THE
INFN-CERN
COLLABORATION
ON
RF SUPERCONDUCTIVITY

AN
OVERVIEW
ON THE
MAIN ACTIVITIES
OF THE COLLABORATION

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CEBAF, October 4,1993

INTRODUCTION

The INFN -CERN Collaboration is granted by INFN under the "Special Project on RF Superconductivity".

The aim of the project is the development of the technology of Superconducting Accelerators to study alternate materials to the niobium for producing high field low loss accelerating cavities for application to the next Superconducting accelerators.

In that effort we planned also the systematic investigation of the properties of Niobium based cavities to asses the maximum achievable fields.

The starting point of the project was an attempt to put together different INFN labs already active in the fields, (GENOA, LEGNARO, NAPLES) the CERN group of the MT-SM division, and two laboratories of the Italian National Council for Research CNR having good expertise and the Technical capability for production, characterisation and analysis of superconducting materials.

The main activities of our collaboration are:

Production of high quality SC RF cavities both using bulk and thin film materials.

Understanding of the field limitation and non OHMIC losses in niobium and niobium based compound cavities (Bulk or thin films).

Investigation of the RF properties of promising superconducting binary alloys.

BASIC IDEAS.

The starting point of our investigations in the field comes out from the Mattis and Bardeen Formulae for the RF impedance of a Superconductor [1]. This theory, developed for superconductors in the anomalous limit, was proven to be still true for superconductors in the local limit when the penetration depth λ is large compared to the coherence length ξ_o of the material.[2].

In the limit of the theory the surface impedance of a superconductor can be written as

$$\frac{Zs}{Zn} = 1 / \sqrt{\frac{\sigma_1 - j\sigma_2}{\sigma_n}} \qquad Zn = \sqrt{\frac{\omega\mu}{\sigma_n}}$$

Where σ_1/σ_n and σ_2/σ_n are given by the integrals of the BCS theory as fund by Mattis and Bardeen and σ_n is the bulk conductivity of the normal metal at the transition.

Because the previous condition still holds for all the metallic superconducting compounds with T_c in the range 9-20 K, a new promising material for RF applications will be an alloy or intermetallic composite with High Tc and low Z_n.

This means that we will restrict our investigations to superconductors with Tc in the range 10-20 K and a bulk resistivity at the transition as low as possible.

Now high Tc intermetallic composites have usually at room temperature a quite high bulk resistivity in the 50-100 μΩ/cm range , to be compared with the bulk resistivity of 13 μΩ /cm of the niobium.

Moreover the ratio between the bulk resistivity of the compounds at room temperature and just before the transition is few units at the best.

The above consideration implies that taking into account the temperature dependence of the surface resistance of a superconductor; and assuming a reduced gap width Δ=2kTc we need a transition temperature of at least 16 K to get a substantial improvement over the Niobium.

Furthermore we need to have materials that can be produced by sputtering or thermal reaction in furnace, easy to process, radiation resistant and eventually having an high thermal conductivity.

All the listed requirements need to be blended to give us the possibility of produce and test a technologically feasible accelerating cavity.

GENOA

The activities of the Genoa group are mainly oriented to the studies and the production of niobium based superconducting composites by thermal diffusion in a UHV Furnace.

The Chemical and physical properties of the composite are first measures by the standard measurement of the resistive transition, the measurement of the real and imaginary part of the AC magnetic susceptibility to get information about the amount , if any, of unwanted low Tc phases on the surface, ESCA and X-Rays diffraction to get further information about the stochoimetry and the crystallographic parameters of the surface.

Once obtained a promising material in a controlled and reproducible way we start the investigation of the RF properties by using a TE_{011} cavity with a removable bottom.

The information we get in those measurements allows us to compare the low frequency measurements with the RF characteristics of the material and are used to improve up to the limit of our measurement system, the quality of the superconductor by improving the reaction parameters.

A best fit of the measured data with the theoretical surface resistance as numerically computed by using the Halbritter's code gives us the relevant parameters of the superconducting material Tc , reduced gap width, coherence length, field penetration, mean free path; and obviously the residual surface resistance.

Typical results for Niobium; Niobium Nitride and Nb_3Sn are shown on figure two and three.

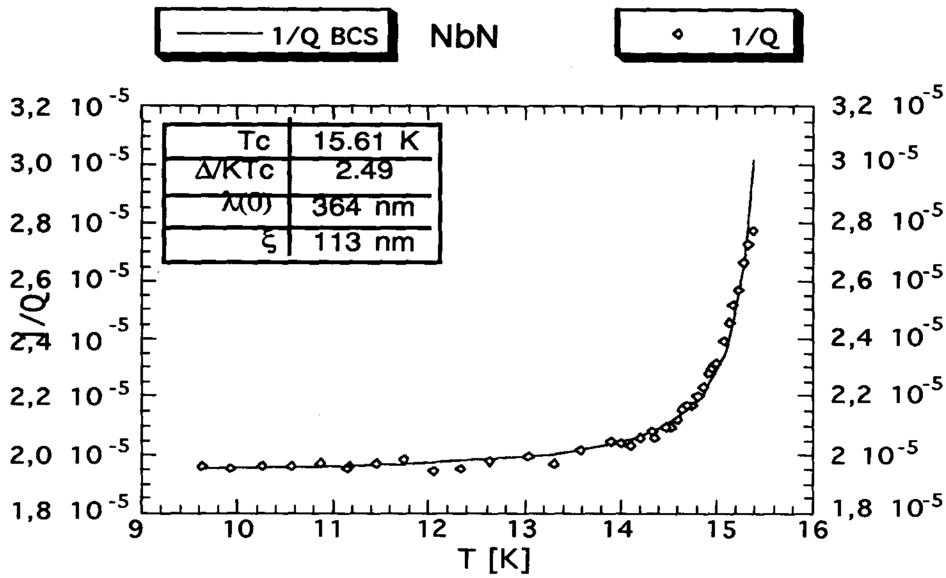

Figure 2. Surface resistance , measured and computed for NbN

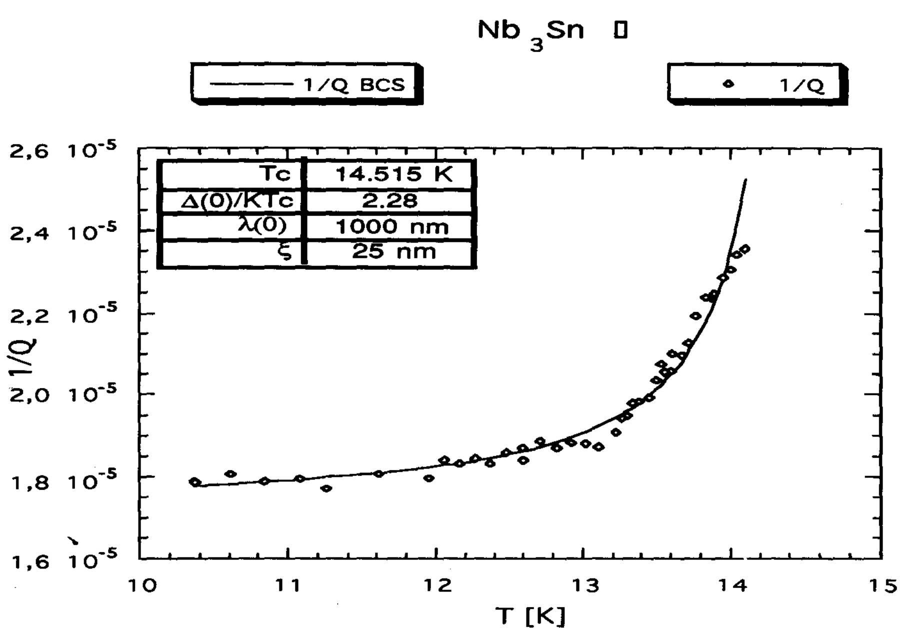

Figure 3. Surface resistance measured and computed of Nb3Sn

A Second field of investigation is the understanding of the maximum achievable field in niobium cavities trying to get information's about the influence of the surface treatment and to understand whether the limitations on the maximum accelerating fields are frequency dependent or not.

Three series of omothetic cavities operating at 3, and 4.5 GHz are currently under test to check the aforementioned effects; data are taken also at 1.5 GHz on a cavity Given Us by the Scaly group.

A Typical plot of Q versus accelerating field is reported in figure 4.

4.5 GHZ CAVITY BABCKOK-WILKOX

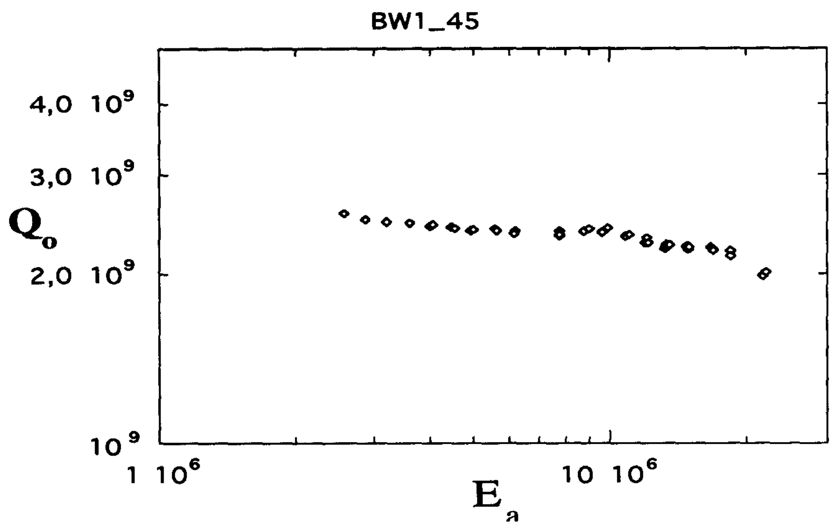

Fig. 4. Typical Qo versus accelerating field for a 4.5 GHz cavity

INFN Legnaro

The Legnaro Team is working to develop the sputtering of High frequency cavities using the already gained experience in the sputtering of quarter Wave cavities for the In house project of the ALPI booster for the Legnaro Heavy Ion Tandem

The group is now vigorously tackling the problem of the sputtering production of 1.5 GHz cavities

To do that a new spinning method for production of seamless cavities was successfully developed and tested.

Second a magnetron sputtering configuration suitable for 1.5 GHz cavity production was designed and tested;

Third a fully computer controlled Rf and cryogenic test set for High precision automatic test of 1.5 and 3GHz cavities.

INFN Naples-Salerno

The Naples Salerno group acts as the leader group for the investigation of new promising superconducting materials niobium based or not.

The group takes advantage from the twenty year experience gained in the production of thin film superconducting devices on different substrates to quickly test small samples of superconductors by magnetron sputtering reactive or not.

Beside measuring the Dc and low frequency AC characteristics of the superconductors the group uses a fast method for the RF characterisation of the produced films by using a ring resonator

The Qo values as function of the temperature as well as the resonant frequency is recorded [3] and analysed to get full information about the superconductor's parameters

The comparison with the theory confirms the method's validity [4] .

CNR -ITM

The CNR-ITM lab in Milan produces the base superconductors to be used by the different partners of the collaboration to build cavities or cathodes for sputtering.

The ITM lab works since thirty years in the field of characterisation, production and metallurgical development of special non ferrous materials including superconducting alloys

The lab can use its own facilities including some medium size electron beam and inert gas arc furnaces, to produce superconducting alloys with the composition we want to obtain the best results from the sputtering or the reactive diffusion.

The ITM lab provides also a first characterisation of the superconductor measuring the Transition temperature both resistive and inductive together with a full analysis of the crystallographic properties.

CNR-LAMEL

The CNR lab in Bologna is the SEM and TEM analysis centre for the study of the sputtered surfaces to understand the morphology of the growing superconducting layer and the influence of the substrate on the film growth.

The LAMEL lab also works actively on the possibility of in situ annealing of films and cavity surface by using high power laser pulses to recover local defects .

Preliminary computer simulations were used to obtain a reasonable set of parameters for the laser pulse.

X ray diffraction, after In situ treatments of the niobium film, has shown a full annealing of the niobium and releasing of the mechanical stresses induced in the deposition process; these observations are confirmed by SEM and TEM analysis of the samples and by the increased RRR of laser annealed films.

CERN MT-SM

The group at CERN MT-SM is actively pursuing the goal of producing NbN cavities at 1.5 and 3 GHz by reactive sputtering and thermal reactive diffusion.

To achieve that goal the group is using the experience gained for the production of the 353 MHz LEP cavities.

The group is actively studying the effect of the substrate processing on the superconducting film quality.

The Samples are characterised mainly by measurement of the RRR, together with SEM and AUGER analysis.

Last a test bench for the measurement of the produced cavities is ready for the first tests.

REFERENCES

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[4] C.Attanasio et al. Phis Rew.B, 43, 6128, (1991)