OF THE «RF SUPERCONDUCTIVITY FOR ACCELERATORS» PROGRAM AT THE FEDERATE PROBLEM LAB AT IHEP

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Abstract

In this report result of the study of electrophysical phenomena on the superconducting cavity surface, including plasma, bifurcation, hysteresis, emission and diffusion phenomena are considered. Science intensive recourse –saving technologies of superconducting cavities are being studied on the base of these phenomena. The superconducting cavities are made of Nb and Nb film, alloy film or HTC ceramics, which cover the working surface of the weldless copper shells using ion-plasma technologies (axial and planar magnetron sputtering).

Quality monitoring (optical, emission, electrochemical and high frequency) of the working surface condition of superconducting cavities is developed under the realization of new technologies.

The brief review of the experimental equipment is used as training base for individual students, post-graduate students and research staff in the field of technologies that use superconductivity phenomenon and ionic-plasma, electrochemical and high-vacuum technologies as well.

For realization of the joint project of accelerator SVAAP (Superconducting Vertical Accelerator for Applied Purpose) on the energy 15-20 MeV the specified science intensive technologies are used in collaboration with MEPHI.

Special attention has been given to the RF superconducting cavity, its geometry, mechanical stresses, HOM and technology.

Results of study of the technology developed in the Federate Problem Lab for Technology and Study SC Cavities at the Institute for High Energy Physics look promising.

STUDY OF THE ELECTROPHYSICAL PHENOMENA

We study and use next electrophysical phenomena in superconducting cavity technology [1]:

1. Electrical Instability Phenomenon in the systems with the negative differential resistance. It is found under certain conditions of the typical electrical instability during the anodic dissolution process for Nb and Cu. It is determined of the common electrical instability features in semiconductors (film Nb_2O_5) and in electrochemical systems [2] .We found bifurcation phenomena and current oscillations, described by strange attractor.

2. We have studied the hysteresis phenomena in electrochemical system and we are found of the good correlation of the hysteresis loop area and crystallographic orientation of the working surface of superconducting materials [2].

3. We have studied the possibility to clean the working surface of the superconducting cavities to the depth, which is more, than of RF field penetration. New cleaning method from Ta impurity has been proposed [3].

It is based on the well-known method of electric transfer, in particular, on its special case of the deep cleaning by means of electric transfer of an impurity through oxide barrier, and a layer of purified metal is kept behind the oxide barrier [4].

4. We have studied the volt - current characteristics and the dissolution process rate of the Nb surface lower or Nb films under superposition of alternating voltage with frequency 100-1000 Hz and we have found frequencies, corresponding to the electrochemical polishing, the impurity removing and the electrical deposition of the very clean Nb [5].

5. One of the ways of solving the problem of the accelerating fields increasing is to suppress the field emission effects. This work is devoted to study the oxide films influence on the Nb surface, specially created to decrease the field emission [6]. The theoretical modeling of oxide cover influence on the Q-factor of TESLA-shape superconducting cavity at frequency 3 GHz and the cover thickness at accelerating fields of 10 MV/m, 15 MV/m and 20 MV/m well correlates with experimental dependence of emission dark currents, measured under of DC field.

The combination of the technological parameters of anode oxidation is different in each case of application and is determined as a result of multifactor optimization.

Investigation of Nb – Nb_2O_5 system in wide temperature range is of certain interest because 300 K provides a metal – semiconductor system, 70 K provides a metal – dielectric system and 4.2 K provides a SC metal - dielectric system, i.e. oxide barrier changes it's nature, too.

6. Study of the thermomagnetic phenomena. Theoretical calculations of the reliable operation of SC cavity on the base of Nb/Cu have been discussed in detail in [7].

7. Study of the plasma phenomena. The peculiarities of magnetron sputtering of the superconducting materials and copper as an accompanying material is being ed. The current – voltage characteristics and curves

of magnetron discharge igniti
geometry are studied in our lab [8].

The geometry of electrode system and the working gas pressure are optimised. We are studying now the peculiarities of magnetron sputtering of the superconducting materials on copper shells of the different magnetron sputtering methods: axial, planar and complex axial and planar. Depending on kind of superconducting material (Nb, allow H2B, High Tc} and the frequency band we use different set-up and equipment.

METHODS OF THE TECHNOLOGICAL CONTROL

It is necessary to underline a special role of the study and technological control methods. We use the next methods:

- It is noteworthy that at manufacturing copper shells

of the superconducting cavities on the base of Nb/Cu,
we need to control quality namely of the first layers at the galvanoplastic copper laying, which then become a working surface at superconducting Nb laying by magnetron sputtering method.. For these purposes we use the acoustic emission as a method of the technological control [9]

- Control of the field emission properties of the Cu and

Nb working surface films [10].

- Control of the secondary emission properties and Auger spectroscopy [11].
- Control of the working surface state by means of SIMS method.

DEVELOPMENT OF THE TECHNOLOGIES ON THE BASE OF OUR RESEARCHES

Electrochemical Polishing

Electrochemical polishing with current oscillation “pocket”, described by strange attractor.
The technological process of Electro polishing has been developed from a very interesting phenomenon – excitation of low frequency current oscillation by constant voltage.
Practically, we have the possibility to conduct this process on the three level with metal removal that varies in thickness (Fig. 1)

Fig.1: Pocket oscillation under Nb electrochemical polishing

Small pockets correspond to 0.1 micron of metal removal per pocket and long ones – to 0.01 micron of metal removal per pocket [2]

Electrochemical cleaning technology of the Niobium working surface from Ta. Fig. 2 shows the effect of cleaning the working surface of Nb from Ta impurity.

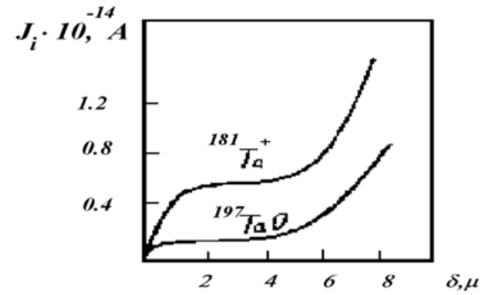

Fig. 2: Effect of cleaning the Nb surface

We see that in this case the Ta impurity in the surface Nb layer is distributed almost uniformly at the depth of 5 μм whereas in deeper layers an exponential growth is observed at the depth of 6.5μм followed by flattop

All results presented here point out at the existence of the Nb purification effects from Ta through the oxide layer [8].

Galvanoplastic Technology

A copper layer is formed electrochemically on a rotating Al mandrel taking the form of cathode, that later will be the working surface of the copper shell of SC cavity. Unfortunately an intricate configuration of cavity results in different distances between the anode and the cathode and therefore in different thickness of copper shell walls. We have solved this problem by means of the optimization of all parameters of the technological process and of development the special setup for it. On Fig. 3 you can see setups to realize this technology .

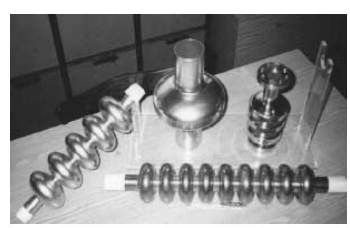

Fig. 3: The copper shells manufactured in the Lab

Buffer Layer Technology

Besides of Nb, high T_c material on the YBaCuO base is perspective for high accelerating field problem. On the seminars on future prospects for high energy physics and the RF Superconductivity Workshops the question about the opportunity to obtain accelerating field of order to 400 MV/m with the use of the YBaCuO film was discussed long ago. We have a lot of difficulties with this question now. To deposit a film of required quality at the working of copper shell it is necessary to solve the problem to guarantee the YBaCuO film stability with 3 –10 μк thickness. The problem is to
e crystallographic structure of YBaCuO and

According to that the conjugation possibility increases if Cu lattice parameters start increasing and approach to the lattice parameters of YBaCuO. There are many opinions of different firms on buffer layers between copper and YBaCuO. Using them different buffer layers have been tested, and the best preliminary results have been got for buffer layer from solid solution of Al-Cu.

Magnetron Sputtering Technology

We felt it necessary to manufacture the accelerating SHF cavities of different geometry for frequencies of 2.45 GHz, 3 GHz and 1.3 GHz and also the SC cavities for stabilising SHF generators by the SC cavities with 9GHz frequency; we decided to develop and use two set-ups: for axial magnetron spattering, for planar magnetron spattering [8] and set-up for complex magnetron sputtering [9]

THE SVAAP PROJECT

The results of the study of the technology and SC cavities were for the first time used in the linear accelerator project for the electron accelerator at the energy of 15-20 MeV with the RF structures on the base of Nb/Cu [10]

CONCLUSION

1. Complex study of the electrophysical phenomena on the superconducting material working surface (Nb films, alloy H2B films and YBaCuO films) has permitted us to develop the high scientific technologies.
2. The high scientific technologies are protected by the patent and Author's Certificates.
3. The complex of the experimental and technological equipment for manufacturing, treatment, technological control and study of the superconducting materials and cavities has been developed, that is the base for scientific researcher, the students and post graduate students.
4. The high scientific technologies have been used in the project of the SVAAP on the energy 15 –20 MeV (Superconducting Vertical Accelerator for Applied Purposes).

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