



TECHNISCHE UNIVERSITÄT  
BERGAKADEMIE FREIBERG

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# Understanding Phase Transformations on the way to $\text{Nb}_3\text{Sn}$

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with contributions of Jonas Lachmann, Alexander Walnsch,  
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# Freiberg, not Freiburg in Germany



sources: Wikipedia, TUBAF



# Topics of Physical Metallurgy group

Metastable phases and related microstructures; thermodynamic description, **Calphad Method**

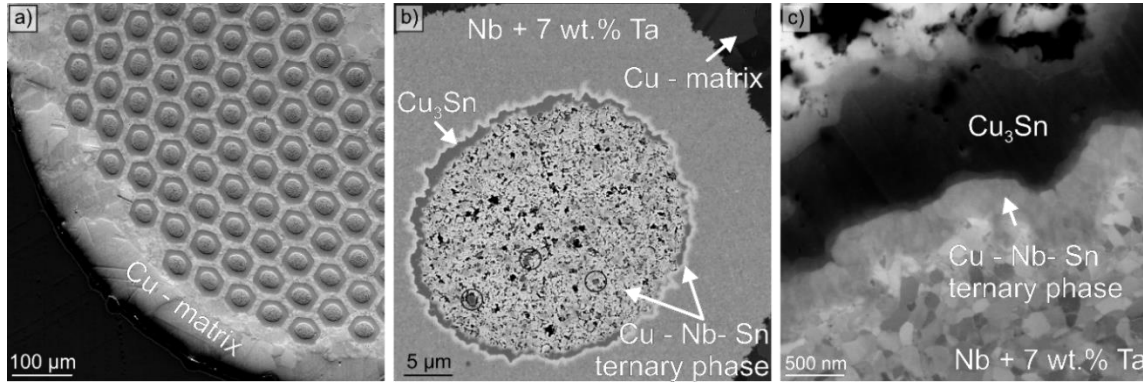
X-ray diffraction and electron backscatter diffraction (EBSD) on defective phases and peculiar microstructures

Phase transformations in alloys with interstitial elements; heat treatment of steel and cast iron

**Intermetallic phase** formation during Sn based solidifying and in Al alloys

methodology

systems



Intermetallics 80 (2017) 16–21

A. Walsch,  
Internship @CERN  
in the meantime  
PostDoc in our group



Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Intermetallics

journal homepage: [www.elsevier.com/locate/intermet](http://www.elsevier.com/locate/intermet)



## The crystal structure of $(\text{Nb}_{0.75}\text{Cu}_{0.25})\text{Sn}_2$ in the Cu-Nb-Sn system

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## 2018-2023 FCC/HFM-funded research activities

### Topics

- Phase equilibria in the Cu-Nb-Sn system, thermodynamic modelling
- Model diffusion couples to mimic processes in cables
- Influence of elements as Ta, Hf, O on phase formation and microstructure
- Microstructure investigations of processed wires

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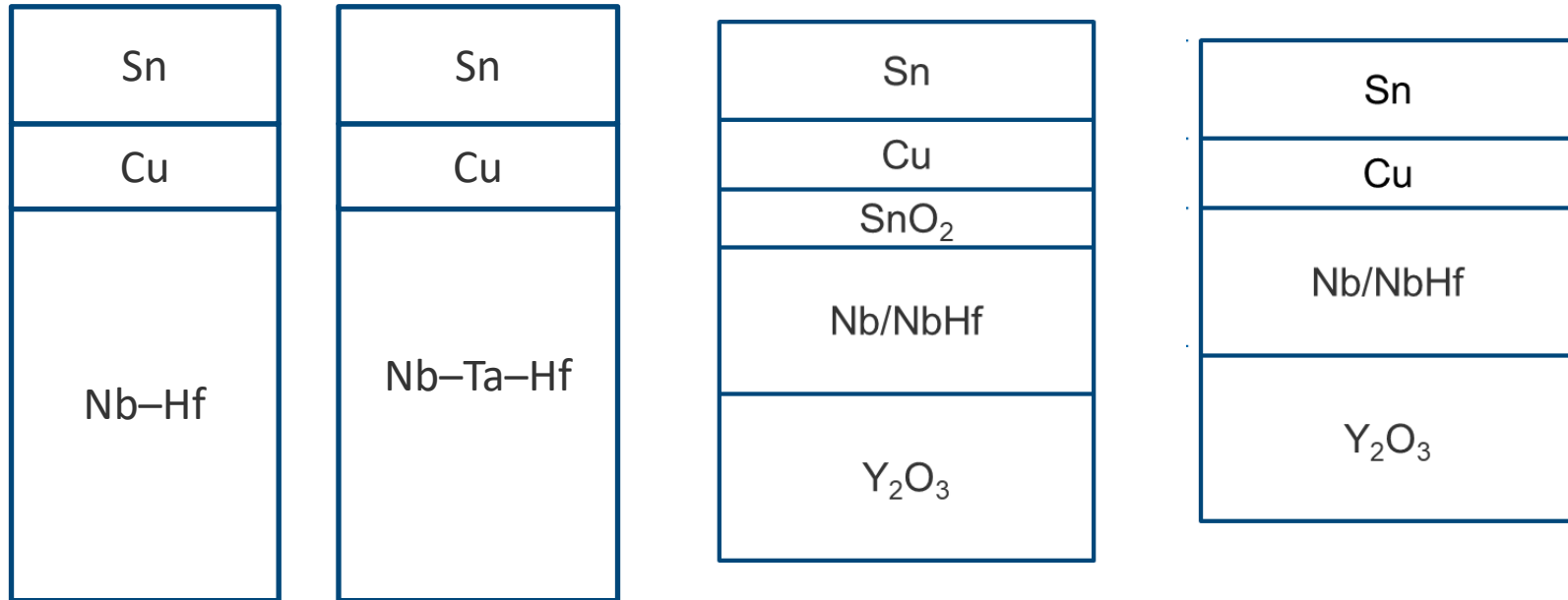
### Topics

- **Phase equilibria in the Cu-Nb-Sn system, thermodynamic modelling**
- Model diffusion couples to mimic processes in cables
- **Influence of elements as Ta, Hf, O on phase formation and microstructure**
- Microstructure investigations of processed wires



J. Lachmann

## Main: Model diffusion couples with different architectures



- Solid substrate (Nb, Nb alloy, alternatively largely inert Y<sub>2</sub>O<sub>3</sub>); covered by electroplating or PVD
- Also a few bulk alloys have been considered



# Methods for investigated developing microstructures



optical  
microscopy



TEM



Calorimetry

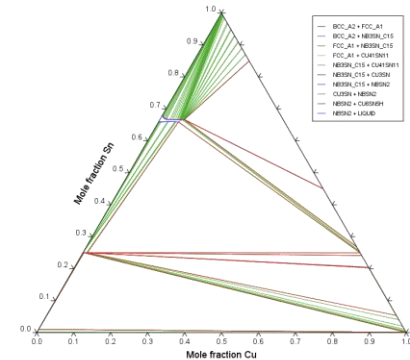


SEM



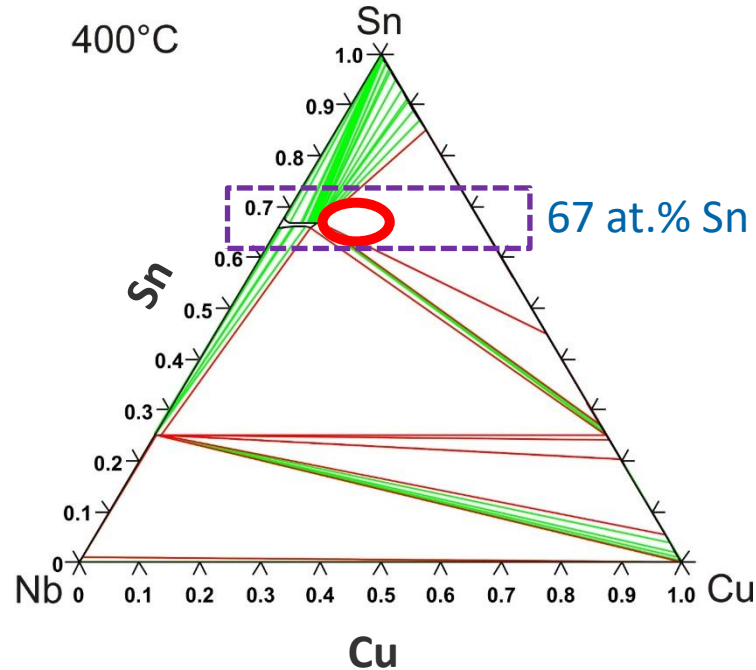
XRD

&  
thermodynamic modelling



# Phase equilibria in the Cu-Nb-Sn system, thermodynamic modelling

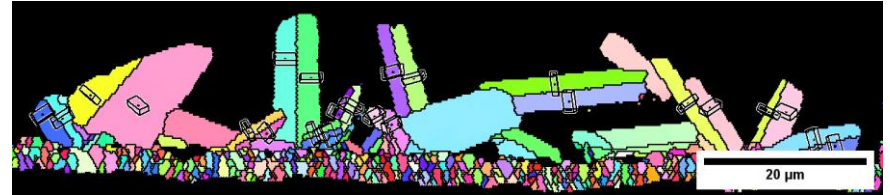
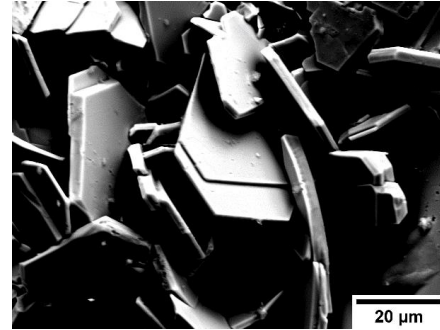
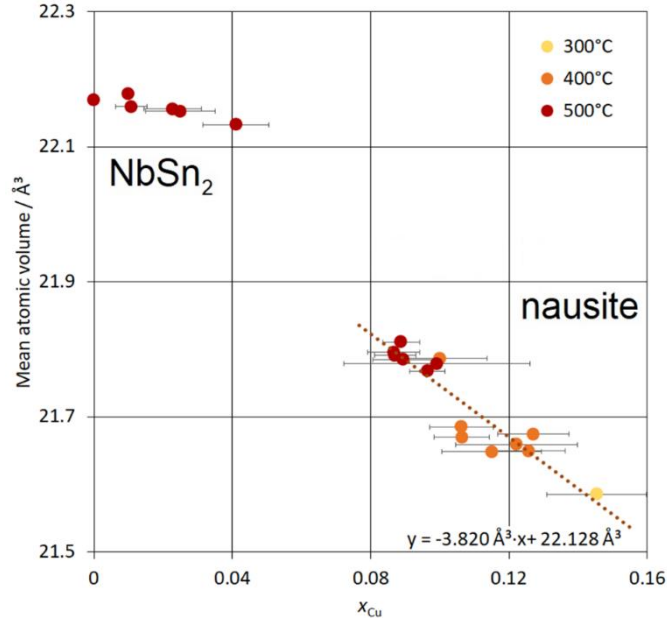
NbSn<sub>2</sub> and nausite (Nb<sub>1-x</sub>Cu<sub>x</sub>Sn<sub>2</sub>); towards a new CALPHAD description of the Nb-Cu-Sn system



- Related crystal structures (polytypes); reliable distinction necessary
- XRD/EBSD methodology adapted

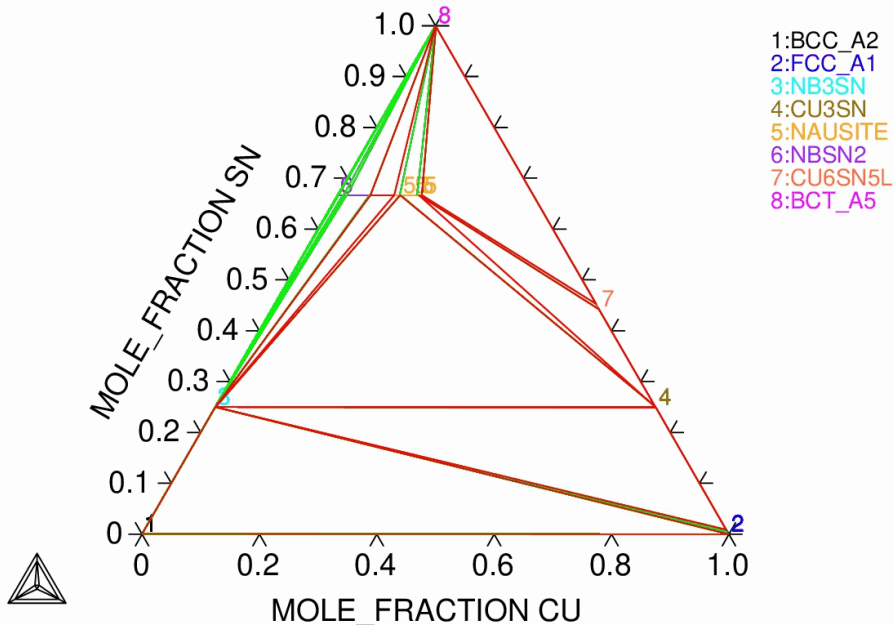
# Basis assessment of phase equilibria

- various samples containing  $\text{NbSn}_2$  and/or nausite
- Further data



# New (public) CALPHAD database Cu-Nb-Sn including nausite (supplemented by DFT calculations)

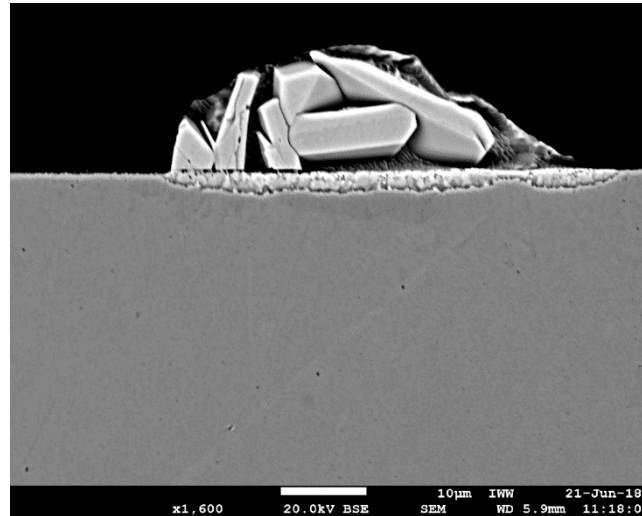
THERMO-CALC (2022.04.19:12.06) :NB-CU-SN at T=373.15 K  
 DATABASE:USER  
 T=373.15, P=1E5, N=1;



Further activities including Ta, Hf;  
 to be published (there is, e.g.  
 (Ta, Cu)Sn<sub>2</sub>)

## Comments on diffusion couple techniques

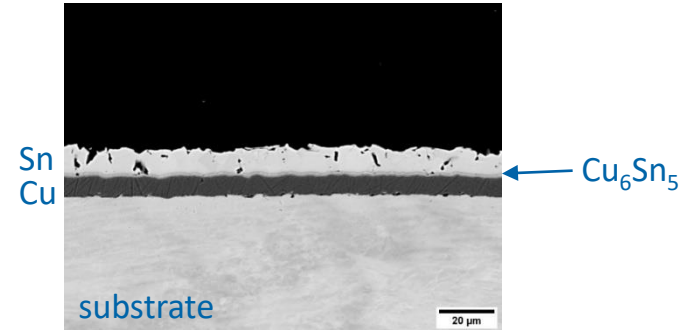
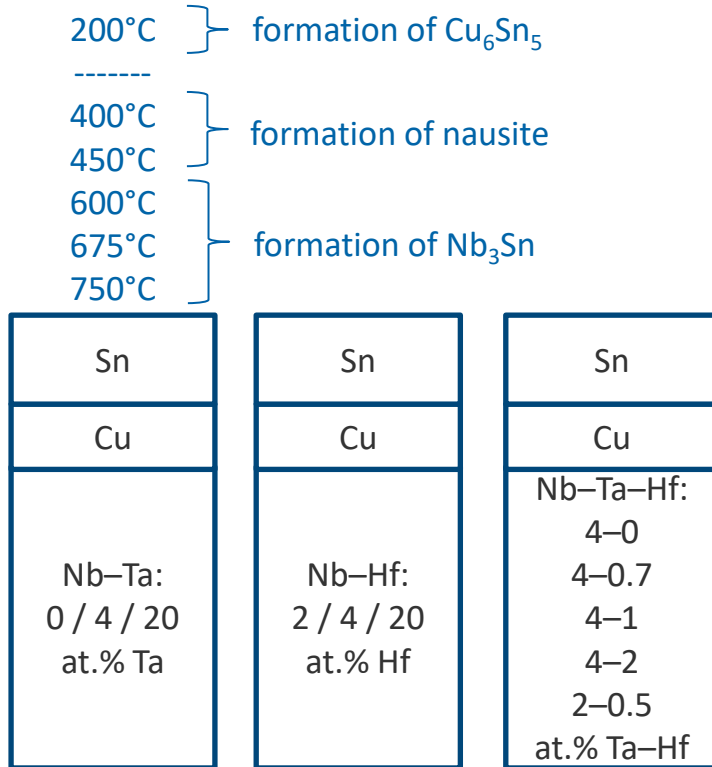
- Access to large-scale microstructures and simplified diffusion geometry
- Fight against unwetting effects in the case of melting
- Learning process for proper design to avoid this



Nb+plated Sn

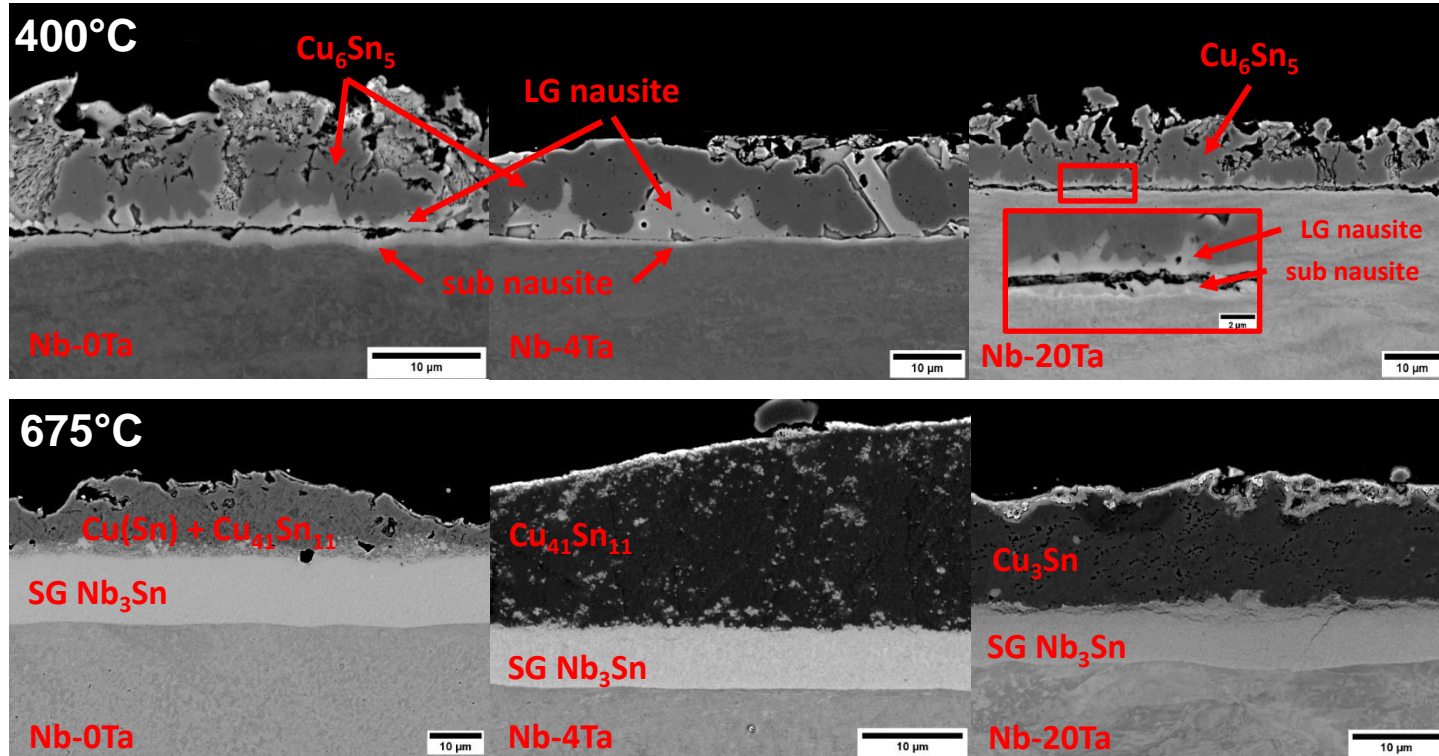
# Influence of elements as Ta, Hf, O on phase formation and microstructure

## Diffusion couple design



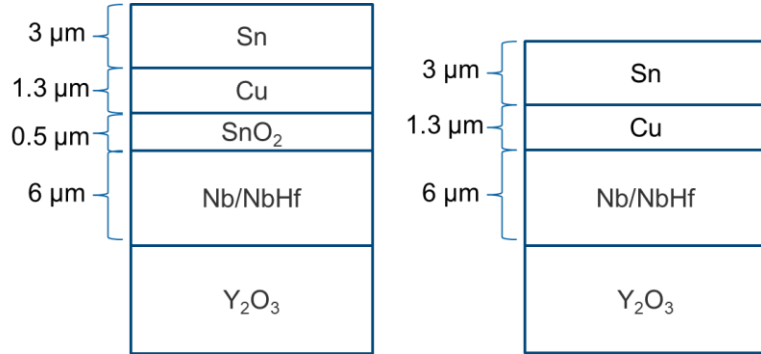
- Nb alloy substrates
- Cu and Sn deposited via PVD
- heat treatment in Ar atmosphere
- quenching in water
- embedding as cross-section

## E.g. investigations on the influence of Ta

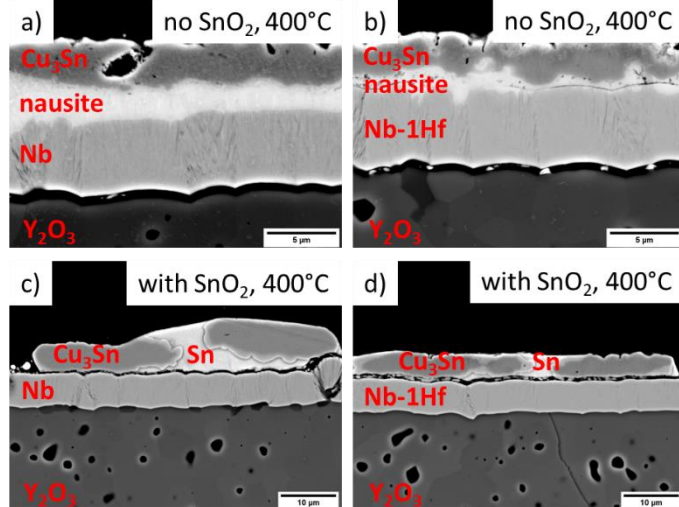


- Ta decreases nausite and  $\text{Nb}_3\text{Sn}$  layer growth

# Effect of O on phase formation and microstructures in the Cu-Nb-Sn-(Ta, Hf) system

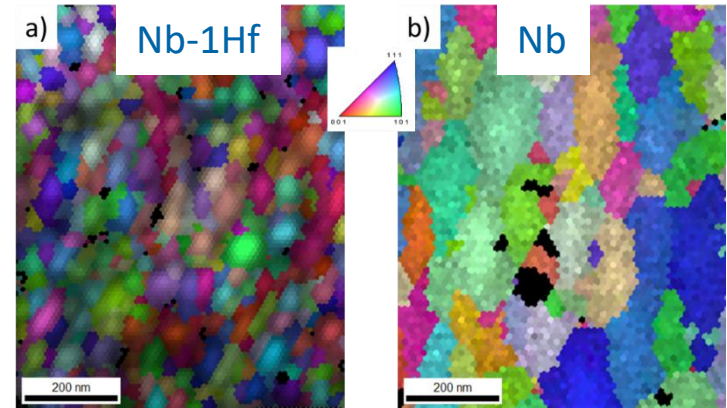


- deposition of Nb/Nb alloy on  $Y_2O_3$  substrate using PVD
- deposition of  $SnO_2$  using magnetron sputtering
- Cu, Sn again using PVD
- heat treatment in Ar atmosphere



→  
675°C

Nb<sub>3</sub>Sn grown from (SnO<sub>2</sub> free)



Nb<sub>3</sub>Sn size not determinable in case of samples with SnO<sub>2</sub>



## Summary

- Better understanding of thermodynamics and kinetics of phase formation
  - (a) CALPHAD description
  - (b) coarse and fine scale versions of  $\text{Nb}_3\text{Sn}$  and of other intermetallic phases
  - (c)  $\text{SnO}_2$  as O source; O is there and reduces grain size. But in particular Hf may have an effect by its own.
- Further development of diffusion couple techniques; further concepts to be tested in the future...?!

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