Electrochemical deposition of Nb_3Sn on the surface of copper substrates

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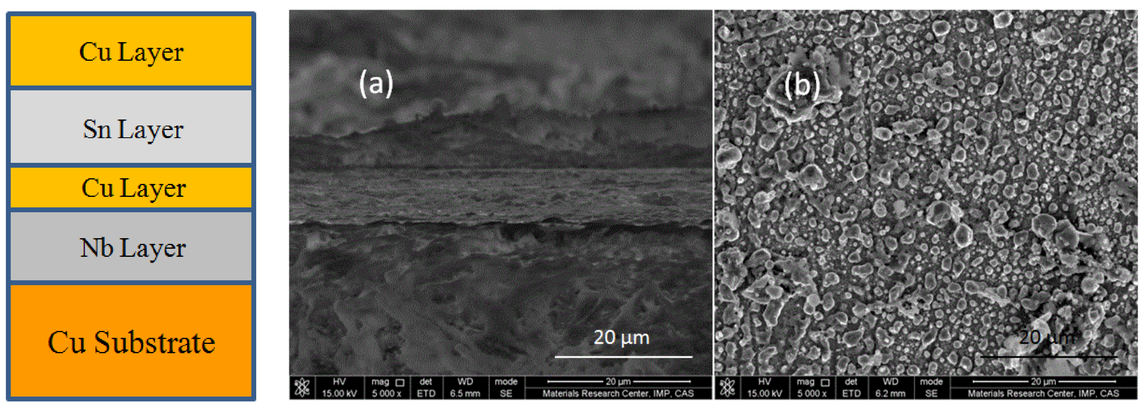
ABSTRACT

Coating superconducting Nb_3Sn thin film on the inner surface of a superconducting RF cavity is one of the most promising approaches to improve the performance of the accelerating cavity. In addition, depositing Nb_3Sn on Cu cavities can further benefit from copper cavities' high thermal conductivity and mechanical stability. In this paper, a new method including multi-layer electroplating and heat treatment is used to deposit Nb_3Sn thin film on top of copper substrates. Important growth parameters, e.g. electrical current density, layer thickness ratio, and annealing temperature are studied. The morphology of the film surfaces was observed by scanning electron microscope (SEM) and the structure of the film was analyzed by X-ray diffraction (XRD). The results showed that a flat and uniform Nb_3Sn layer on copper can be obtained, and the thickness is about 7 μm.

Preprocessing and SEM Results

- The copper sheet is electropolished, then soaked in diluted acid, and washed with deionized water and soaked in anhydrous ethanol.
- A layer of niobium was deposited on the surface by magnetron sputter, with a thick-ness of about 3 microns and a time of 170 minutes.
- The SEM showed an average Nb_3Sn film thickness of $7.0 \pm 0.5\mu m$.



Final sample design (a) SEM image of section (b) SEM image of surface

Electro-deposition of Cu and Sn Layers

- ✓ An aqueous solution of pyrophosphate-based electrolyte for both copper seed layer and copper barrier layer.
- ✓ The temperature of two layers of copper plating is room temperature (about 24℃).
- ✓ The current density is 40mA/cm², but the plating time is 0.5 minutes, the latter is 3 minutes. The PH value is 8.0~8.8.
- ✓ The electrodeposition of tin was performed using a sulphate-based electrolyte at 40 mA/cm².
- ✓ Electrolytes are all analytical grade chemicals and deionized water, the magnetic stirring rate is 200r/min.

Chemicals	Concentration (g/l)
$Cu_2P_2O_7$	20
$NaNO_3$	5
$Na_4P_2O_7$	175
$C_6H_{17}N_3O_7$	15

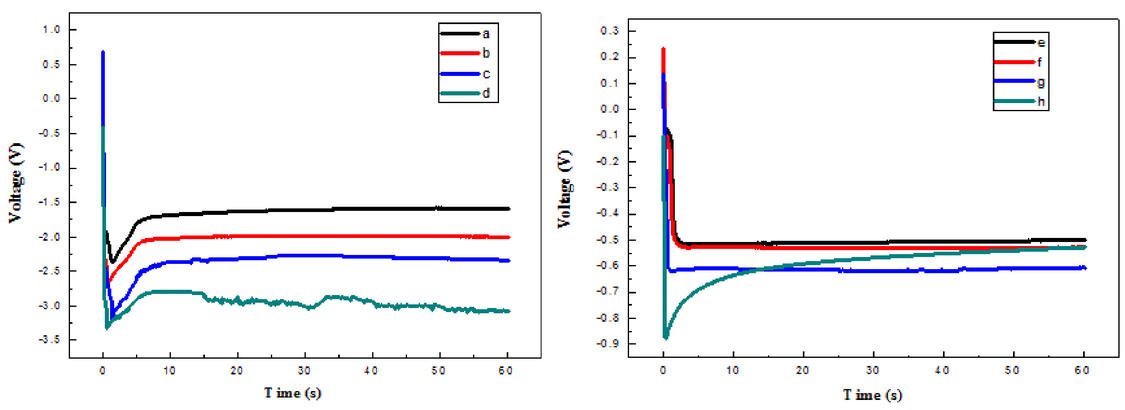
Composition used for the deposition of the copper layer

Chemicals	Concentration (g/l)
Sn_2SO_4	25
H_2SO_4	50ml/l
$C_4H_6O_6$	12
$C_4H_8O_6$	1.5

Composition used for the deposition of the tin layer

Constant Current V-T Curve

- The *constant current V-T curve* of niobium electrode in pyrophosphate copper/tin plating solution.
- When the current is 40 mA/cm², the activation degree of the Cu/Sn substrate is higher and electroplating uniformity is the best.



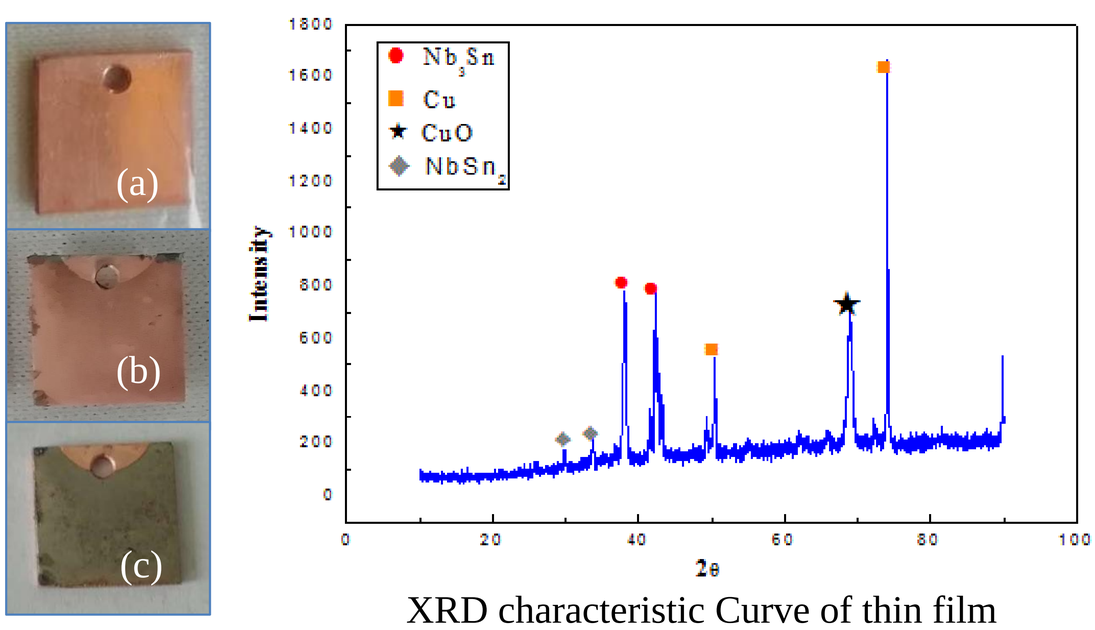
The constant current V-T curve* of niobium electrode

The constant current V-T curve* of copper electrode

**Curve a(e), b(f), c(g), d(h) represents 20,30,40 and 50mA/cm² respectively.*

Characterization of Nb_3Sn Samples

- ✓ XRD using a Rigaku D/max-2400 instrument was performed in the 2θ angular range of 10–90° .
- ✓ The XRD pattern shows the reflection of a crystalline cubic Nb_3Sn phase (A15 structure).
- ✓ Other reflections can be attributed to $NbSn_2$, and CuO. In particular, cubic Nb_3Sn having strong (211) preferred orientation (P.O.).



XRD characteristic Curve of thin film

(a) Cu substrate (b) After electrodeposition (c) After heat treatment

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