Superconducting coatings synthetized by CVD / PECVD for SRF cavities

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Bulk niobium cavities are widely employed in particle accelerators to create high accelerating gradient despite their high material and operation cost. In order to reduce this cost, thin layer of niobium are deposited on a copper cavity which has lower material cost with higher availability and higher thermal conductivity. Cavities currently are coated by PVD method which suffers from lack of conformity. Chemical vapour deposition (CVD) allows to deposit film in geometrically complicated volumes.

IS IT POSSIBLE TO DEPOSIT A SUPERCONDUCTIVE LAYER OF NIOBIUM WITH CVD?

Chemical vapour deposition
Two or more chemicals react in a heated chamber, leaving the reaction product on the substrate.

Niobium Pentachloride (V)
• Reacts with H\(^+\) to create thin film of Nb
• Crystalline solid, vapour pressure at 95 – 110 °C
• Requires high substrate temperature to reduce Cl contamination in the film (at least 500 °C)

Deposition Rig
• In-house assembled system
• Vacuum: 10\(^{-6}\) mbar of base pressure
• Plasma source
• \(T_{\text{Sample Max}} = 800 \, ^\circ\text{C}\)

Residual resistivity ratio
Thin film resistivity difficult to measure on copper samples!!!

RRR measurements:
Plasma enhanced CVD: 9 and \(T_c = 9.4 \, \text{K}\)

Thickness measurements
The sample has been sliced via Focused Ion Beam (FIB), to analyze the structure of the deposited layer (D).

Glancing angle X-ray diffraction
• Used to study the crystalline structure of thin samples
• Niobium peaks verified, with a (110) preferred orientation
• Copper substrate diffraction peaks still present (F) due to the very thin nature of the film

Conclusions
We successfully deposited superconductive thin films of metallic polycrystalline Nb via PECVD with RRR of 9 and \(T_c = 9.4 \, \text{K}\). Preliminary results of NbN has been also shown. We achieved a starting point for Atomic Layer Deposition (ALD) studies of superconductive films for RF cavities.

Future plans
• RF performance tests
• Synthesis of Nb-based compounds (NbN, NbTiN) using NbCl\(_5\) with Ammonia, TiCl\(_4\) and metalorganics
• Deposit multilayered devices via ALD

Glancing angle X-ray diffraction

Niobium Pentachloride (V)

Film deposited on copper coupon 5 cm of diameter

Scanning electron microscopy (SEM)
SEM images show that the substrate surface is well covered by the deposited film (A – B – C).

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Glancing angle X-ray diffraction

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