中色东方 CNMNC

东方钽业 OTIC
中国有色集团成员企业

Improvement and industrialization of SRF cavity manufacturing technology

Ningxia Oriental Superconductor Technology Co. , Ltd

2024-10-20

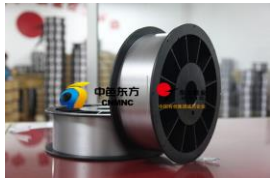
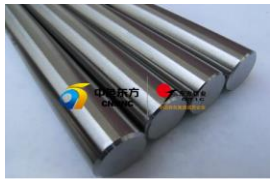
东方钽业 OTIC
中国有色集团成员企业

- Introduction and Quality Management of OTIC
- Manufacturing capacity and industrialization of niobium
- Development course of OSTEC
- Cooperation projects and honors
- Equipment manufacturing capability
- The improvement of manufacturing technology
- Industrialization

Introduction and Quality Management of OTIC

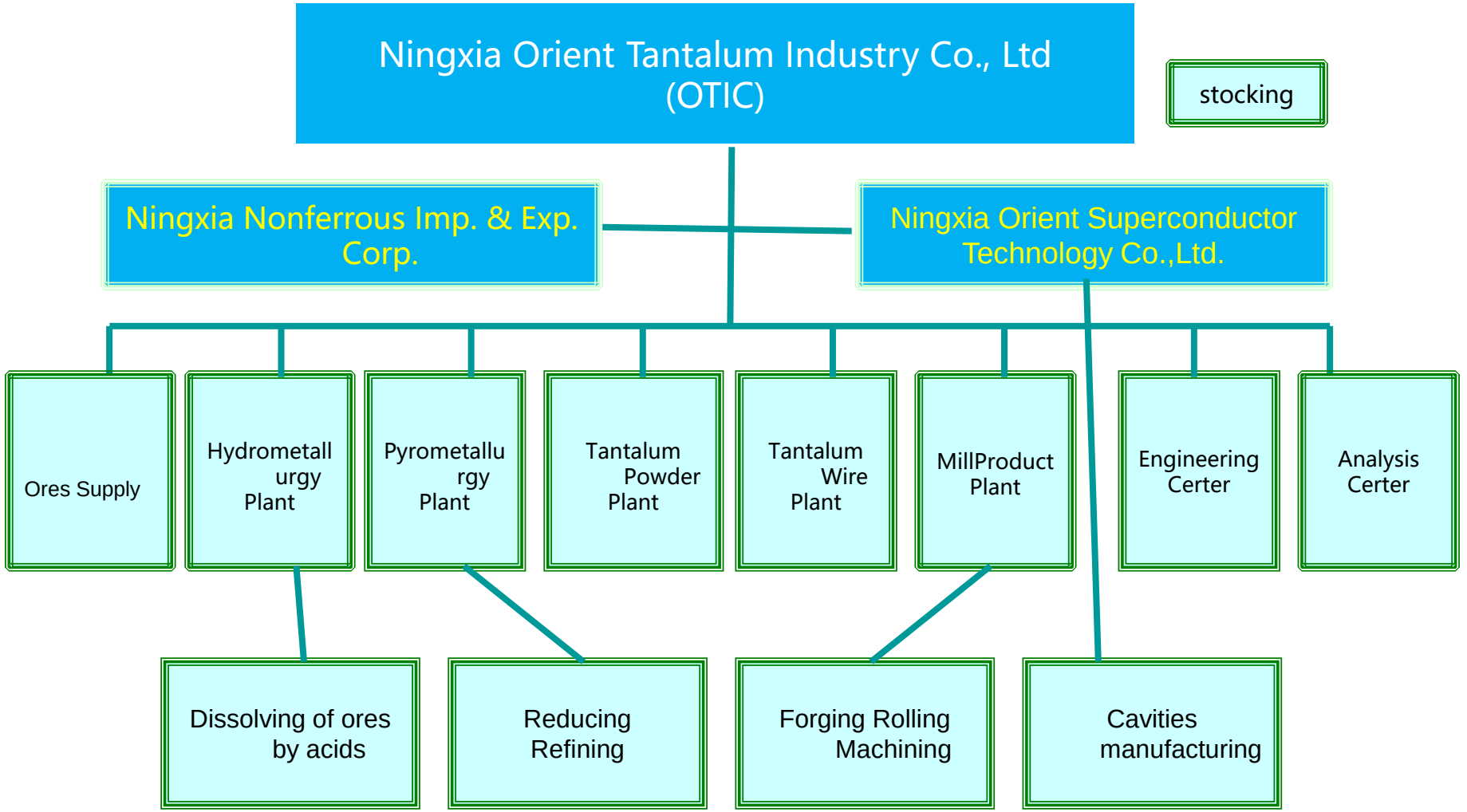
OTIC is a subsidiary holding company of CNMNC , a member of the CNMC .It was incorporated in 1999, publicly issued 65 million A-shares in 1999, and was listed on the Shenzhen Stock Exchange in 2000. In 2023, it will be selected into the list of SASAC specialized and special new demonstration enterprises, and is one of the world's major tantalum raw material manufacturers.

OTIC has been engaged in the production of tantalum and niobium materials for nearly 30 years, among which sodium reduction tantalum powder has been selected as the national manufacturing single champion, and the quality of high purity niobium oxide, tantalum oxide, tantalum niobium metal and its alloys, such as plates, rods, wires, strips and metal products ranks the domestic first-class level.




Introduction and Quality Management of OTIC



Introduction and Quality Management of OTIC

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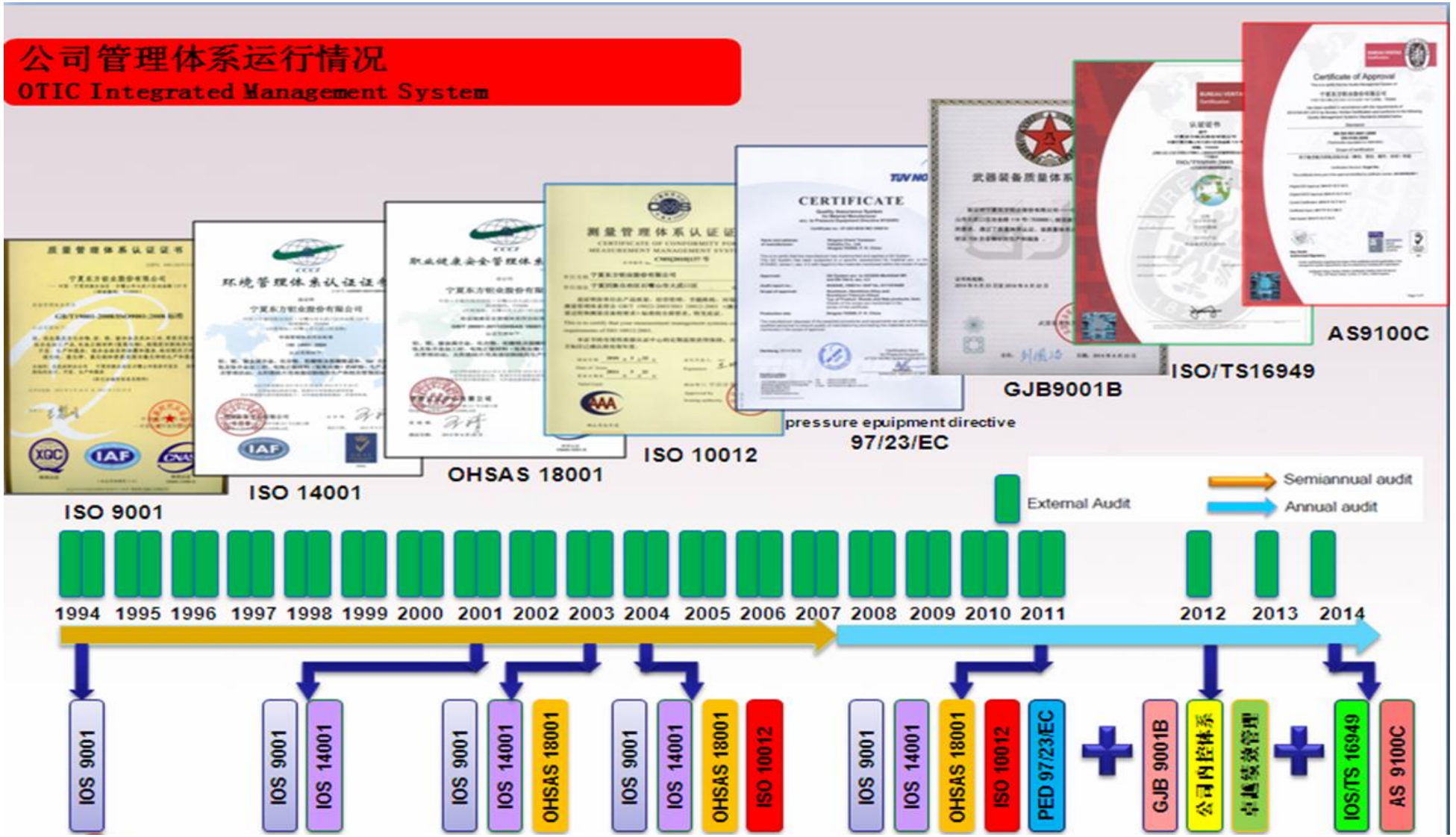

Manufacturing capacity and industrialization of Nb

东方钽业 OTIC
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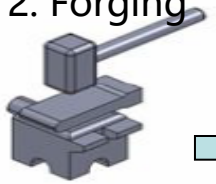
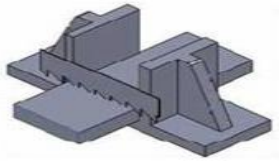
1.Ingot

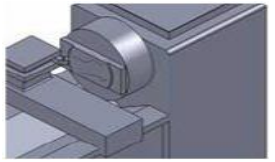
2. Forging



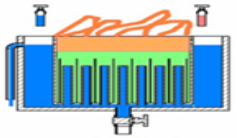
3.Sawing



4. Machine peeling



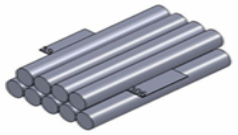
5. Acid Etching



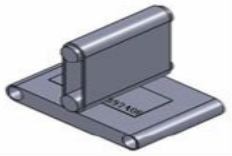
6. Annealing

7.Rolling

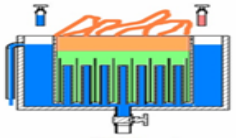
8. levelling



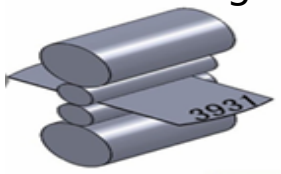
9. Polishing



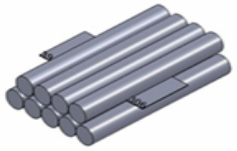
10. Acid Etching



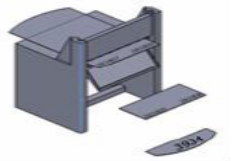
11. Rolling



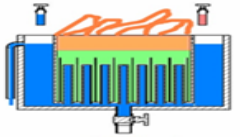
12. levelling



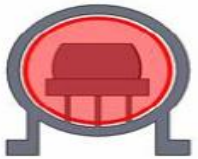
13.Cutting



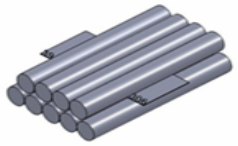
14. Acid Etching



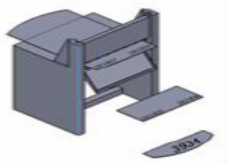
15. Annealing



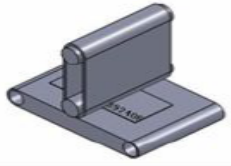
16. levelling



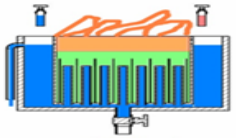
17. Cutting



18. Polishing



19. Acid Etching



20. Packaging

Manufacturing capacity and industrialization of Nb

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Products	Annual capacity	Spec.
RRR Nb sheet	20 Tons	RRR40, RRR250, RRR300
RRR Nb tube	5 Tons	RRR40, RRR250, RRR300
RRR Nb rod	5 Tons	RRR40, RRR250, RRR300
Nb-55Ti rod	20 Tons	ASTM B381

Manufacturing capacity and industrialization of Nb

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2011 DESY - XFEL
RRR300 Nb: 8 tons, 30% of the project

2012 Michigan State University - FRIB
RRR250 Nb: 8.5 tons, 70% of the project

2014 Fermilab - LCLS II
RRR300 Nb: 5 tons, 50% of the project

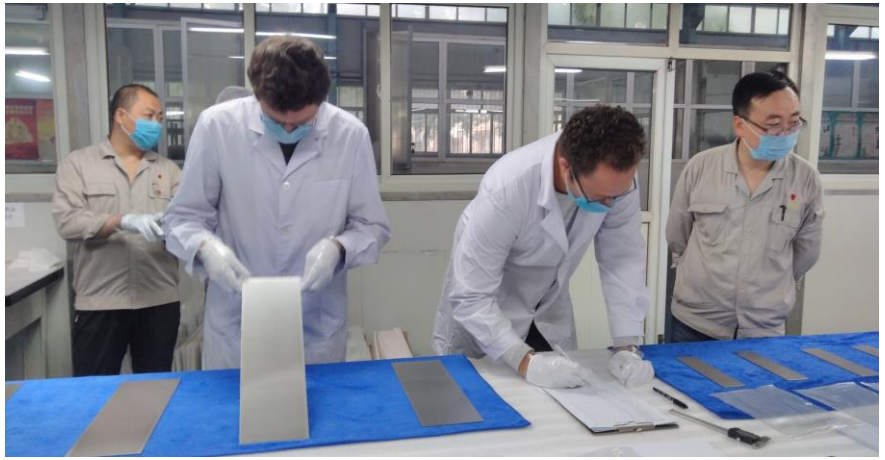
2017 INFN and STFC - ESS
RRR300 Nb: 12.5 tons, 100% of the project

2019 IBS - RISP, CERN - HL-LHC, Fermilab - PIP-II, Shanghai - SHINE
RRR300 niobium material procurement in progress

We had built the business relationship with many great customers such as DESY, MSU, Fermilab, JLAB, INFN, STFC, CERN, TRIUMF, RI, ZANON, IHEP, IBS, RRCAT etc.

Manufacturing capacity and industrialization of Nb

On-site inspection by DESY



On-site inspection by RI

On-site inspection by INFN

On-site inspection by STFC

Manufacturing capacity and industrialization of Nb

CS-600 carbon-sulphur measurement meter

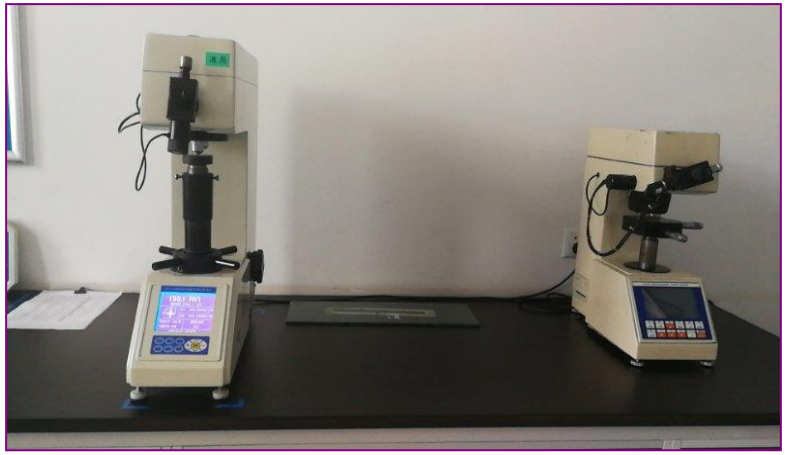
TC-600 oxygen-nitrogen measurement meter

ICP full spectrum direct reading spectrometer

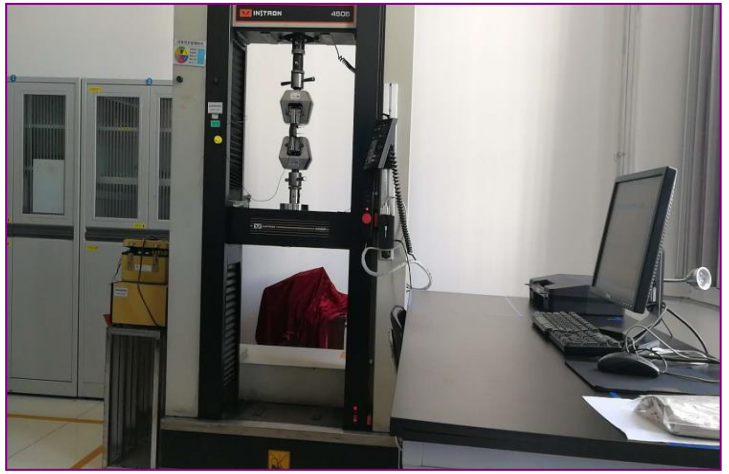
ICP-AES spectrometer

Manufacturing capacity and industrialization of Nb

GX51 metallographic microscope



HMV-2T microhardness tester



WDW-B100G electron universal testing machine

SEM

Manufacturing capacity and industrialization of Nb

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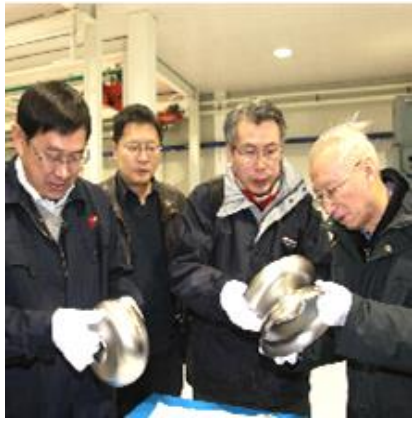
■Superconducting niobium production line

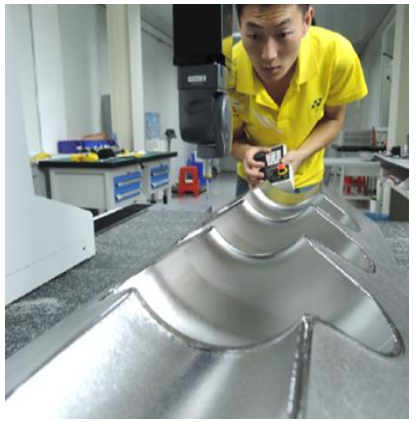
Take the lead in undertaking the future industrial superconducting materials source of SASAC of The State Council, and build a research and manufacturing base with superconducting niobium materials and superconducting cavity of the whole industry chain.

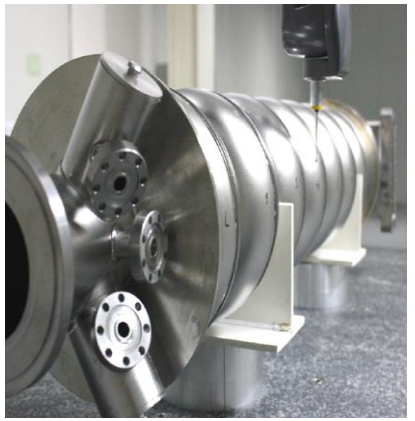
Development course of OSTEC

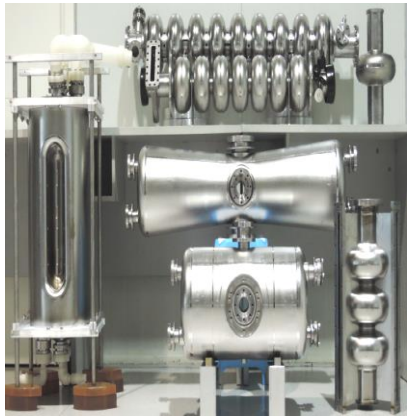
OSTEC founded in 2010, mainly engaged in SRF cavities manufacturing, welding and post-processing work. OSTEC has a total of 44 employees, professional and technical personnel accounted for 38.64% . Since its inception, a total of more than 30 kinds of completed more than 210 SRF cavities product delivery.

2010	2011-2017	2017-2023	2024
Founded	Pre-research	Trial-produce	Mass Production
	R&D	breakthrough	curing
	iterate	optimization	promote
	verification	Trial-produce	expand market
	20 SRF cavitiesr/y	35 SRF cavitiesr/y	100 SRF cavitiesr/y



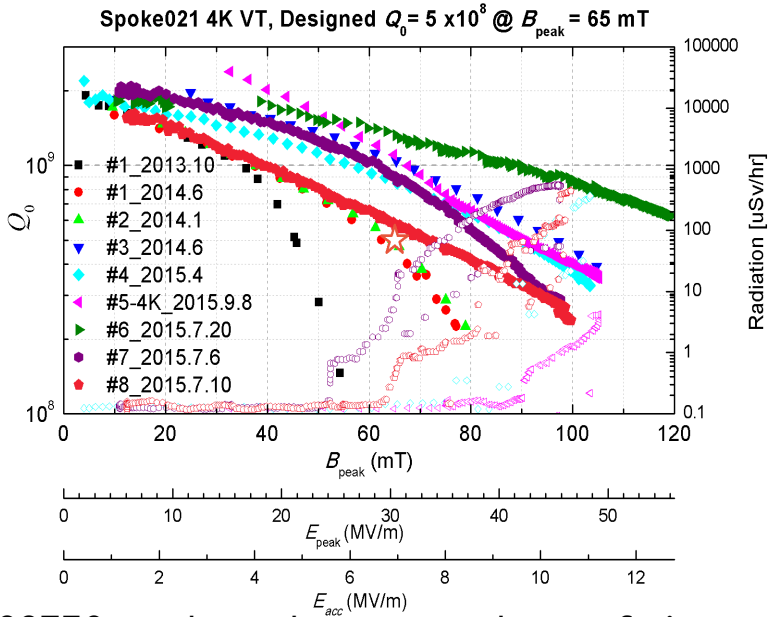






Cooperation projects and honors

Item	Chamber	amount	level
美国FRIB项目	HWR029	7	符合项目要求
加拿大TRIUMF实验室	HWR QWR	2 2	符合项目要求
国际合作项目	1.5GHz 7cell	2	符合项目要求
中国CiADS、HIAF项目预研	Spoke012 Spoke021 TaperHWR015 325MHz HWR Taper HWR009 HWR010	5 5 2 2 2 12	符合项目要求
上海硬X射线项目	大晶粒1.3GHz 9cell 细晶粒1.3GHz9cell 3.9GHz 单cell 3.9GHz -9cell 1.3GHz 单cell	6+6 16 8 2 12	国内首家制造 符合项目要求 国内首家制造 国内首家制造 符合项目要求
CEPC项目预研	细晶粒650MHz 单 cell 大晶粒650MHz 单 cell 650MHz-2-cells	6 4 2	国内首家制造 国内首家制造 国内首家制造
东莞散列中子源	648MHzSpoke	1	国内首家制造
中核集团BISOL项目（中国原子能科学研究院）	QWR	1	国内首家制造



OSTEC undertakes a number of important science and technology projects: the international cooperation plan of the Ministry of Science and Technology, the national science and technology support plan, the technology innovation fund project of small and medium-sized science and technology enterprises, and the key research and development project of the autonomous region.

Cooperation projects and honors

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Equipment manufacturing capability——machine

hydropress

CNC lathe

CNC milling

Equipment manufacturing capability——welding

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EBW machine

TIG machine

LBW machine

Equipment manufacturing capability—surface processing

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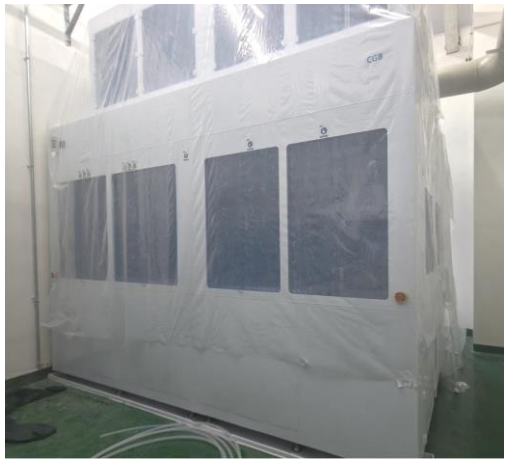
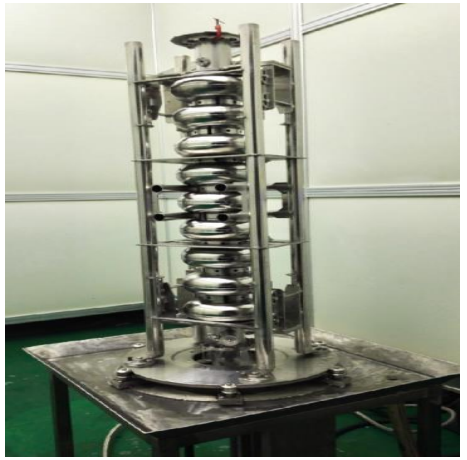
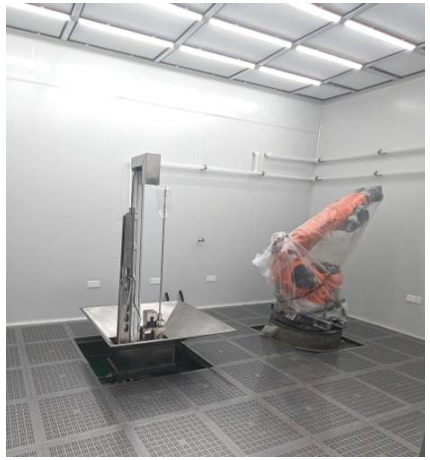


BCP

Hyperpure water system

EP





HPR

Equipment manufacturing capability—Surface processing

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Clean Room

Vacuum furnace

Equipment manufacturing capability——measure

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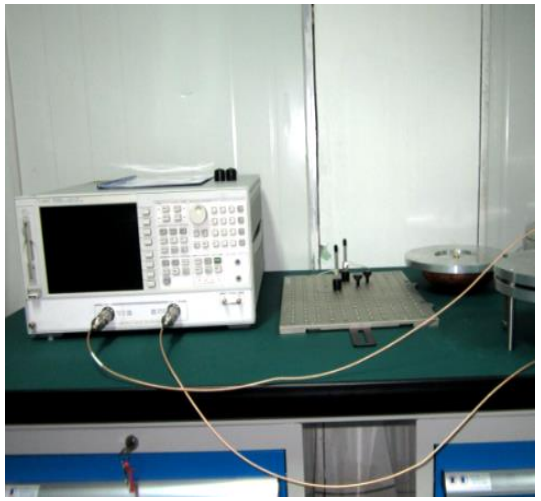
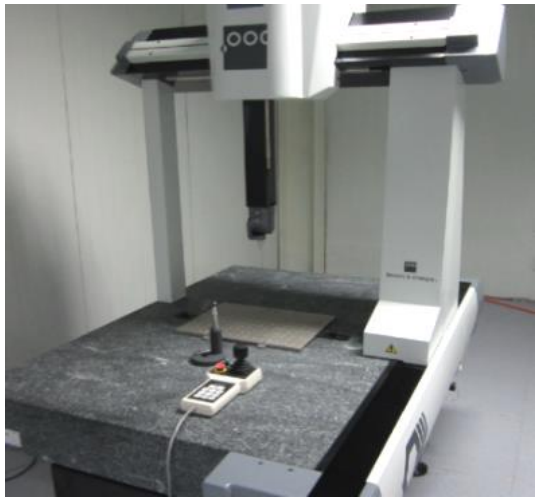
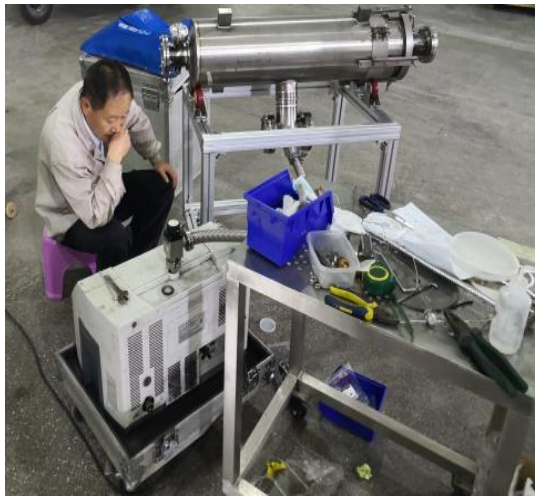


RF meas.

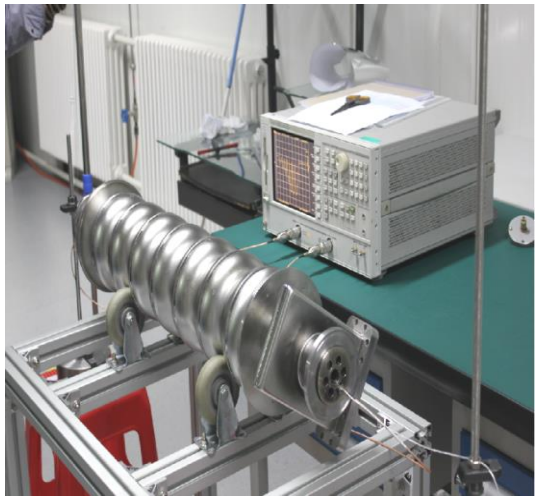


3D CMM

Articular arm measuring



He leak.



Equipment manufacturing capability

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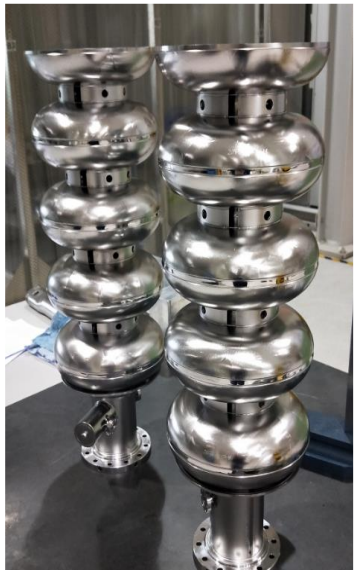
parts of SRF cavities



Equipment manufacturing capability

东方钽业 OTIC
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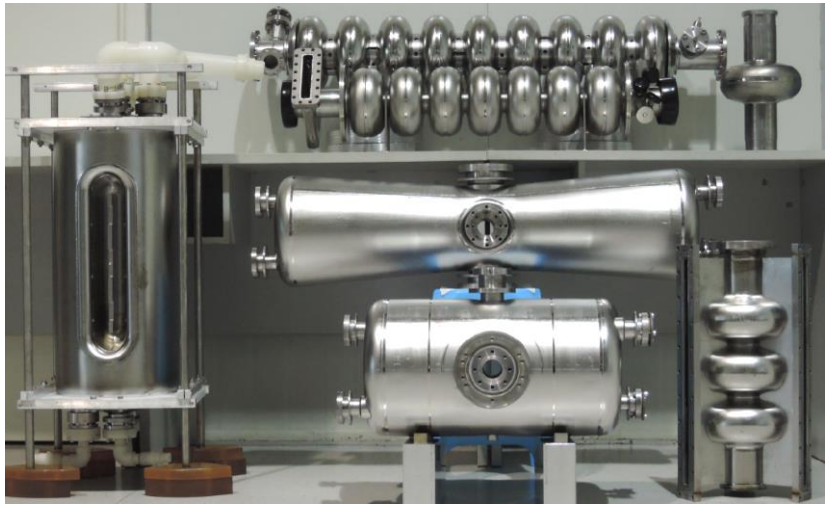
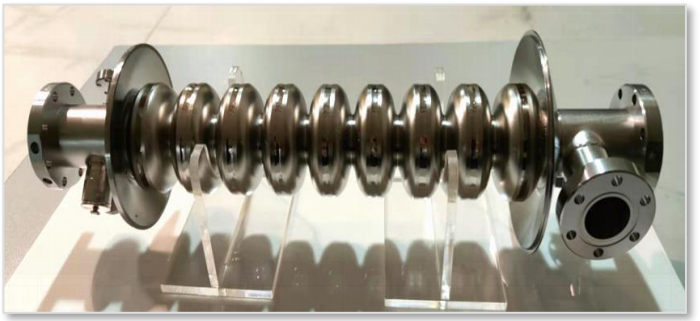


HWR010



3.9GHz 9-cell

spoke

1.3GHz 1.5-cell

Completed more than 30 kinds, more than 210 SRF cavities products, high customer acceptance.

Equipment manufacturing capability

东方钽业 OTIC
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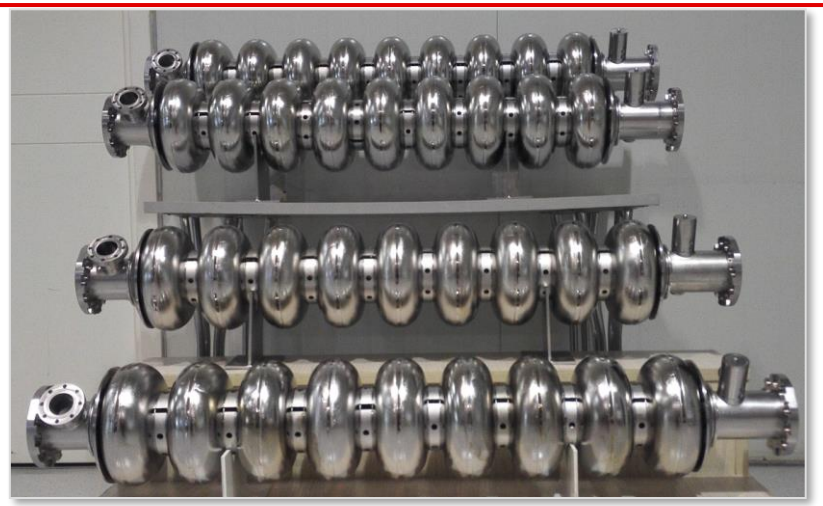
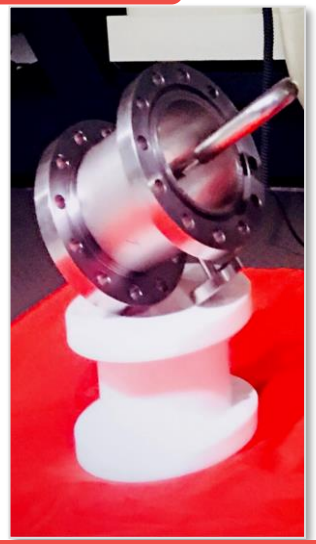
3.9GHz 1-cell



1.3GHz 9-cell

HWR021

1.3GHz 1-cell



650MHz coupler

HWR015

QWR

Slit cavity

The improvement of manufacturing technology

东方钽业 OTIC
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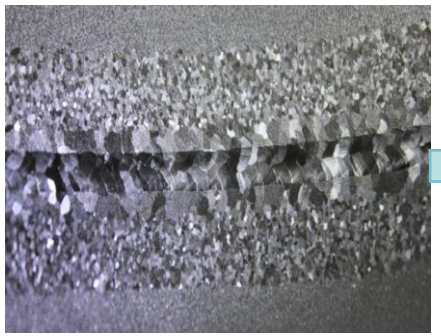
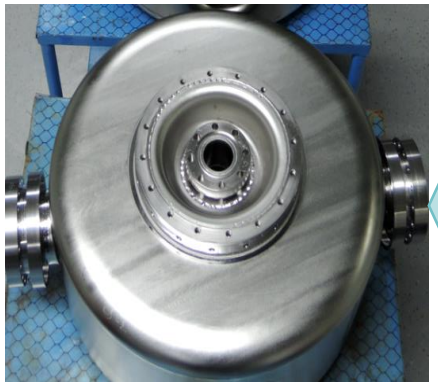
1：Forming, machining and welding technology of SRF cavity parts



Weld inner surface

Welded parts

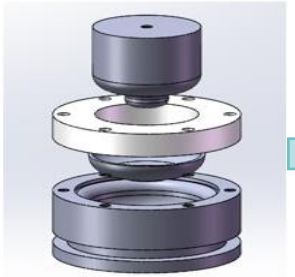
assembly



SRF

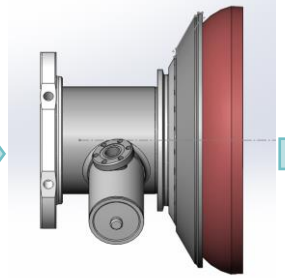
4D

HOM assembly



Half bowl

profile



assembly

HOM

According to the physical design model of the RF superconducting cavity, the precision machining and welding of the parts of the superconducting cavity are realized through the process test, parameter optimization, verification and iteration, and the standardized processing and manufacturing process is formed.

The improvement of manufacturing technology

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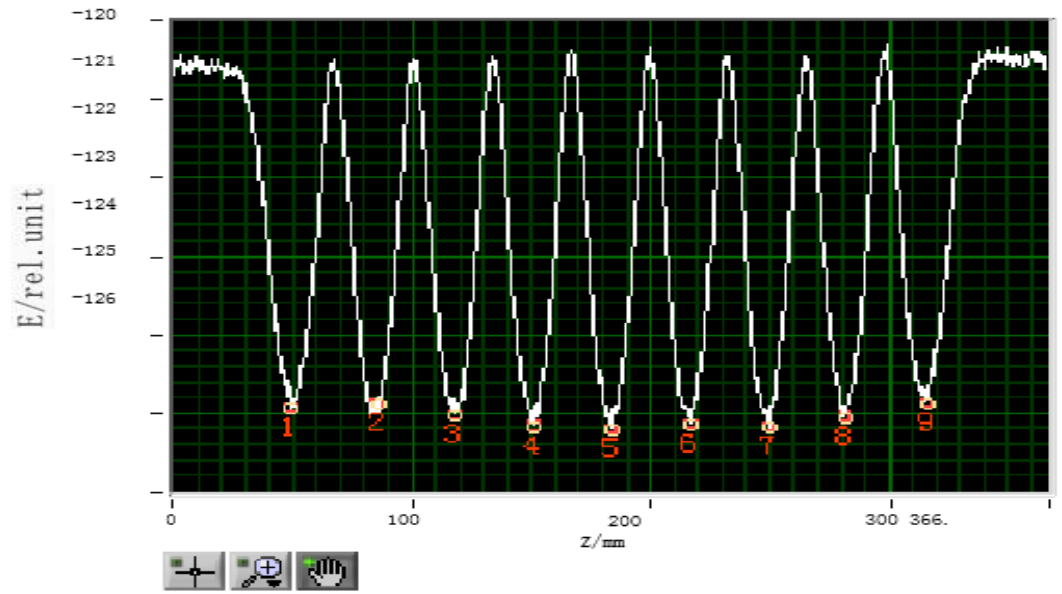
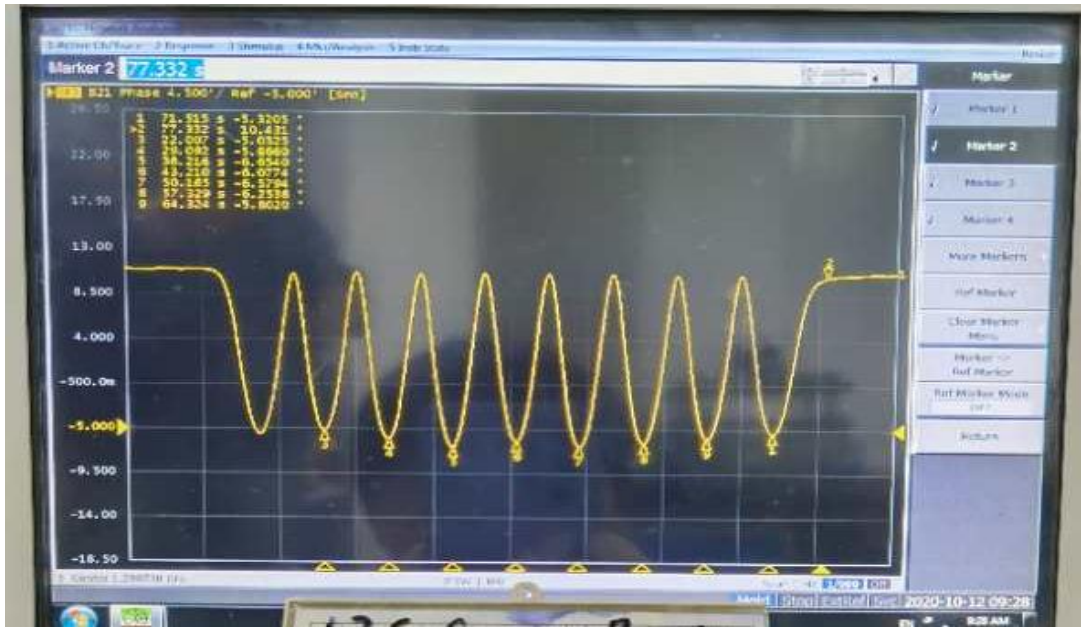
2：Frequency control technology of SRF cavity



Frequency



PKU1.3G9cell-1# 97.1%

According to the physical design of the SRF cavity, the frequency of each acceleration unit of the SRF cavity is accurately controlled to improve the uniformity of the overall acceleration capability of the SRF cavity, and the field flatness of the 1.3GHz-9Cell SRF cavity is above 95%.

The improvement of manufacturing technology

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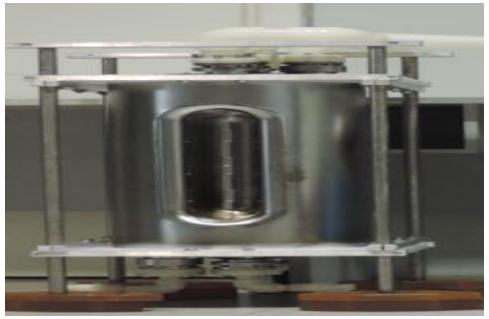
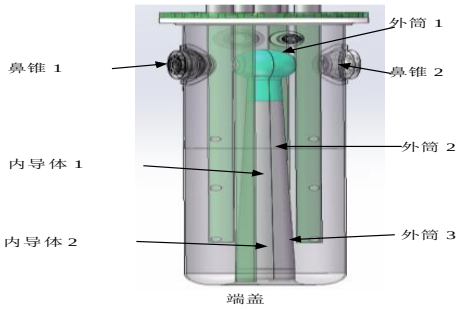
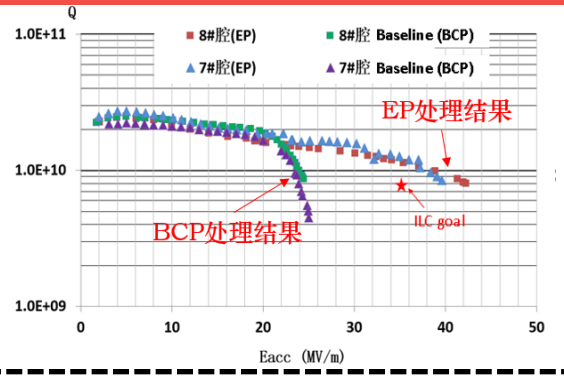
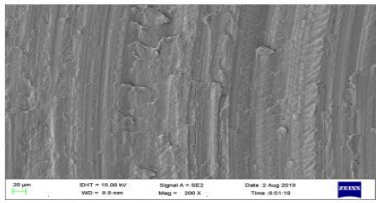
3：Surface processing technology of SRF cavity



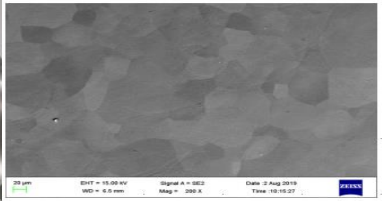


BCP Model





(a) 200X 扫描电镜（EP 前）



(b) 200X 扫描电镜（EP 后）

The relationship between the technical parameters (voltage, current, acid temperature) of BCP and EP of the SRF cavity and the surface removal amount and surface quality was studied to achieve accurate control of the surface removal amount of the SRF cavity and meet the requirements of surface finish and cleanliness.

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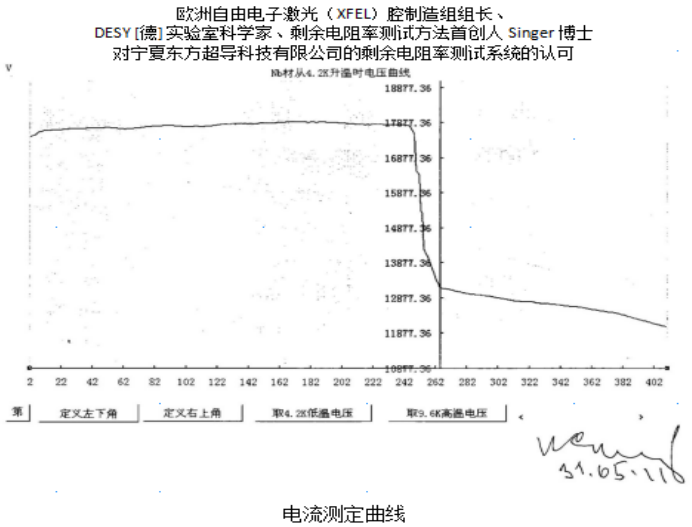
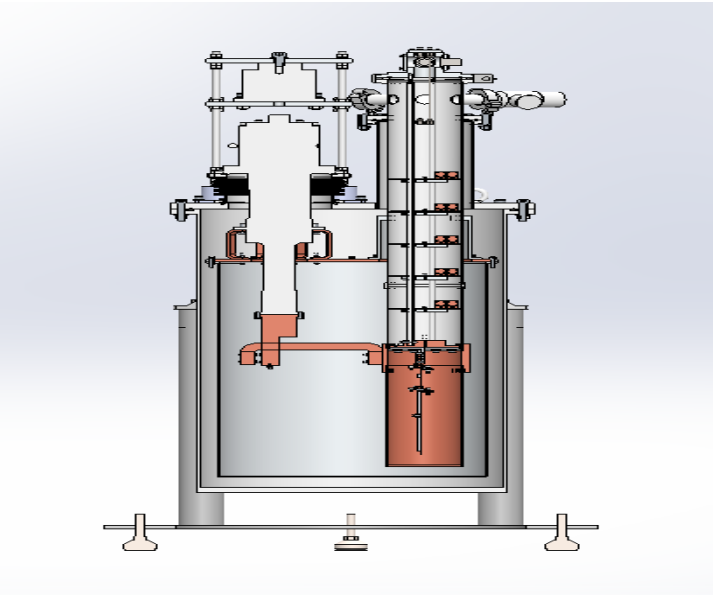
4: Detection technology of RRR value of high purity niobium material

The RRR value measurement method of high purity niobium materials in different low temperature environments is realized. The new cryogenic pump cold chain conduction replaces the traditional liquid helium environment to form a low temperature environment, and the RRR value is more accurate.



电流测定曲线



Technical approval

- RRR test system
- Singer Dr

Detection system

- Intelligent detection
- Cold chain conduction

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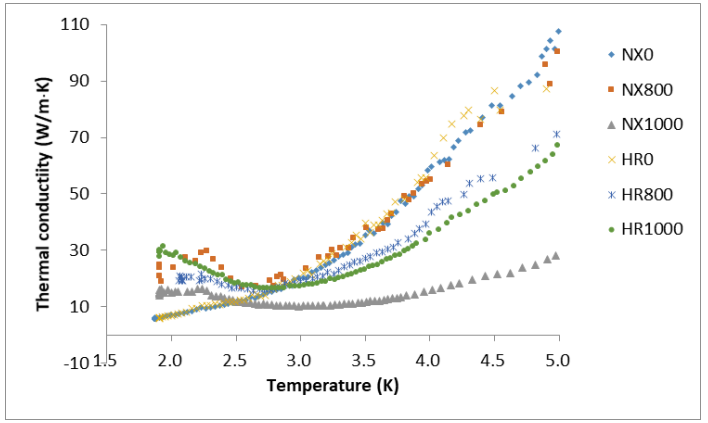
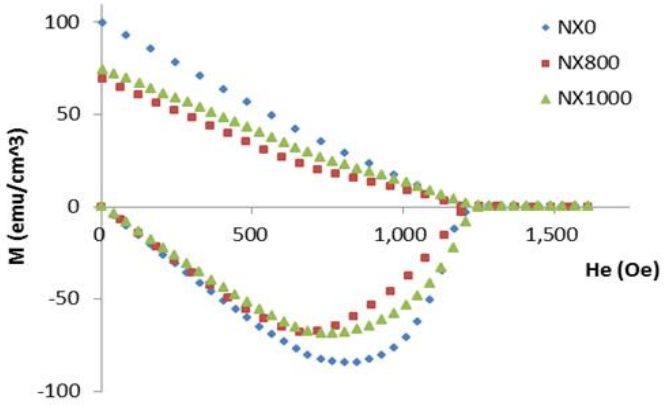
5: SRF cavity made by large grain niobium material



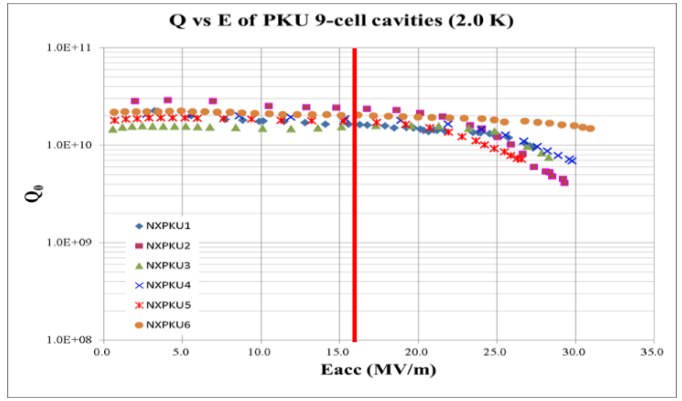
Thermal conductivity



Magnetization curve

The study of thermal conductivity of large grain niobium materials will help to improve the performance of large grain SRF cavity.

TESLA 1.3GHz 9-cell



9-cell test results@ 2.0 K

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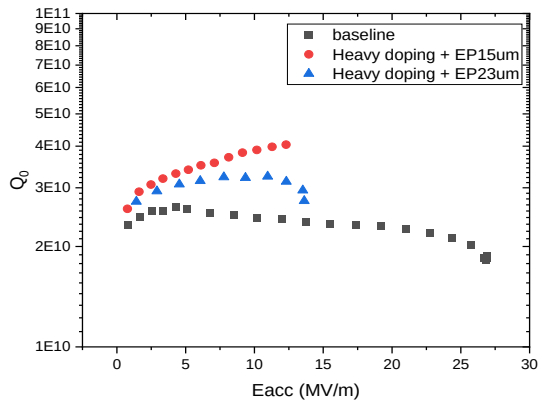
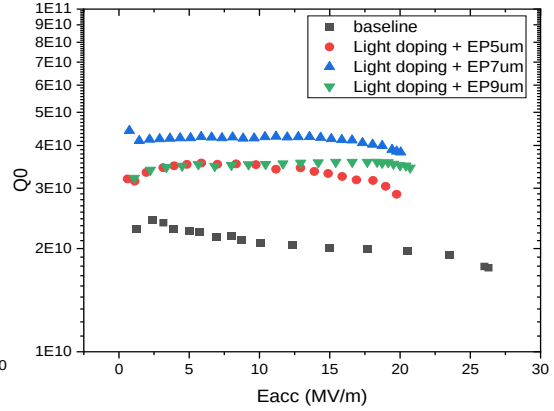
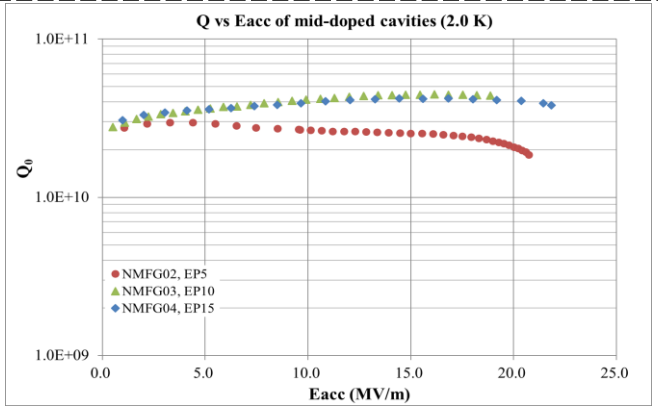
6: Doping technique of SRF cavity



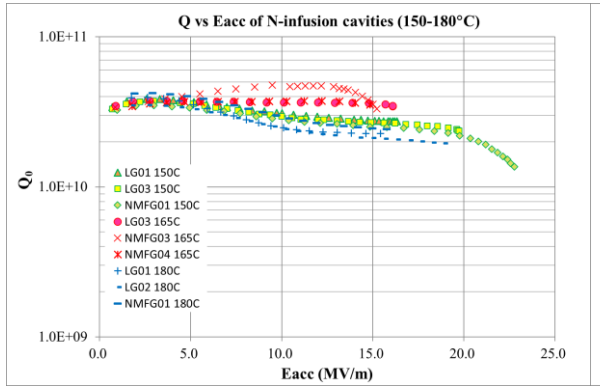
Heavy doping



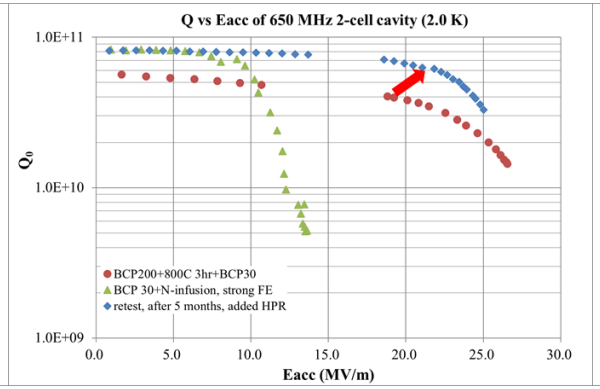
medium-doping



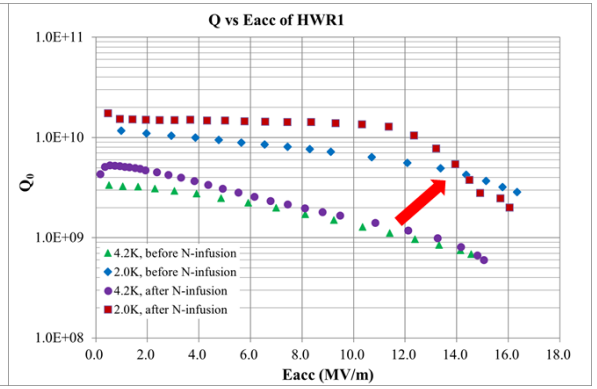
Light doping



1.3GHz 1-cell Low temperature N-doping



650MHz 2-cell Low temperature N-doping



162.5MHz HWR Low temperature N-doping

Result

The optimized nitrogen doping parameters were obtained by studying the nitrogen doping process and testing the properties of superconducting cavity and niobium sample.

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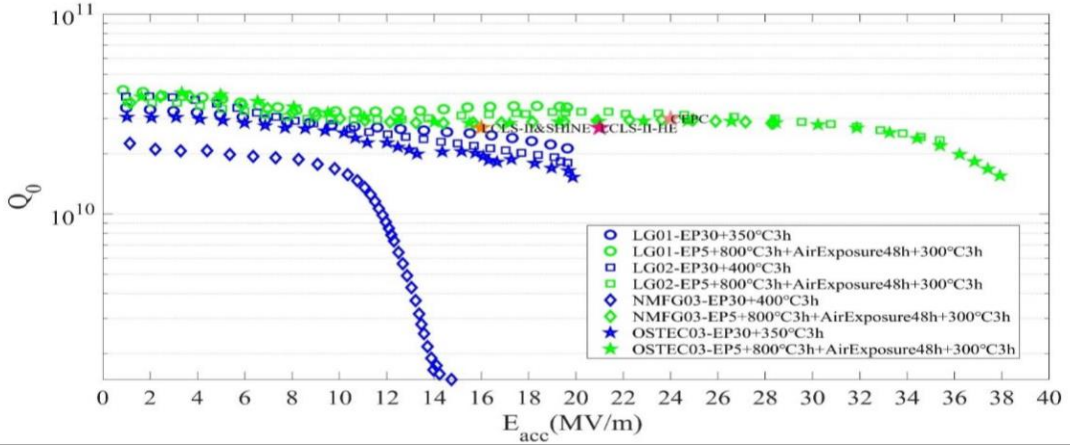
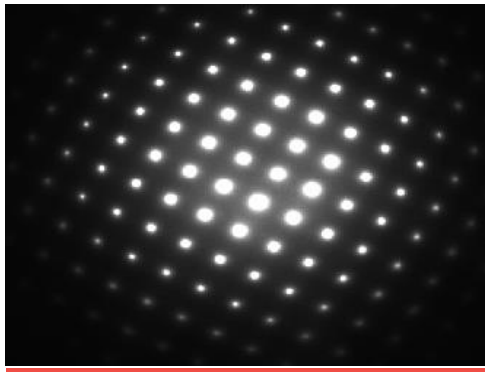
7：Medium temperature baking and mechanism of SRF cavity

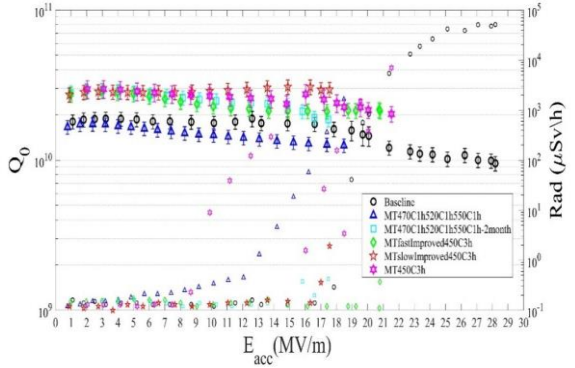


1.3GHz 1-cell result

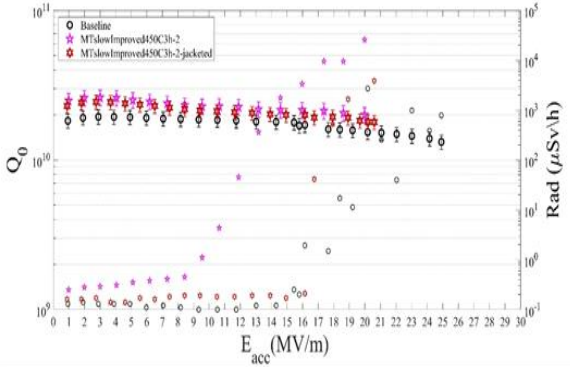
According to the analysis of resistance composition at low field and 2K temperature, the BCS resistance of niobium cavity can be significantly reduced by the medium temperature baking scheme, which makes the surface resistance decrease and the Q0 value increase.



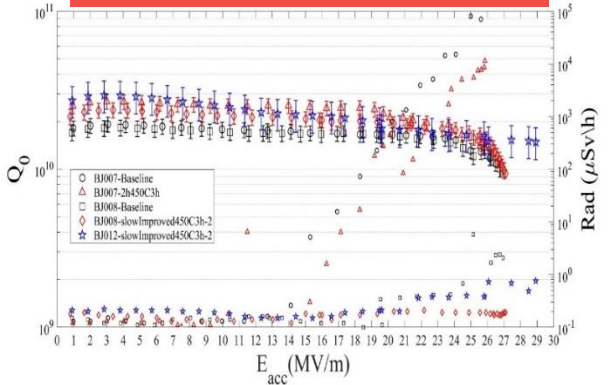
ED



BJ004



BCP



EP

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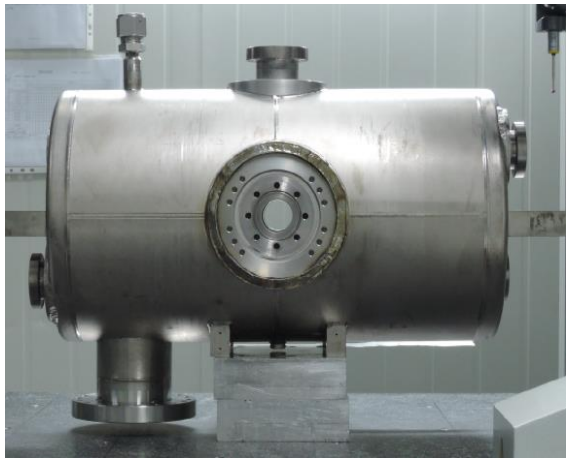
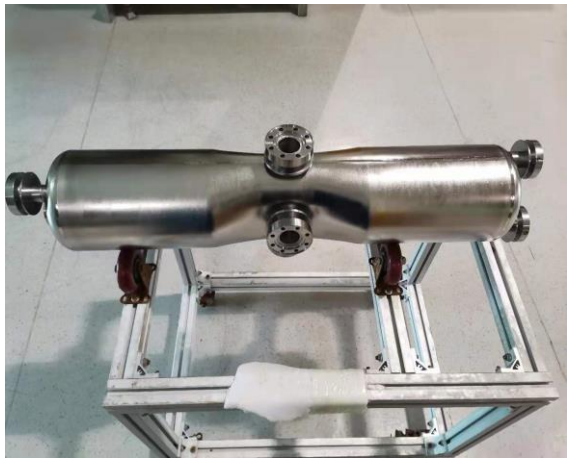
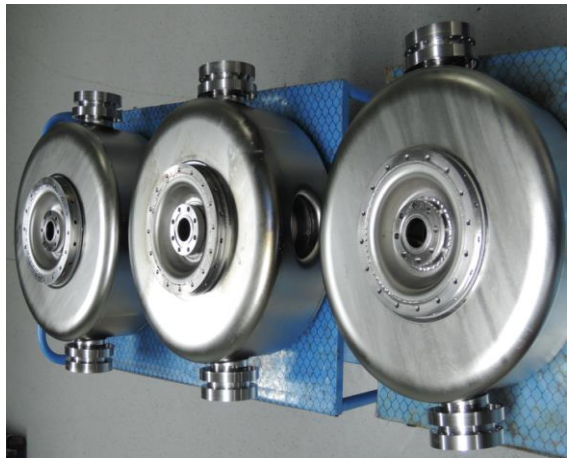
HWR015



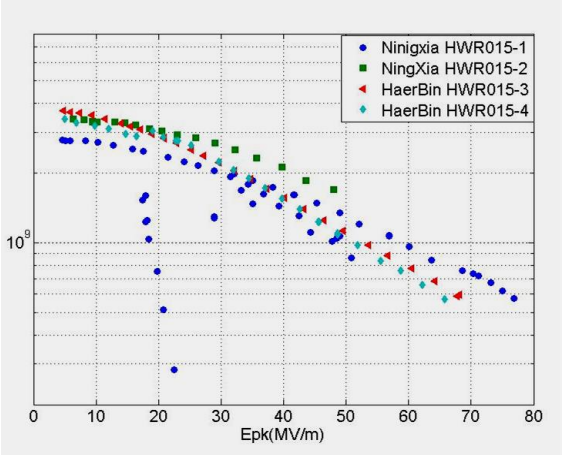
HWR 029

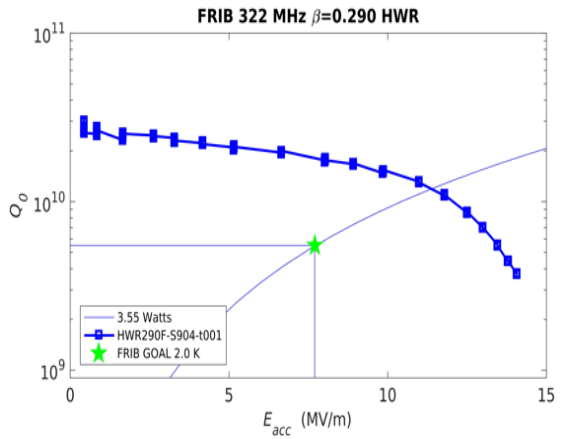


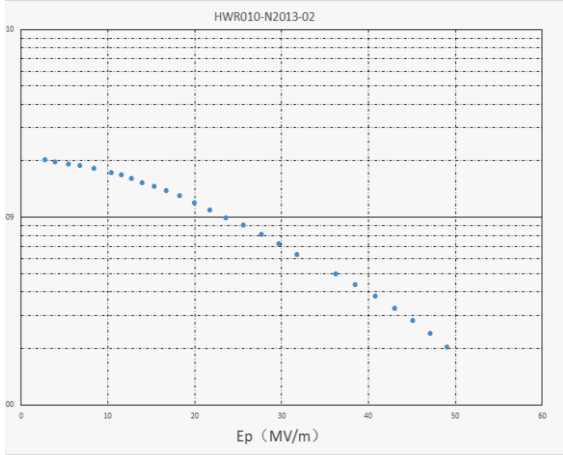
HWR010

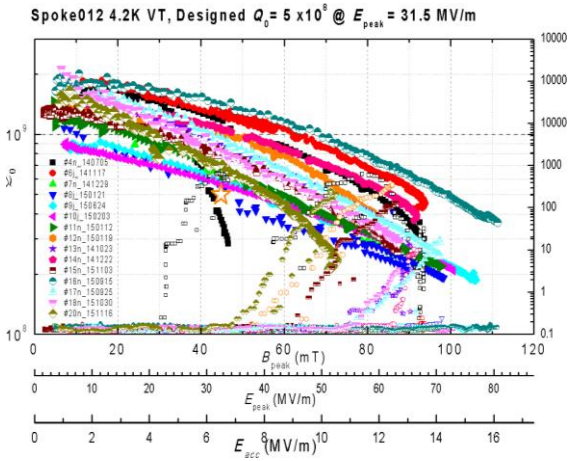


spoke 012

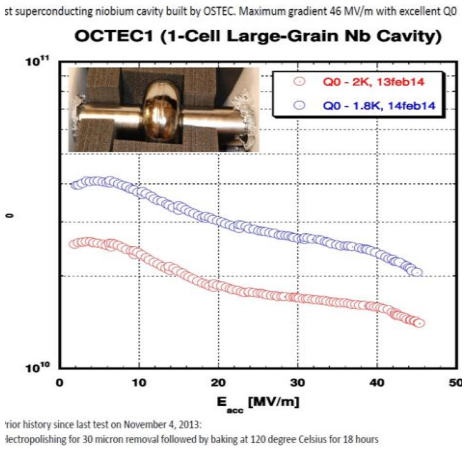




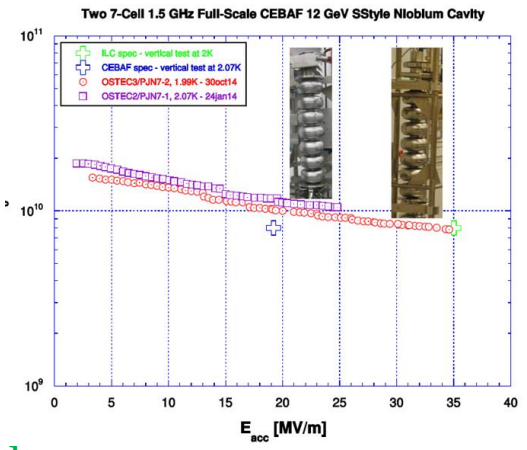




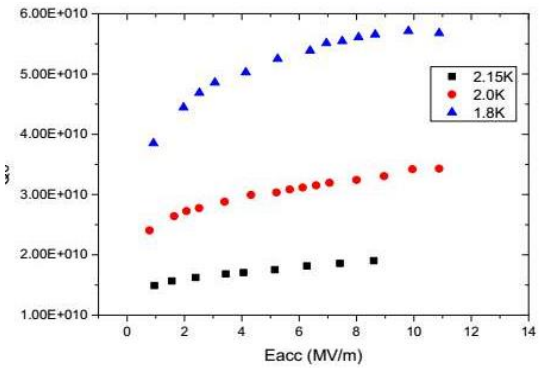
The improvement of manufacturing technology



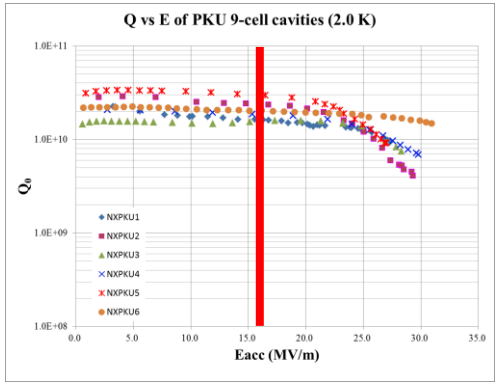
1.5GHz large grain single cell superconducting Nb cavity, its maximum acceleration gradient reached 46MV/m. It was the first Nb cavity which was manufactured in OTIC in 2013.



In 2013, OTIC cooperated with Jlab for the first time to develop a 1.5GHz 7-cell superconducting cavity for CEBAF upgrade. Superconducting cavity was tested at 2K low temperature and the acceleration gradient reached 36MV/m. It was the first time for OTIC to have the manufacturing capability of superconducting cavity.



In cooperation with IHEP and Peking University, OTIC established BCP and HPR post- processing facilities, improved nitrogen doping process and EP facilities, and possessed the capability of post-processing of superconducting cavity in the first half of 2019.



1. E_{acc} of all 6 cavities larger than 25 MV/m
2. Q_0~1.6-2.4E10 @ 16 MV/m

#3, 2nd test (Sept. 2017), with additional BCP &HPR

Industrialization

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■Superconducting cavity production line

OSTEC has completed the technical transformation project, adding 7 sets of key equipment such as electron beam welder, laser welder, boring and milling machining center, which greatly improves the manufacturing capability of the company, at present, the company has a yearly output of 100 SRF cavities manufacturing capacity.

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THANKS!

BY OTIC 20/10/2024