 nm thick Pt layer
- The block-like whiskers also contained ***Cu_6Sn_5 inclusions (4-5 at. %).***

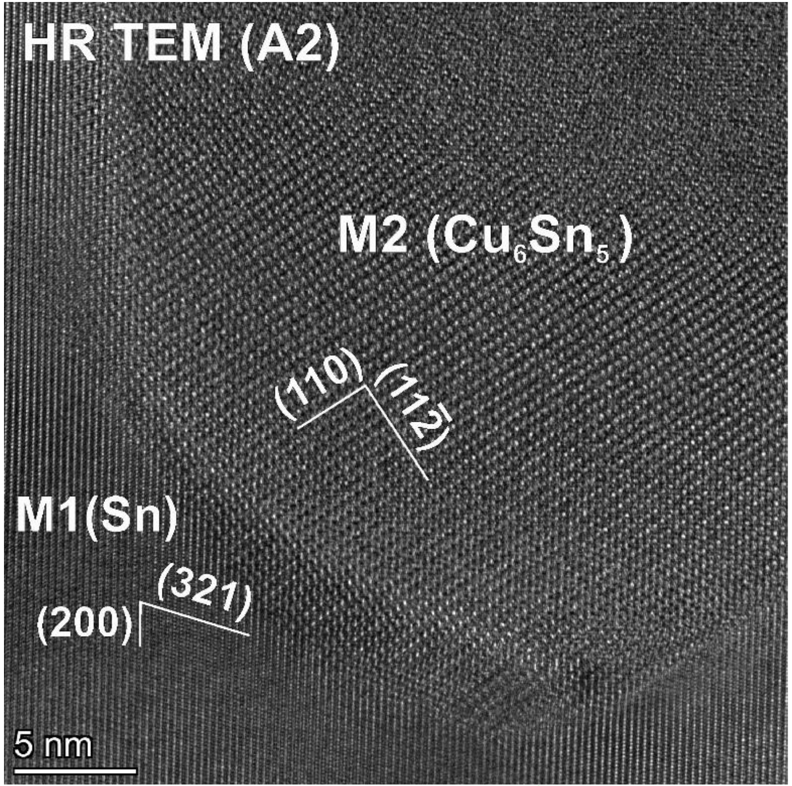


STRUCTURAL PROPERTIES

TEM investigation of the whiskers (block-like):

- The whisker was single crystal ((200) and (321) and contained only SOME Cu_6Sn_5 inclusions, was single crystal ((110) and (11-2)).





ESA 4000140874/23/NL/FE - Current Capacity and Effects of Vacuum of Tin Whiskers (WISFUSE)

STRUCTURAL PROPERTIES

Whiskers growth in ambient vs. vacuum:

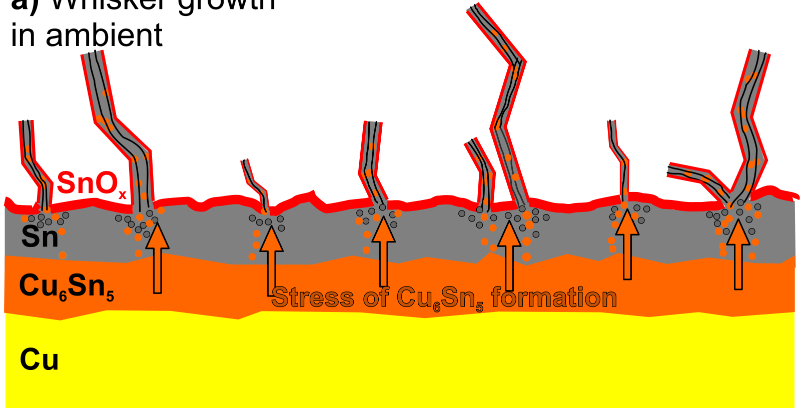
Ambient conditions:

- SnO_x layer formation; ***stress relaxation and whisker growth only at the cracks/holes.***
- The accumulation of the stress results in ***less but longer whiskers*** and more Cu_6Sn_5 in the whiskers

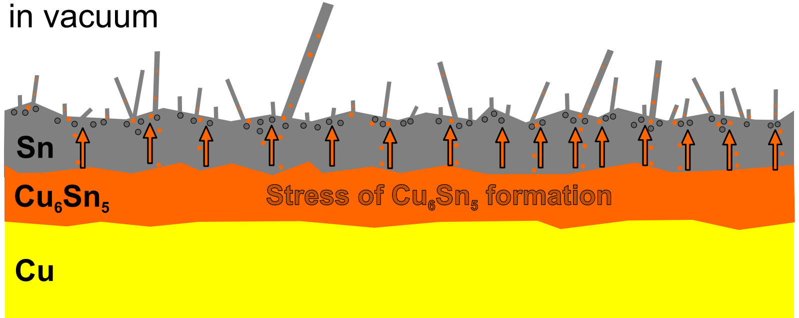
Vacuum conditions:

- *No SnO_x layer formation*
- ***Uniform stress relaxation***
- ***More but shorter Sn whiskers with fewer Cu_6Sn_5 inclusions***.

a) Whisker growth in ambient



b) Whisker growth in vacuum



CONCLUSIONS

- Sn whiskers on the PVD Sn after 75 h of thermo-vacuum test
- ***Matt Sn (whikskers) <->Bright Sn (No whiskers)…??***
- In vacuum 50% more but 50-70% shorter whiskers than in ambient conditions.
- ***Vacuum whiskers had a block-like body…?***
- Weak correlation between the crystal structure and the shape of the whiskers
- *Cu_6Sn_5 inclusions* in the whiskers by interface flow mechanism
- Twice as many Cu_6Sn_5 inclusions in the twisted whiskers
- ***Role of Cu_6Sn_5 inclusions…?***