ON THE FURTHER DEVELOPMENT OF NB_3SN SRF CAVITIES: THE INVESTIGATION OF TA THIN FILMS AS A DIFFUSION BARRIER

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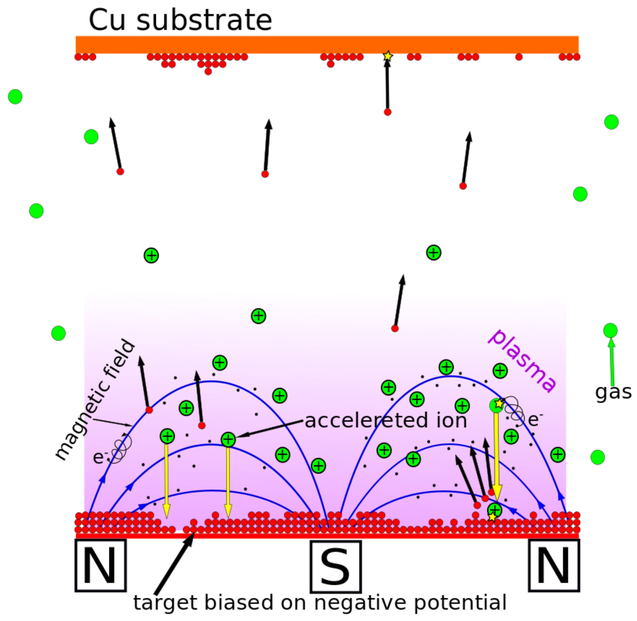
ABSTRACT

The accelerator science has long sought to increase the quality factor of superconducting radio frequency cavities to make the next generation particle accelerators more efficient and economical. Our approach is to use Nb_3Sn in a thin film form grown on Cu. One main advantage of Nb_3Sn is its high critical temperature- twice the one of Nb which is currently used. The challenge of growing Nb_3Sn directly on Cu is multiple and requires the use of a barrier layer in between Nb_3Sn and Cu due to their high miscibility property. In this work, we hence propose Ta as the barrier layer, which we fully investigated prior to the Nb_3Sn sputter deposition. The results will show that Ta is indeed preventing for any Cu inter diffusion, hence allowing a optimal growth of the Nb_3Sn on top.

EXPERIMENT SETUP

MAGNETRON SPUTTERING

- Sputter gas: Ar or Kr [1]
- Power: 200 W
- Coating pressure: 0.001 mbar



COATING PLAN

Plan:

- **Step1**: Sputter Ta on a Cu substrate
- **Step2**: Transform brittle Ta beta-phase into stable alpha-phase by annealing
- **Step3**: Coat Nb_3Sn on top of Ta layer
- **Step4**: Annealing of Nb_3Sn for maintaining superconducting A15 structure

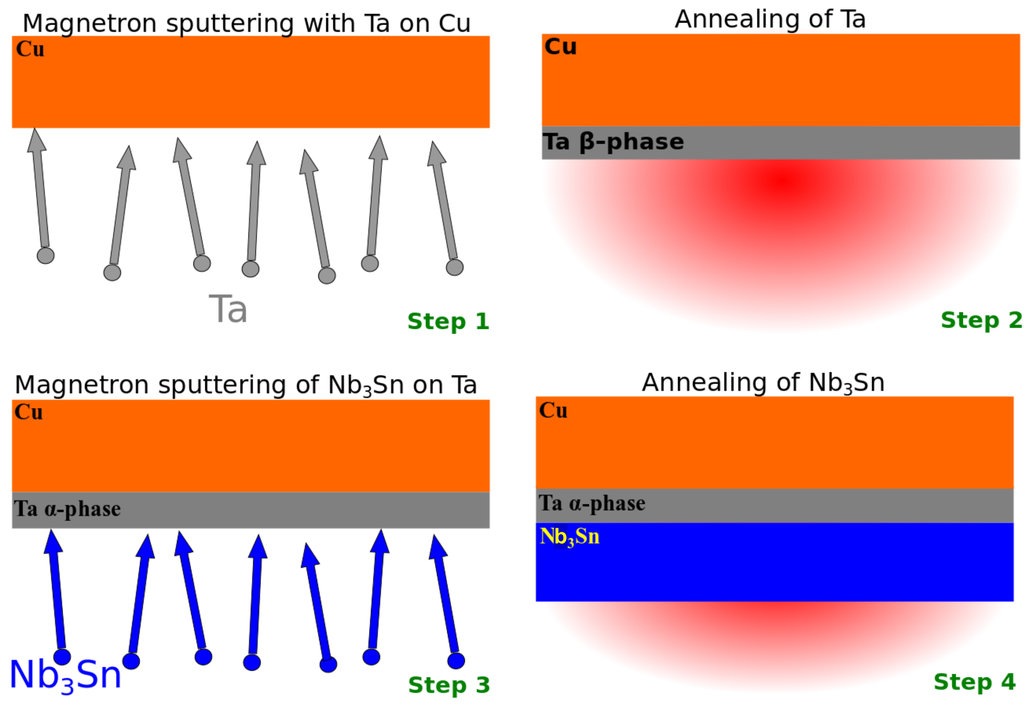
Parameter variation:

Ta film:

- Vary coating gas: Ar or Kr for 10 min
- Temperature: no annealing or at 750°C
- Annealing time: 24 h

Nb_3Sn film:

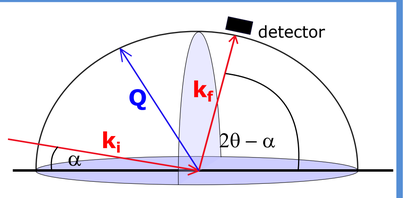
- Coating gas: Kr for 60 min
- Vary annealing temperature: 650°C, 700°C and 750°C
- Annealing time: 24 h

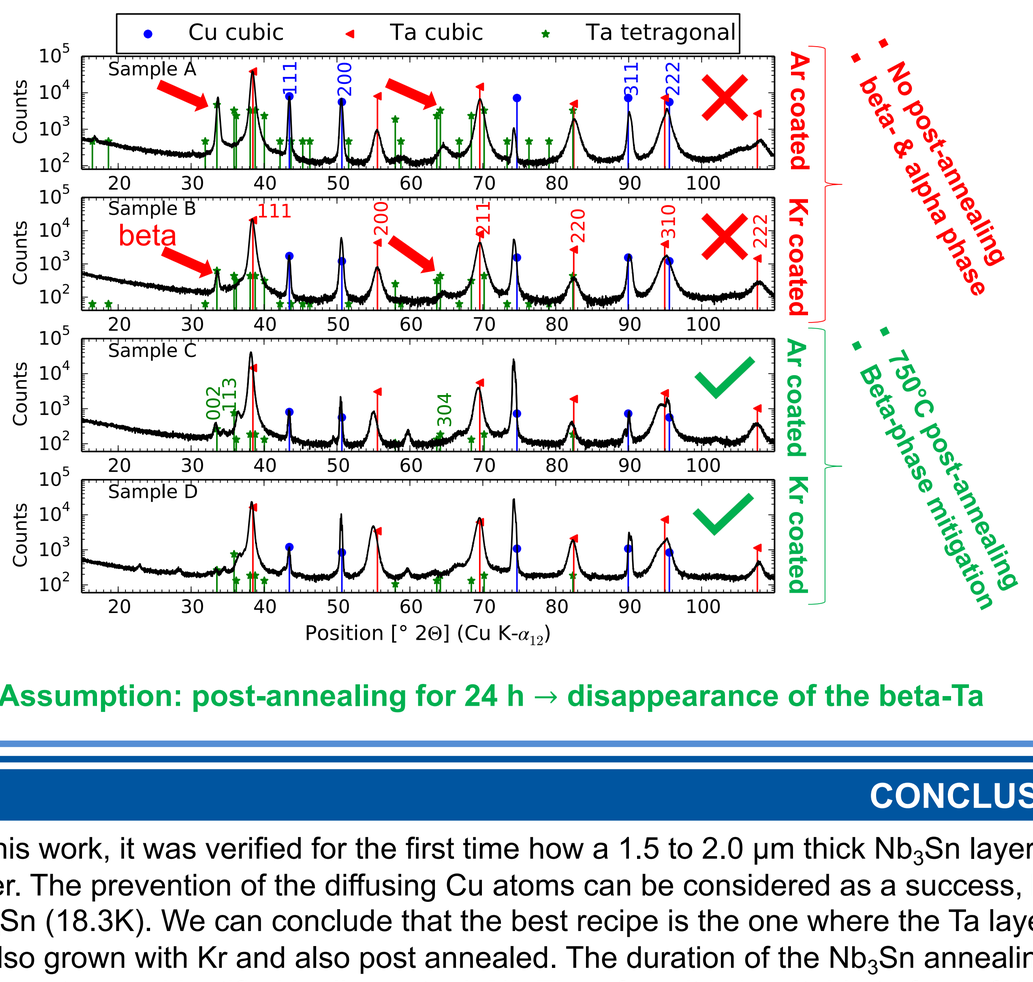


RESULTS

1. GIXRD ANALYZES OF TA LAYERS

- Ta-alpha: cubic, stabile
- Ta-beta: tetragonal, brittle
- Typical XRD can not be used
- Ta thickness 100 nm: Cu background too high
- No Ta signals would be measureable
- Using Gazing Incidence X-ray Diffraction (GIXRD)

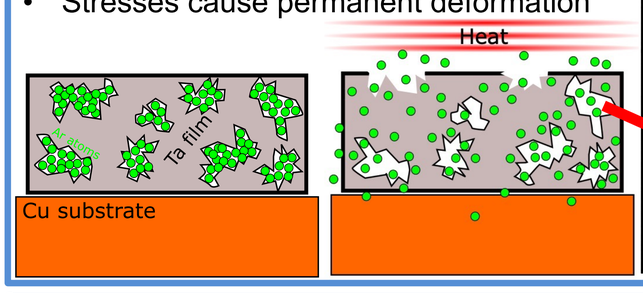


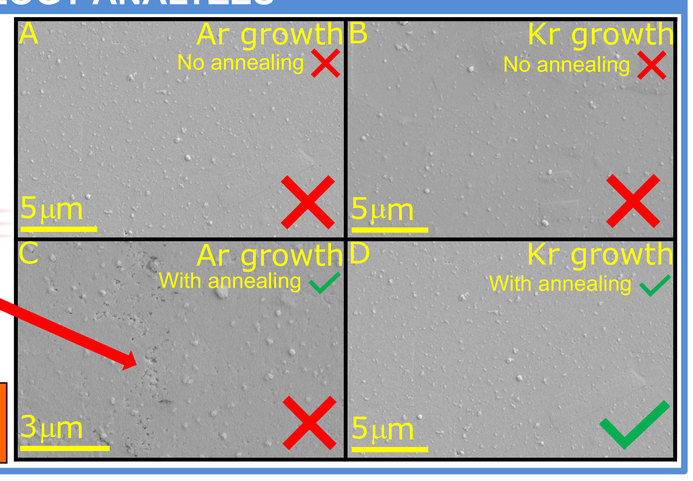


Assumption: post-annealing for 24 h → disappearance of the beta-Ta

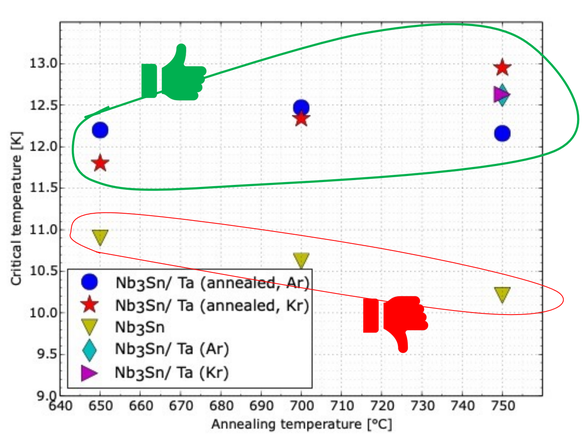
2. MORPHOLOGY ANALYZES

- Incorporation of gas atoms into layer
- It depends on m_{target}/m_{gas} [2]
- Ar accumulates into clusters
- Temperature: gas atoms leave the voids
- Stresses cause permanent deformation





3. Superconducting Properties of Nb_3Sn



Critical temperature measurement: double coil inductive method [3]

With Ta interlayer:

✓ Higher critical temperature of samples with intermediate layer

No Ta interlayer:

× Critical values are lower
× Cu atoms diffuse into Nb_3Sn
× Disturb the sc. A15 crystalline structure

CONCLUSION AND PERSPECTIVES

In this work, it was verified for the first time how a 1.5 to 2.0 µm thick Nb_3Sn layer behaves on a Cu substrate, where the two materials have been separated by an intermediate Ta layer. The prevention of the diffusing Cu atoms can be considered as a success, but the results show that a lot of work and effort is needed to reach the normal critical temperature of Nb_3Sn (18.3K). We can conclude that the best recipe is the one where the Ta layer is grown with Kr and annealed for 24 h in order to reduce the beta-phase. The Nb_3Sn subsequently is also grown with Kr and also post annealed. The duration of the Nb_3Sn annealing processes could be varied in the near future to determine the existence of a changing the critical temperature as identified by Ilyna et. al. [1]. Therefore, it is inevitable to focus future researches on Ta layers to advance the development of SRF cavity technologies with Nb_3Sn.

REFERENCES

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