Large scale production at Ansaldo of 352 MHz niobium coated LEP-CERN cavities: development activities and first results.

A. Bixio, P. Gagliardi, M. Marin, S. Moz, W. Sciutto, F. Terzi, G. Zoni
ANSALDO GIE - Magnet & Special Product Div.
v. N. Lorenzi 8, 16152 Genoa, ITALY

Abstract

The program of energy upgrading of LEP needs about 200 superconducting RF cavities of 352 MHz frequency.
Since 1984 CERN has developed a method to produce niobium coated cavities by sputtering procedure.
During last years, an intensive collaboration between Ansaldo and CERN, has carried out the necessary transfer of technology from laboratory to industry.
In this paper we present the activities developed for a series production of 13 cryomodules, with special attention to the first rf results.
The excellent performances obtained with the first cavities gave a confirm of the feasibility of the production of high quality superconducting cavities at Ansaldo.

I. INTRODUCTION

For several years CERN developed the necessary technologies to produce superconducting cavities required by the LEP energy upgrading project [1].
That development work started, at CERN, with the construction of bulk niobium cavities. However at high accelerating field, the RF performance of a superconducting cavity is mainly limited by strong dissipation of the stored power because of low thermal conductivity of niobium at liquid helium temperature.

In a superconducting material, the penetration depth of the electromagnetic field is a few nanometers. This characteristic induced CERN laboratories to develop a new technology [2] to produce 4-cell cavities with the internal surfaces coated by a very thin (1 micron) niobium film: this solution reduces considerably the RF losses at cryogenic temperature.
During last years the necessary technology for a large scale production of Nb/Cu cavities has been transferred from CERN to Ansaldo [3].

At the end of 1990, Ansaldo drew up a supply contract about 52 superconducting cavities equipped with cryogenic and RF components, and assembled in 13 cryomodules for LEP 200 project. (Fig. 1)
Now Ansaldo is equipped with high-tech manufacturing plants to carry out the industrial production of 352 MHz superconducting niobium copper coated cavities by magnetron sputtering [4].

II. MANUFACTURING PROCEDURE

The production of superconducting RF cavities, needs high technology plants (Table 1) to ensure excellent quality of each manufacturing procedure.
Half cells are made by spinning or by deep drawing from OFHC copper sheets and chemical treated by electropolishing. The 4-cell assembling is performed by electron beam machine to weld all the components from the inside. So the whole cavity is tuned at the resonant frequency and the field profile adjusted to reach the necessary field flatness within a +/- 5 % of maximum deviation of the field of each cell, from the average value.
The chemical polishing is performed by a circulating bath to produce a deoxidized, high polished surface which guarantees a good film adhesion: then the cavity is rinsed with demineralized water and alcohol and finally dryed.
Niobium coating of internal copper surfaces is made by magnetron sputtering. After coating, cavity is rinsed again with ultrapure (18 MOhm cm) water jet by a moving tube and dried. All these operations about rinsing and drying are executed under high cleanness conditions in cl.100 clean-room to avoid any kind of contamination
Then cavity is sent to CERN for RF test at 4.2 K: if RF performance is acceptable (Target values: Q_0= 8.0 10^9 at E_{acc}= 0.1 MV/m and Q_0= 4.0 10^9 at E_{acc}= 6 MV/m) the cavity is ready for the assembly of He-tank, tuners and cryostat; otherwise, in case of poor RF performance because of bad

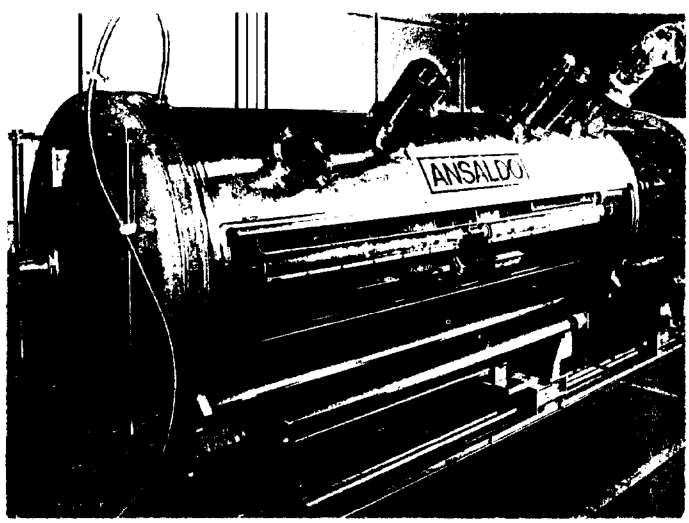

Fig. 1 - Assembly of a 4-cavities module

0-7803-1203-1/93$03.00 © 1993 IEEE

Table 1
352 MHz Nb/Cu LEP cavities production - Installations in ANSALDO

CLEAN-AREAS
- cl.100 clean-room for Nb cathode mounting, cavity rinsing and drying
- cl.100/1000 clean-rooms 30 m. long for module assembling
- Laser particle counter monitoring system

CHEMICAL PLANTS
- Electropolishing plant for components treatment
- Chemical polishing plant for 4-cell treatment: both plants operate under computer control
- Chemical degrasing equipment for stainless steel UHV components
- Water demineralizing 2-level system and ultrapure (18 MOhm cm) water plant for final cavity rinsing

BRAZING AND WELDING INSTALLATIONS
- Electron beam welding machine:
- - two guns of 6 KW and 70 KW output power with 90 ° magnetic deflector
- - stainless steel vacuum chamber 32 m^3 of volume, at present one of the larger EB welding equipment in Italy

- Vacuum electric furnace for copper tube-stainless steel flange brazing
- - 280 litres volume; ultimate vacuum of 10^{-6} Torr at 1320 °C

SPUTTERING PLANT
- UHV turbomolecular pumping system
- Diagnostic system with quadrupole mass spectrometer for residual gas analysis
- Cathode power supply 800 V /50A
- Data acquisition system for continuous monitoring of sputtering parameters

DIAGNOSTIC DEVICE
- Cromatography system for chemical solutions analysis (Anions, Cathions, Alcohols analysis)

film adhesion or film contamination, cavity is stripped, chemically treated and Nb coated again.
Finally each cavity with cryostat is assembled in a 4-cavities module in a cl.100 clean room and mylar alluminized superinsulation blankets for thermal insulation are installed.

A. Chemical treatments

All copper components, half cells and cut-off tubes, are degreased and prepared, before welding, with electropolishing treatment.
First a thorough decreasing is carried out with alkaline detergent at T = 60 °C with ultrasonic agitation. Then the electropolishing eliminates the layers damaged by the copper sheet lamination or any other manufacturing process.

This treatment removes about 100-120 microns from the inner surface of a half cell, using a mixture of phosphoric acid and n-butanol at room temperature with a current density of about 5.5 A/dm^2.
After assembling the cavity is treated with a circulating bath (sulfamic acid, n-butanol, hydrogen peroxide and ammonium citrate) at T = 72 +/- 2 °C, for about 45 min., to produce a removal of 25-30 microns.
Then cavity is carried in a cl.100 clean room to perform the final rinsing with ultrapure water and ethanol, and dried under dust free air laminar flow.

B. Niobium sputtering

Niobium coating of cavity internal surface is performed by magnetron sputtering with a glow argon discharge.
The large volume of a 352 MHz 4-cell cavity and the peculiarity of its geometrical shape, has necessarily induced to carry out a sputtering system with cylindrical configuration: a niobium cathode coaxial to cavity is used and an internal set of magnets ("magnetron") gives the necessary rate of argon ionization to obtain the uniformity of the film both on the equator and on the iris regions.
This configuration, together with the intrinsic instability of the argon discharge, involved many efforts to define the sputtering parameters (Ar pressure, cathode voltage and magnets current).
In particular we had to perform a fine adjustment of the electronic control unit between cathode and magnetron power supplies to minimize the oscillations of the discharge at such a low argon pressure of 6.0 10^{-4} Torr.

The niobium RRR values as well as the RF performance of the cavity at liquid helium temperature, are strongly affected by any kind of contamination which may occur before, during and after the coating process.
Residual components of the chemical bath may remain trapped inside surface microdefects and they could cause poor adhesion of the niobium film.
So before coating, cavity (under vacuum) is submitted to a baking process of about 24 hour at 200°C: that also drastically reduces the probability of film contamination by surface degassing during the film growing.
Another sort of contamination could come from the niobium cathode: some high power sputtering process are useful for a good niobium conditioning before starting with the coating of a copper cavity for series production.
The sputtering plant is also equipped with a diagnostic system for residual gas analysis: a quadrupole mass spectrometer is used and the rates of argon and nitrogen are continuously monitored during the process.
At last, great attention has to be paid during the final water rinsing to eliminate the large amount of electrons which may be trapped on the niobium film.

III. FIRST RESULTS OF RF TEST

We send each cavity to CERN laboratories for RF test at 4.2 K temperature: that consists in a high power RF test to evaluate the Q_0-value vs. accelerating field Eacc and, eventually, in a temperature mapping of the cavity to identify the causes of field and Q_0 limitation.
A conditioning process of the cavity (He processing) is also performed to eliminate the electron loading effect.
The RF performances of the first cavity prototypes, were badly influenced by a sort of soft global contamination of the film perhaps caused by low conditioning of niobium cathode, stainless steel vacuum components or copper cavity surface.

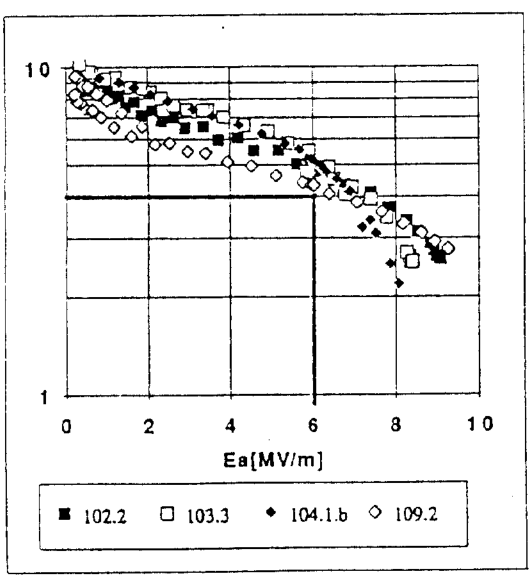

Fig. 2 - Q_0 vs. accelerating field E_{acc} (courtesy CERN)

After these first results, a continuous increasing of the Q_0-value was obtained and high quality niobium coated cavities were produced ($Q_0 = 5.4\ 10^9$ at 6 MV/m). (Fig. 2)
We also noted that, in some cases, a second standard water rinsing of the cavity after niobium coating, may increase the Q_0-value expecially at high accelerating field.

IV. CONCLUSION

Series production of superconducting niobium copper coated cavities for LEP is a very important result for European industries. Many efforts have been carried out in Ansaldo to develop and get ready the necessary technologies about chemical treatments, electron beam welding and thin film deposition.
At present Ansaldo is delivering to CERN the first accelerating module fully equipped with tuning system, RF couplers, diagnostic devices and the assembly of the second one is being done.
Ansaldo plants have showed their reliability in large scale production of high performance cavities according to the specifications required by the LEP 200 project.

V. RESEARCH AND DEVELOPMENT WORKS

Ansaldo is also engaged in cavity production for INFN-LNF. The design of two accelerator modules has been completed and the production of two 4-cell bulk Nb and Nb/Cu coated prototypes started. On the basis of the experience we carried out during LEP cavities production, we are developing, in collaboration with INFN-LNF/TOV (Frascati and Roma -Tor Vergata) and INFN-LASA (Milano), a method to produce a 500 MHz niobium coated 4-cell protoype.

VI. REFERENCES

[1] C. Benvenuti, "Superconducting coatings for RF accelerating cavities: past, present and future", *Proc. of 5th Workshop on RF superconductivity*, DESY, Hamburg, 1991
[2] C. Benvenuti et al., "Superconducting niobium sputter-coated copper cavities modules for LEP energy upgrade", *Proc. of 1991 Particle Acc. Conference*, San Francisco, USA, 1991
[3] C. Arnaud et al., "CERN's technology for superconducting cavities in European industry", *Proc. of 3rd European Particle Acc. Conference*, Berlin, 1992
[4] A. Bixio et al., "Manufacture at Ansaldo of 352 MHz superconducting cavities for LEP", *Proc. of 3rd European Particle Acc. Conference*, Berlin, 1992