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Design And Construction of Nb₃Sn Vapor Diffusion Coating System at KEK

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Introduction

[1] S. Posen et. al. Supercond. Sci. Technol. 34 (2021) 025007 (10pp)

- \blacktriangleright Nb₃Sn cavity : smaller heat load at 4.2 K & higher efficiency than Nb cavity
 - > Possible to operate at 4.2 K using a cryocooler
- \blacktriangleright Nb₃Sn coating method for the cavity : Vapor diffusion
 - \succ Best cavity performance at present.
 - ➢ Q0 = 3.0 × 10¹⁰ (at low field, 4.2 K), Eacc max = 22.5 MV/m [1]
- \blacktriangleright Nb₃Sn cavity R&D was started at KEK.
 - To realize a Nb₃Sn cavity cryomodules with the cryocooler
 - Constructed the coating system for development of Nb₃Sn coating cavities

Requirement for Nb₃Sn Coating System

- \succ Nb₃Sn coating temperature by vapor diffusion
 - Coating temperature : around 1100°C
 - > Avoid the growth of Nb-Sn compound
 - \succ formed Nb₃Sn when tin composition ratio 17-25 at%



- Cleanliness inside of the coating system
- \succ Impurities are possible to degrade the cavity performance
 - > To prevent contamination from coating chamber

⇒Need to prepare coating chamber made of Nb

- \succ To prevent contamination outside of the system. ⇒Need to build clean booth
- \succ Condition for uniform coating
 - > The mean free path of the tin needs to be short

⇒Need to install additional heater for tin crucible

Design of Nb₃Sn Coating System

Furnace

- > Operation temperature : **100°C** ~ **1200°C** (\pm 10 °C)
- Vacuum pressure

 $: < 1 \times 10^{-4}$ Pa (RT) < 1 × 10⁻² Pa (600°C) < 1 × 10⁻¹ Pa (1200°C)

Coating Chamber

 \succ Material : Nb (ASTM commercial grade) Inner size : Φ 305 [mm] \times 2272 [mm] (Cavity) + Φ 30 [mm] \times 80 [mm] (Tin crucible) > Vacuum pressure : < 1 \times 10⁻⁵ Pa (RT, after baking) < 1 × 10⁻⁴ Pa (Coating process)





- Tin heater
 - Maximum temperature : 1500°C
- \succ Tin crucible & Tin chloride crucible
 - Material : tungsten
- Clean booth
- Class 3, 2m in height, 1m in width, and 4m in length

Mo heater Inside of furnace





Fig.5Tin heater

Commissioning of Furnace

 \succ After constructing, stand-alone test was performed.

- ➢ Furnace
 - ➢ 500°C for 4.5 hours : Nucleation
 - > 1100°C for 3 hours : Coating, Annealing
- > Tin heater
 - > 1300°C for 1.5 hours : Coating
- Vacuum pressure of the coating chanber was less than 1×10^{-4}
- > The coating system is possible to coat Nb₃Sn film

Summary and Outlook

- At KEK, Nb₃Sn coating system was constructed.
- \succ Consists of the furnace, the Nb coating chamber, and the tin crucible heater.









 \succ Tin crucible heater : 1100°C for 1.5 hours





