A.6: Tantalum-impurity contents in Niobium materials and their possible effect on the performance of Superconducting Radio Frequency (SCRF) cavities

The high energy (1 GeV) proton linac for the future Indian Spallation Neutron Source will be based on Superconducting Radio Frequency (SCRF) cavity technology. The type-II superconductor Niobium (Nb) in its highly pure form is currently the material of choice all over the world for the fabrication of such SCRF cavities. The purity of Nb materials for cavity fabrications is specified by the residual resistivity ratio (RRR) of the material, and currently the acceptable degree of purity is RRR > 300.

Tantalum (Ta) is found in the highest concentration amongst the metallic impurities in Nb and considerable amount of technical resources and expenditure are involved in refining Nb-materials to the low level of Ta purity. The correlation of the RRR values of SCRF Nb-materials with the contents of Ta impurity is not very straight forward. It is also to be noted that the high RRR value while ensuring good thermal conductivity required for reducing the thermal instability problem in the SCRF cavities, does not, however, give any clue to the very important parameter of peak magnetic field H_{Peak}, which is linked to a rapid drop in the SCRF cavity quality factor (Q-drop) without any field emission.

To address to the question on the tolerable level of Ta-impurity in Nb, we present here a study of the superconducting properties of Nb materials that have been used earlier in the fabrication of SCRF cavities. Ta and other trace impurity contents of these Nb materials are determined using *Indus-2 synchrotron based X-ray fluorescence (XRF) spectroscopy beam line BL-16* at RRCAT. BL-16 is a bending-magnet-based beamline and has an acceptance of ~ 1 mrad (h) × 0.5~mrad (v). It works over the 4-20 keV photon energy range. The 1.5 mm^3 cube shaped fine grain (average 50 micron grain size) Nb samples with different Ta-impurity contents used in this study were obtained from the original 2.8~mm thick sheets. They were subjected to the buffered chemical polishing (BCP) (as is employed in the chemical processing of SCRF cavities), and that was followed by annealing at 600°C for 10 hrs, and then baking at 120°C for 10 hrs. The detection of the trace impurity elements on all the six faces of these cube shaped Nb samples gives a gross idea on the inhomogeneity (if any) of distribution of such trace elements in these Nb samples. Fig. A.6.1 presents XRF spectra of three Nb samples with different amount of Ta-impurities, and Table A.6.1 presents the estimated Ta impurity contents in these Nb materials.

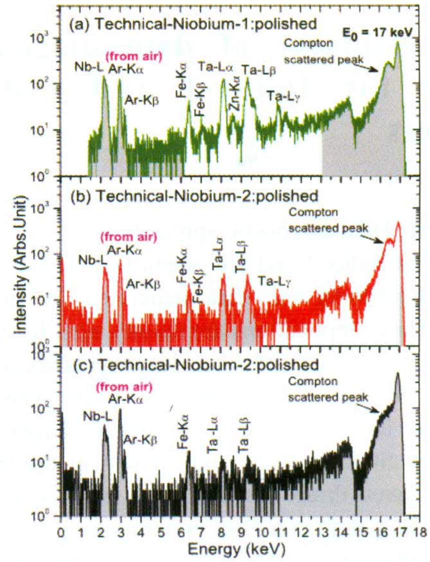

Fig. A.6.1: XRF spectra of chemical polished Nb materials with different amount of trace impurities.

The superconducting transition temperature T_C, the critical magnetic field H_P at which magnetic flux-lines start penetrating the superconducting material and upper critical field H_{C2} of Nb samples are measured using the technique of high resolution magnetometery. The measured superconducting parameters are presented in Table 1.

Table 1. Superconducting parameters of Nb materials with different amount of Ta-impurities. P stands for pristine or as received materials and C for chemically polished materials.

Sample	Ta-content (ppm)	T_C at 100 Oe (K)	H_P (Oe)	H_{C2} (Oe)
Technical-niobium-1P	1339 ± 36	9.18	1700	4150
Technical-niobium-2P	802 ± 80	9.18	1600	4125
Technical-niobium-3P	243 ± 10	9.2	1600	4090
Technical-niobium-1CT	1285 ± 35	9.05	1150	3930
Technical-niobium-2CT	684 ± 54	9.05	1290	3735
Technical-niobium-3CT	149 ± 11	9.06	1350	3820

It is observed that Ta- impurity content even up to 1300 wtppm does not significantly affect the superconducting properties of the Nb materials. This result is consistent with the earlier SCRF cavity test results performed at Jefferson Laboratory, USA indicating no significant dependence of the SCRF cavity performance on Ta concentration. These observations suggest that a less refined Nb material may be deployable for SCRF cavity applications, provided the inclusions of the impurity materials do not substantially influence the surface conductivity of Niobium. The usage of moderately refined Niobium will significantly reduce the cost of SCRF cavity.

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