Precise evaluation of characteristics of the multilayer thin-film superconductor consisting of NbN and Insulator on pure Nb substrate

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Outline

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- Measure
- Experime
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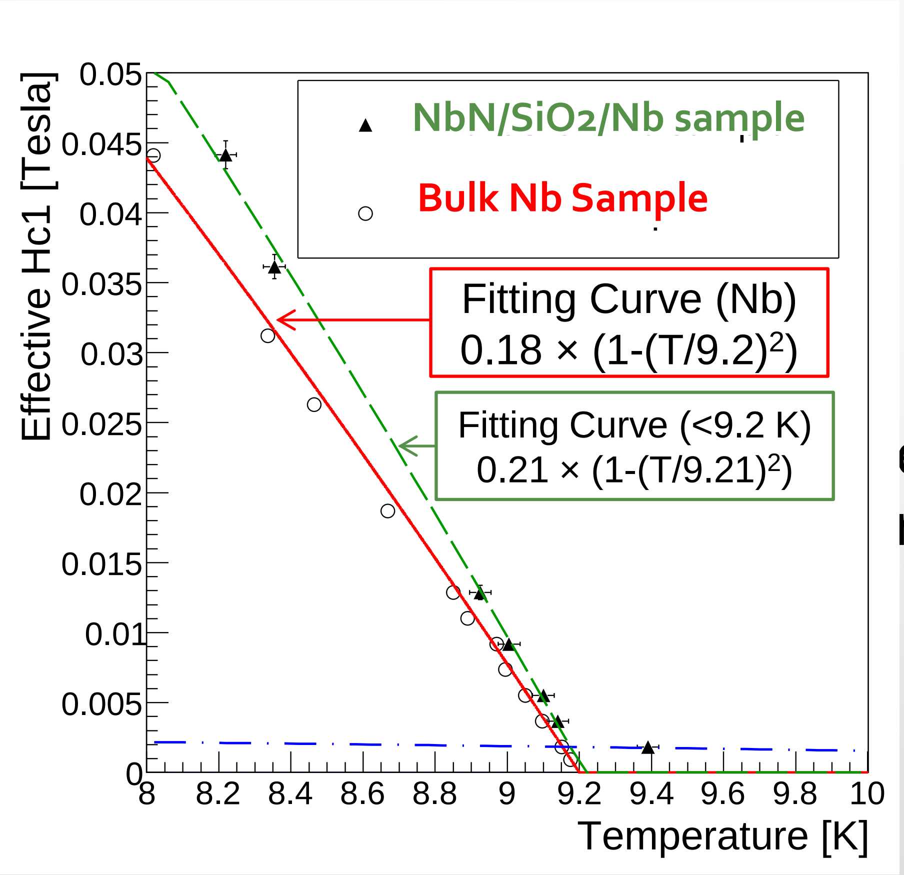
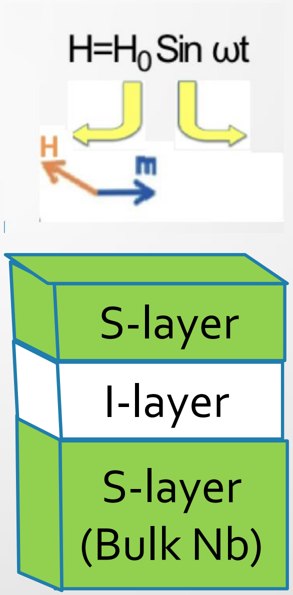


- Summary

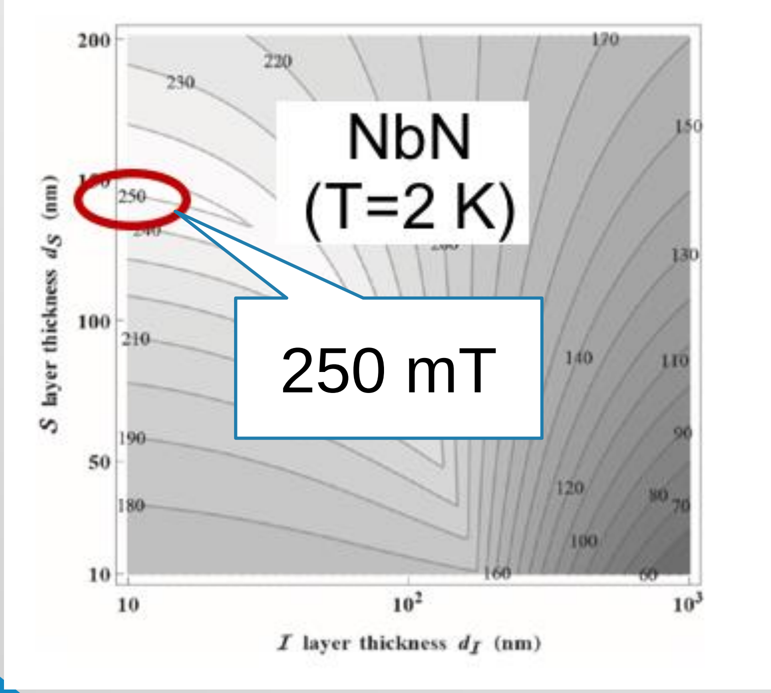
Introduction

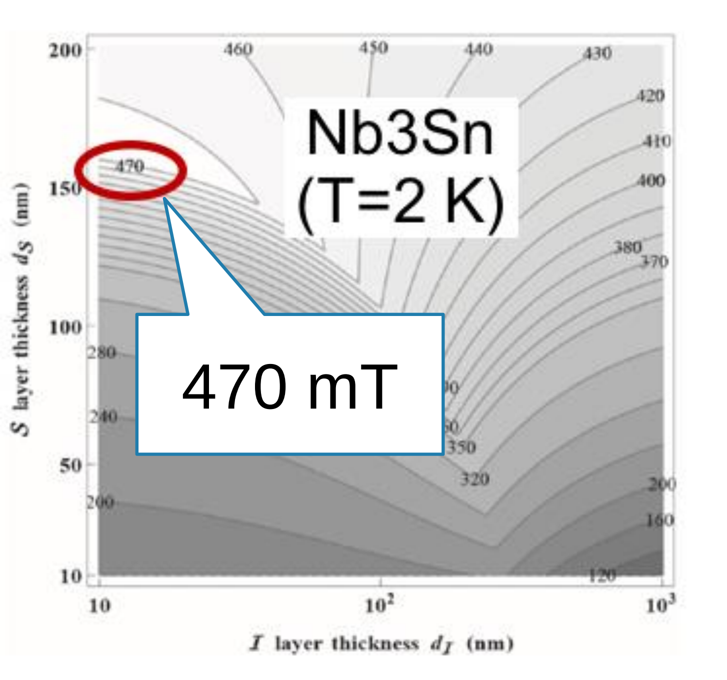
- The maximum accelerating gradient of superconducting cavity is limited by the magnetic field at which vortex avalanche occurs.
    - In this study, we calls such magnetic field as “**effective H_{c1}**”, H_{c1}.
- Recently proposed theory predicts that H_{c1} is pushed up by Superconductor-Insulator-Superconductor structure (**S-I-S structure**).
- In order to verify this scheme, we are trying to make some experiments at Kyoto University.



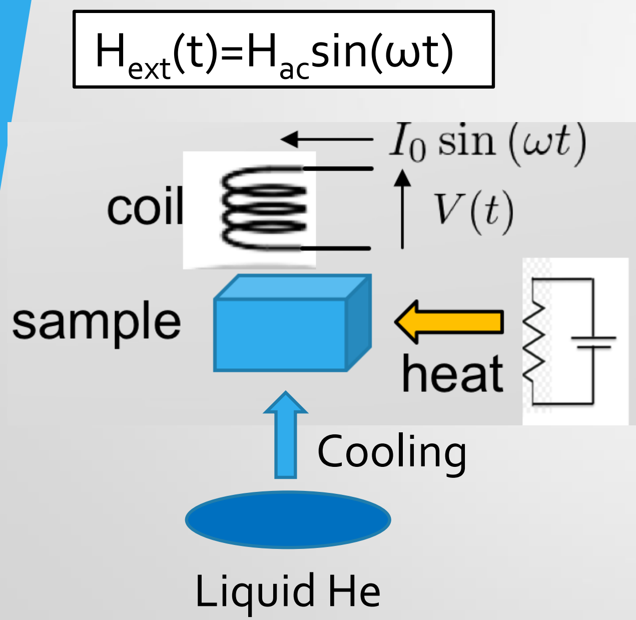
Motivation of this study

- The proposed theory predicts an optimum set of the parameters to exhibit a good performance.
  - The H_{c1} is shown in the following two contour plots.
    - The effective Hc1 of bulk Nb is assumed to be 200 mT.



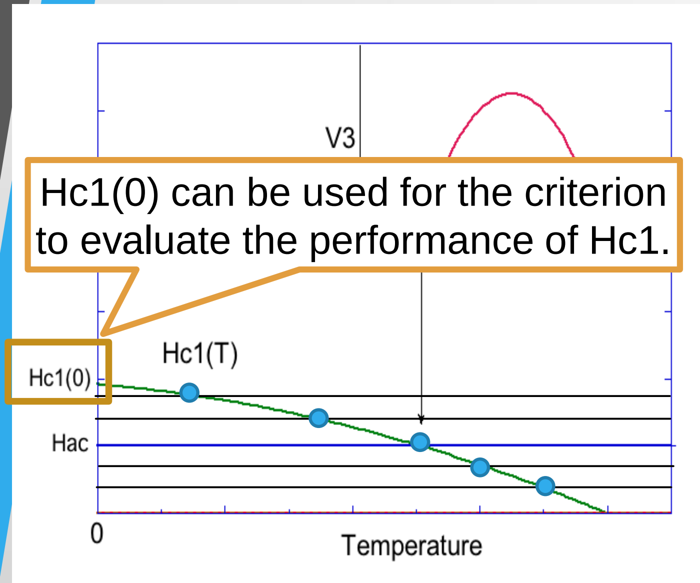


Measurement method



- Schematic diagram of experimental setup is shown in the left figure.
- AC magnetic field $H_{ext}(t)$ is generated by a coil close to a sample.
- Third harmonic voltage $v_3(t) = V_3 \sin(3\omega t)$ induced in the coil is measured.
  - $I_0 \sin(\omega t)$ is the current flowing in the coil.
  - ω is the frequency of a sinusoidal drive current.
- If the temperature of a sample is being raised while H_{ac} is fixed, V_3 suddenly rises when H_{ac} exceeds Hc1 of a sample at a certain temperature.
  → **Can evaluate the temperature dependence of Hc1.**
- In this study, ω=5 kHz is used.
  - **NOTE: it is expected that super heating does not occur in the frequency region.**

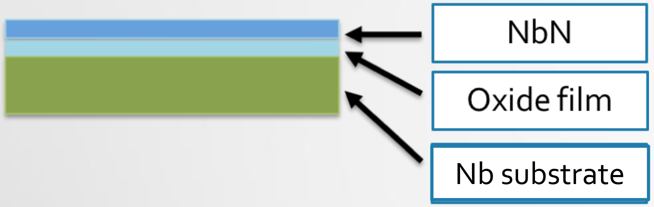
Measurement method

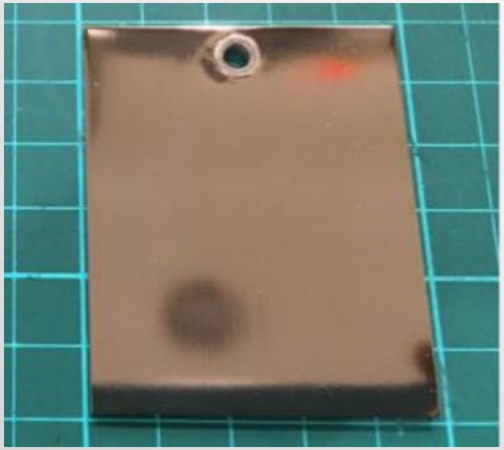


- The H_{c1} at a certain temperature can be determined as left figure.
  - Expected curve:
    - $H_{c1}(T) = H_{c1}(0)\times(1-(T/T_c)^2)$
  - H_{ac} is the amplitude of the AC field.
  - H_{c1} is determined from the cross point.
- By repeating measurements for different combination of H_{ac}, we can clarify the temperature dependence of H_{c1}.

These data points are fitted to the above expected curve.

S-I-S sample used in this study



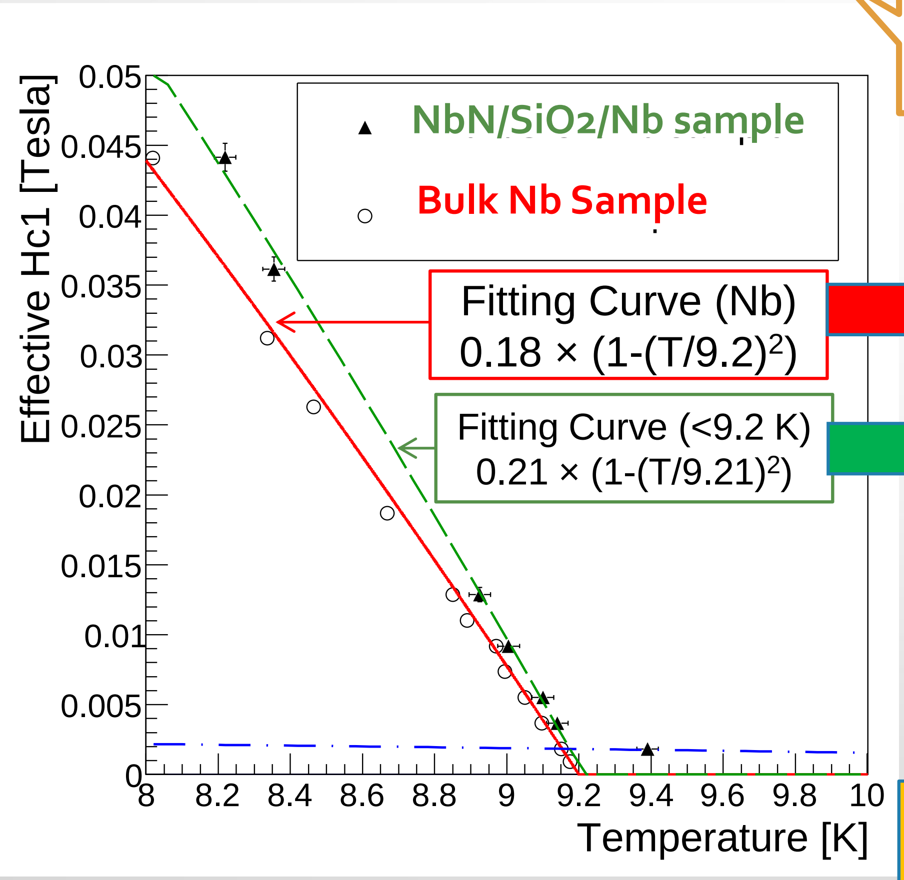


- We prepared S-I-S sample for measuring the effective Hc1.
  - NbN/SiO2(30 nm) thin-film is formed on pure bulk Nb substrate (Left Figure)
    - NbN film thick are 200 nm or 50 nm.
  - This sample is fabricated by ULVAC inc. with DC magnetron sputtering.

Effective Hc1 of S-I-S sample (200 nm)

- Expected curve: $H_{c1}(T) = H_{c1}(0)\times(1-(T/T_c)^2)$

the criterion to evaluate the performance of Hc1.



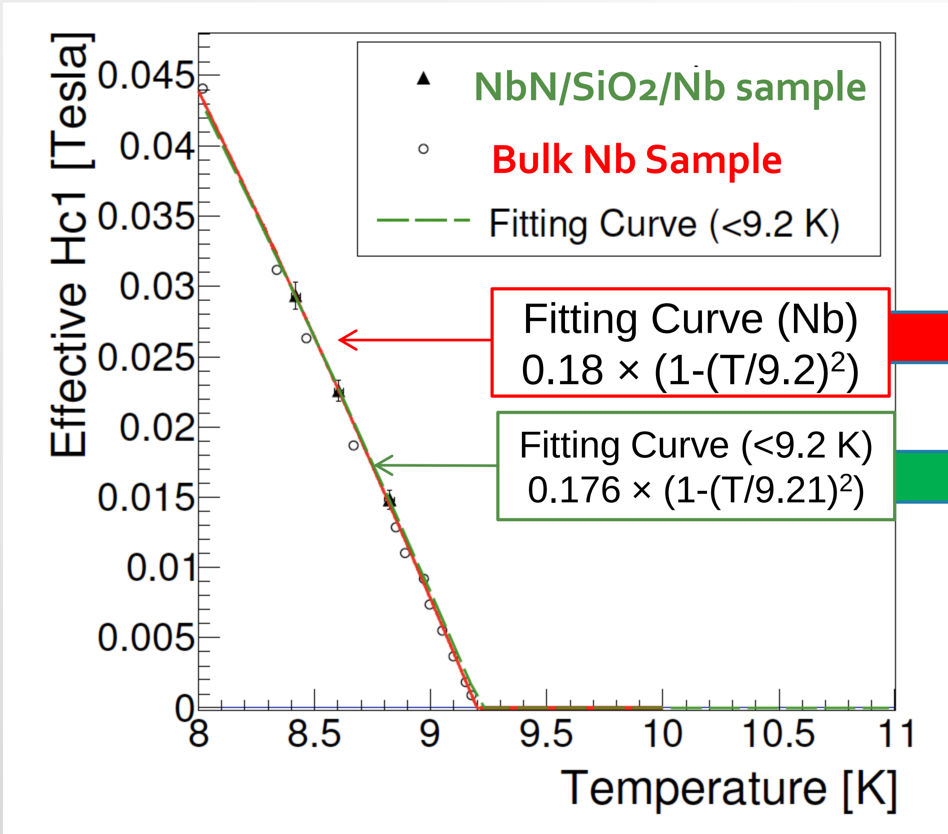
Hc1(0)=180 mT
(pure bulk Nb)

Hc1(0)=210 mT
(S-I-S structure)

Gain Factor:
210/180 ~ 1.17

LINAC18:TUPO030

Effective Hc1 of S-I-S sample (50 nm) (Preliminary)



LINAC18:TUPO030

Hc1(0)=180 mT (pure bulk Nb)

Hc1(0)=176±16 mT (S-I-S structure)

No difference!

The obtained results are qualitatively consistent with the prediction of theory!

Summary

- We evaluated the temperature dependence of effective Hc1 of multi-layer thin-film sample that consists of NbN superconducting layer and SiO_2 insulating layer formed on pure bulk Nb.
- The measurement result clearly showed that the effective Hc1 of pure bulk Nb improved after NbN/SiO_2 film coating, whereas effective Hc1 changed depending on the film thickness.
- **We could successfully demonstrate that the S-I-S structure can improve the effective Hc1 by 17 %.**