

# **CEPC vacuum chamber production line**

**Yongsheng Ma**  
**Vacuum group, IHEP, CAS**  
**Jan 13<sup>th</sup> 2026**

# Content

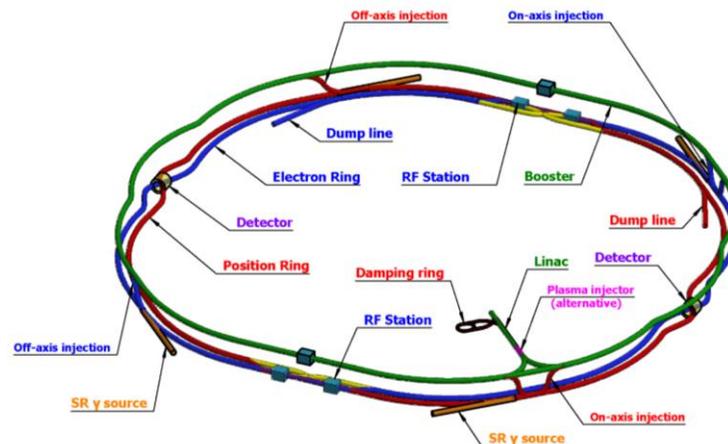
- **Preview of CEPC vacuum system**
- **Production line development of NEG coating/ Spray for heating film in EDR**
- **Prototype of thermal-spray heating layer and testing**
- **Summary**

# Preview of CEPC vacuum system

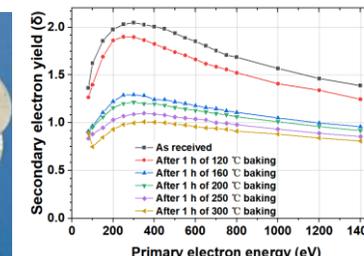
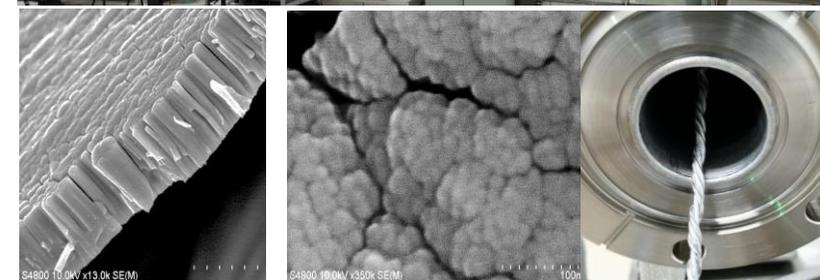
## Machine and Vacuum Parameters

	<b>E</b>	<b>I</b>	<b><math>\rho</math></b>
	Gev	A	m
Higgs	120	0.0167	10700
W	80	0.084	10700
Z	45.5	0.803	10700
tt	180	0.0033	10700

<b>Accelerator</b>	<b>length/m</b>
LINAC	1,601+335
Damping ring	147
Booster	100,000
Collider	200,000
Transport line	4,680
<i>Total length/m</i>	<i>306,763</i>



## ◆ Technical developments in TDR



Those prototypes have a good application in HEPS.

# Structure of vacuum chamber for CEPC collider rings

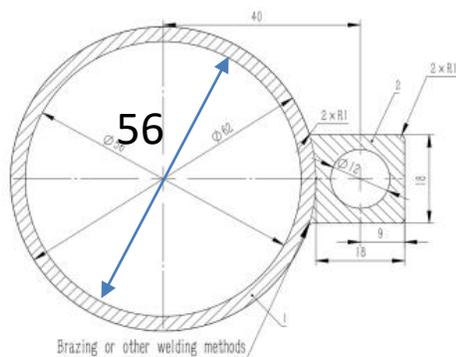
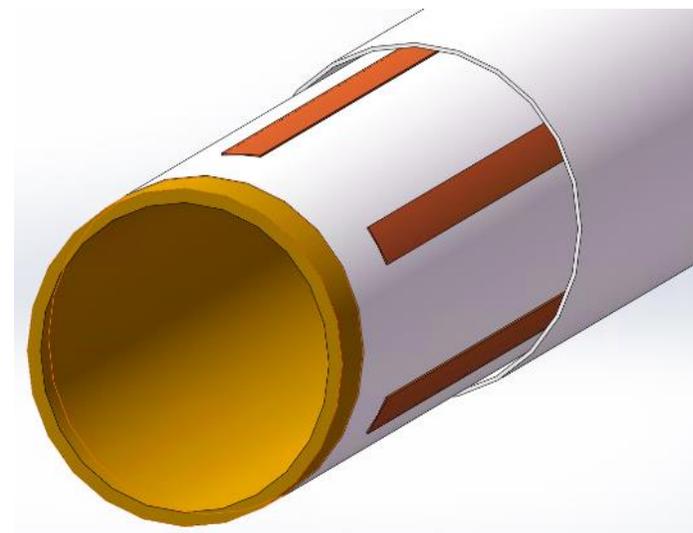
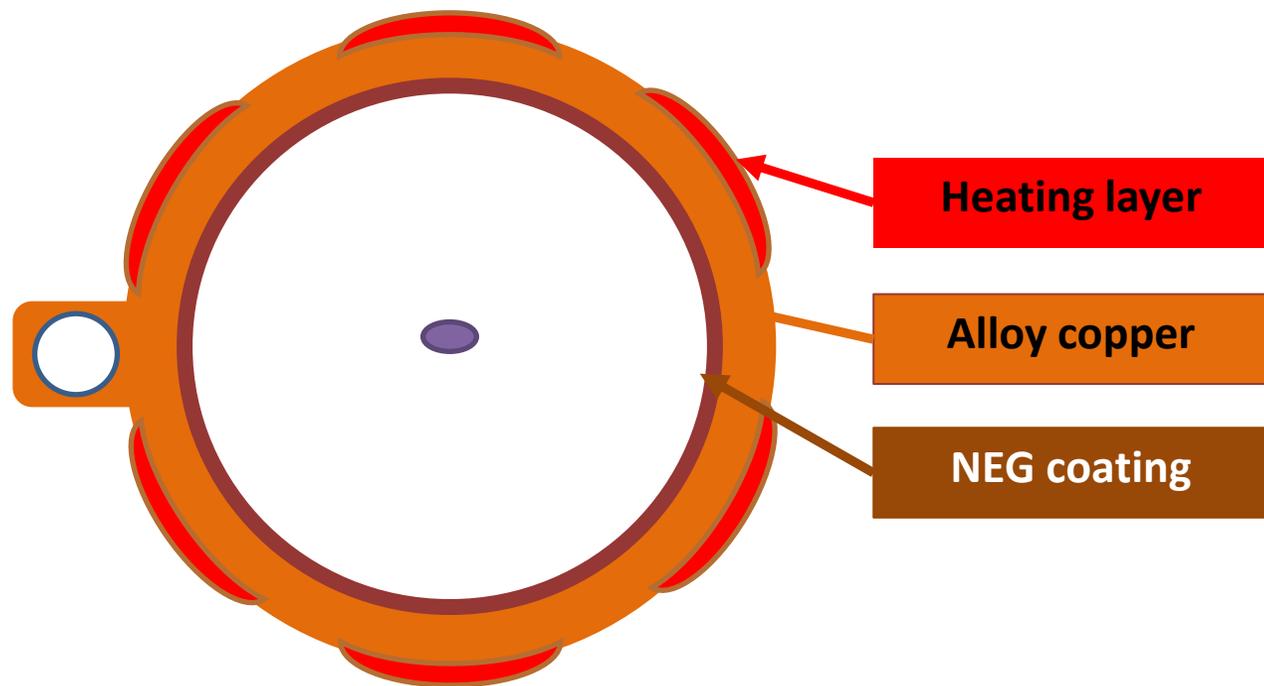
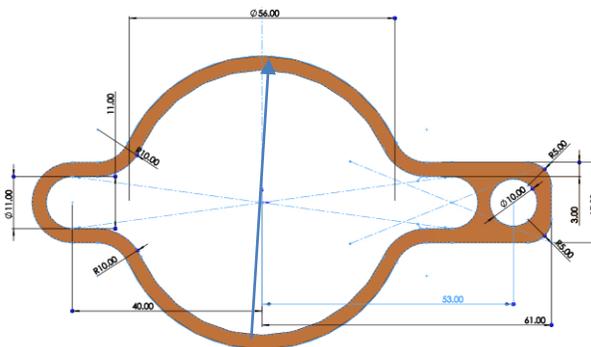
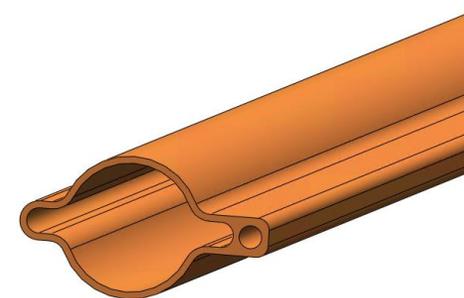


Figure 4.3.6.2: Copper dipole vacuum chamber

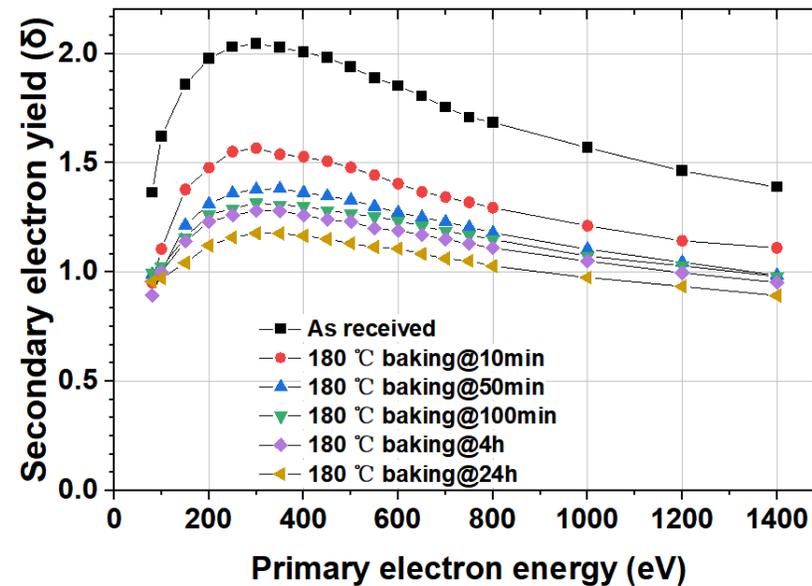
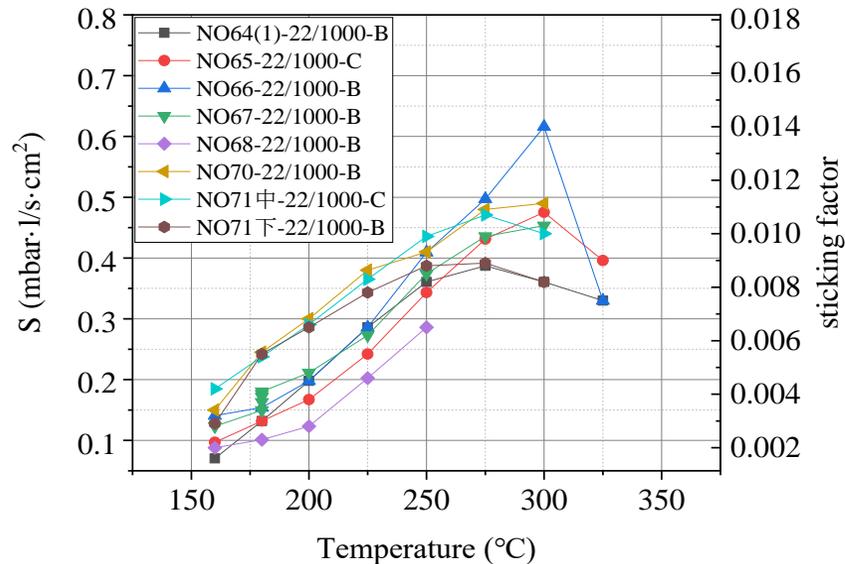


VC with photon absorber



# Benefits from NEG coating

- NEG coating of 200nm is employed to suppress e-cloud of positron ring and absorb residual gases simultaneously. SEY will blow 1.2 after 24h activation of 180°C and could even lower under higher activation temperature.
- Similar to positron ring, NEG coating is proposed to vacuum chamber of electron storage ring to absorb extra gas load.



# VC baking & Why spray heating film

*The baking is the most crucial procedure in achieving ultra-high vacuum*

□ Necessity:

- ✓ In order to meet the ultra-high vacuum requirement of achieving a dynamic vacuum level of 3.0E-10 mbar.
- ✓ NEG coating reactivation

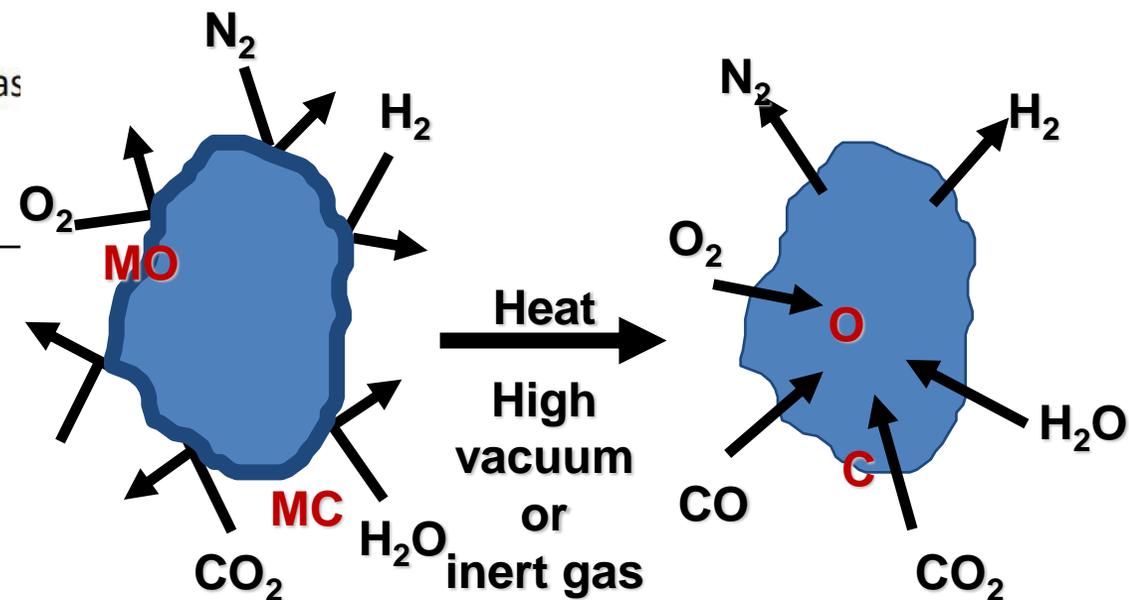
For metals:

- If not baked (not heated) in-situ **water** is the dominant gas specie.
- If baked (heated above ~120°C) in-situ **hydrogen** H<sub>2</sub> is the dominant gas

$$q_{H_2O} \approx \frac{3 \times 10^{-9} \text{ [mbar l]}}{t[h]} \text{ [s cm}^2\text{]}$$

Outgassing rates  $q \text{ [} \frac{\text{torr l}}{\text{s cm}^2}\text{]}$  at 20°C:

Austenitic stainless steel not baked, after 10 h pumping	$3 \times 10^{-10}$ (main gas: H <sub>2</sub> O)
Austenitic stainless steel baked in-situ for 24 h at 150°C	$2 \times 10^{-12}$ (main gas: H <sub>2</sub> )
OFS copper baked in-situ for 24 h at 200°C	$\sim 10^{-14}$ (main gas: H <sub>2</sub> )



# Spraying for heating film

- ◆ Multilayer heating film will be coated outside of the vacuum chamber which composed by ceramic and conductivity layer
- ◆ The heating temperature could reach 250°C

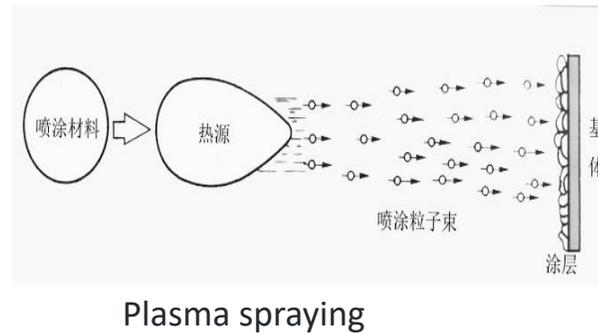
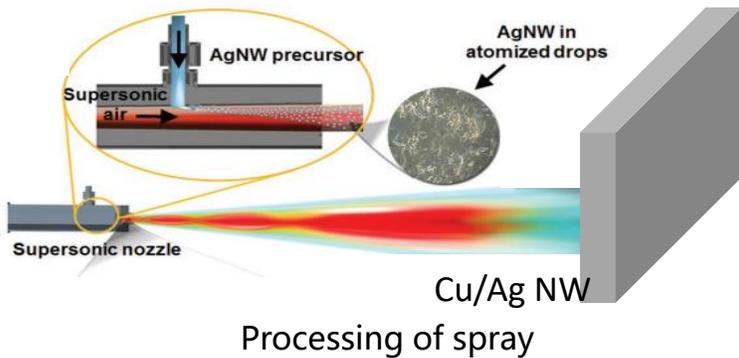
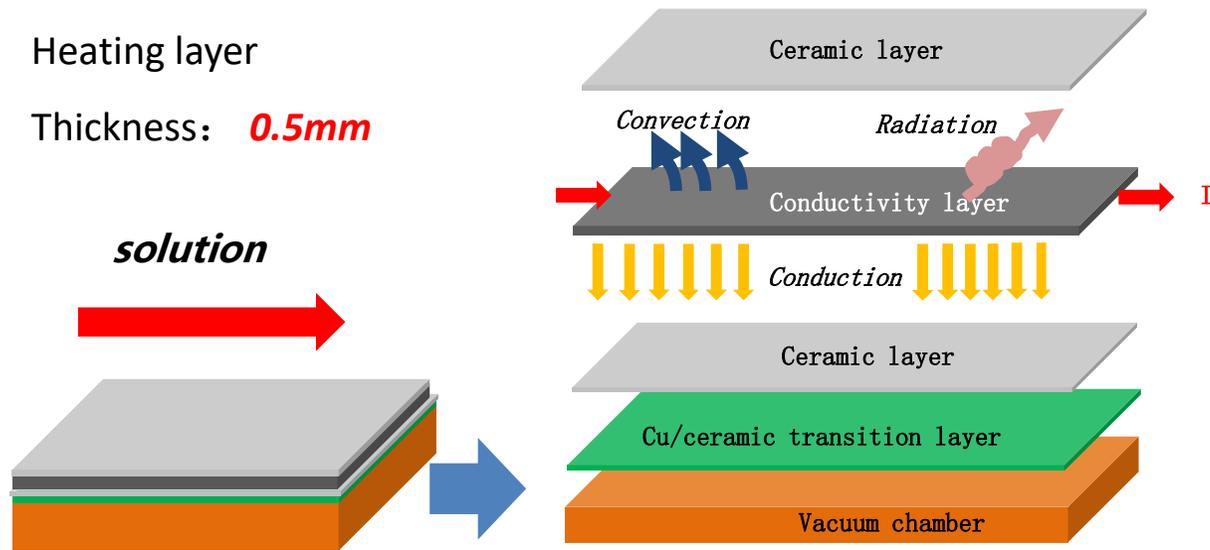
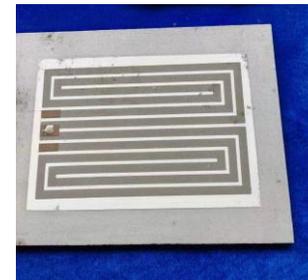
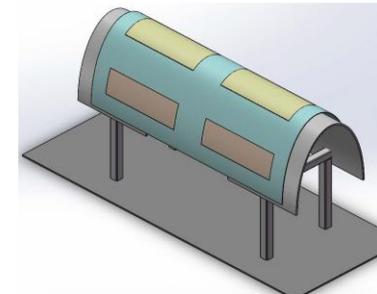


图 2.4 Oerlikon Metco UniCoatPro 大气等离子喷涂设备: (a)控制部分; (b)喷涂部分

## Related commercial products



Electric heating circuit



De-icing for airplane



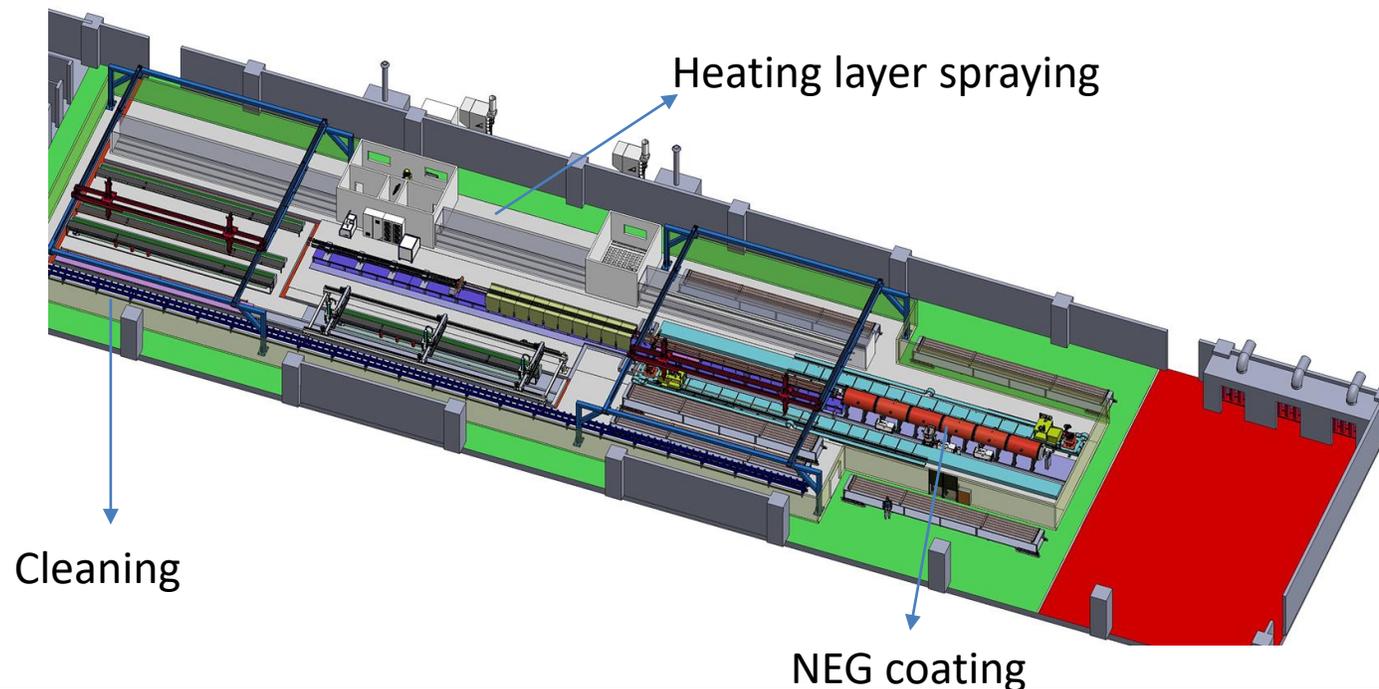
# Preview of NEG coating/ Spray for heating film production line

## ■ Requirement

- Due to the difference in length, two production lines will be used to complete the production of vacuum chambers for the CEPC collider. The quantity of NEG coating and spraying facilities for the two lines varies to match the production speed.
- The full quantity of vacuum chambers for the collider will be manufactured within five years, utilizing two production lines operating at a combined capacity of 4,500 units per year.

## ■ Advantages

More stable process, less manpower, less NEG coating facility, more adaptive capacity in production, etc.



Items	Specifications
Dimension	<ul style="list-style-type: none"><li>• L 11400-d56-D62</li></ul>
Weight	<ul style="list-style-type: none"><li>• 50~100kg</li></ul>
NEG coating	<ul style="list-style-type: none"><li>• Thickness: 200nm ± 30%</li><li>• SEY &lt; 1.1</li><li>• S、Q、 life-times</li></ul>
Spraying heating	<ul style="list-style-type: none"><li>• Thickness &lt; 0.5mm</li><li>• Heating temperature &lt; 300°C</li></ul>

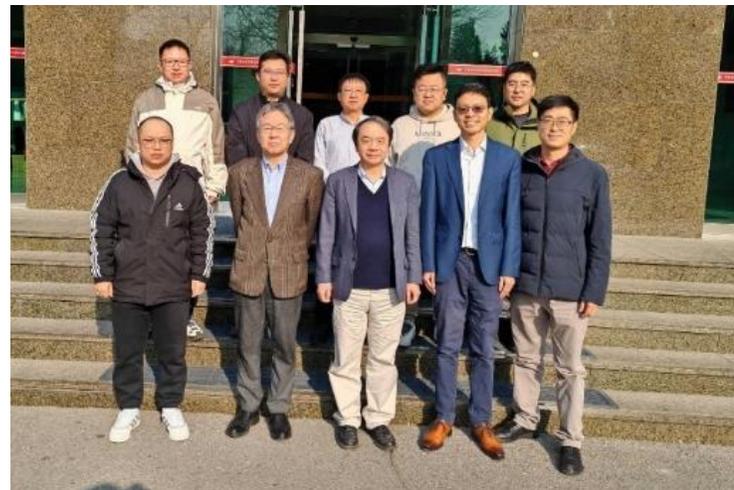
# Critical Step in the Production Line

## ◆ Important nodes and progresses

- ✓ Technical scheme review 2024.10
- ✓ Procurement bidding 2024.12
- ✓ Process Review prior to Manufacturing 2025.6
- ✓ Most of components have been manufactured 2025.11
- ✓ The production line will be conditioned 2026.3



Manufacturer visit



Project kicker off



Process Review prior to Manufacturing

# Production line composition



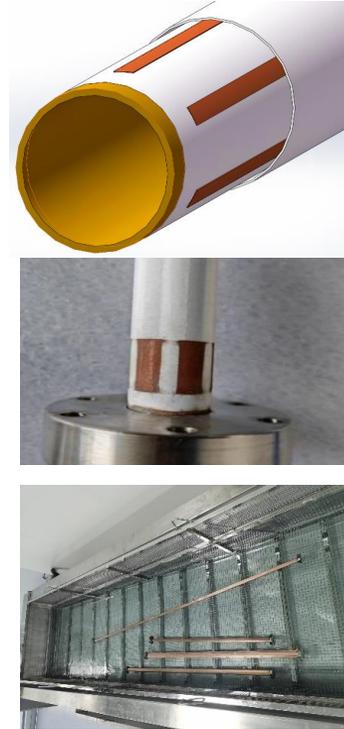
Classification	Sub-devices	Parameters	Note
Electron-beam welder	<ul style="list-style-type: none"> <li>• Electron-beam gun</li> <li>• Power supply</li> <li>• Vacuum chamber</li> </ul>	<ul style="list-style-type: none"> <li>• Meets the Length of 11.4m vacuum chamber</li> <li>• 6 working position</li> </ul>	Design and manufacturing
Brazing	<ul style="list-style-type: none"> <li>• Mechanical holder</li> <li>• Power supply</li> </ul>	<ul style="list-style-type: none"> <li>• 350°C</li> <li>• 11.4m long</li> </ul>	Low temperature brazing in air by conductivity heating, expecting steady by double hole copper tube
Heating film spraying facility	<ul style="list-style-type: none"> <li>• Electron-beam gun</li> <li>• Power supply</li> <li>• Controller</li> <li>• Mechanical Structure</li> </ul>	<ul style="list-style-type: none"> <li>• Meets the Length of 11.4m vacuum chamber</li> <li>• Multilayer Spray</li> <li>• Ceramic and conductivity layer</li> </ul>	R&D
NEG coating tower	<ul style="list-style-type: none"> <li>• Pumping system</li> <li>• Vacuum measurement</li> <li>• Power supply</li> <li>• Vacuum chambers</li> <li>• Discharge Gas</li> <li>• Cathode、controller</li> </ul>	<ul style="list-style-type: none"> <li>• Meets the Length of 11.4m vacuum chamber</li> <li>• 6 working position</li> <li>• Background vacuum &lt;math&gt;5 \times 10^{-7}&lt;/math&gt;Pa</li> <li>• Baking temperature 200°C</li> </ul>	Developing to be more fitted the production line
Measurement and testing	<ul style="list-style-type: none"> <li>• Dimension measurement</li> <li>• Leakage testing</li> </ul>	<ul style="list-style-type: none"> <li>• Dimension measurement 11.5m/0.1mm</li> <li>• Leakage testing <math>1 \times 10^{-10}</math> mbar·L/s</li> </ul>	Design and manufacturing
Cleaning	<ul style="list-style-type: none"> <li>• rinsing</li> </ul>	<ul style="list-style-type: none"> <li>• deionized water rinsing</li> </ul>	Design and manufacturing
Production line auxiliary equipment	<ul style="list-style-type: none"> <li>• Moving band</li> <li>• robot arm system</li> <li>• controller</li> </ul>	<ul style="list-style-type: none"> <li>• Meets the Length of 11.4m vacuum chamber</li> </ul>	Design and manufacturing

# Procedure of NEG coating & spraying of production line



## ■ Spraying (Air plasma spraying)

- Sandblasting
- Spraying\_Isolation\_layer
- Spraying\_Conductivity-layer
- Spraying\_Isolation-layer
- Spraying\_Contactor-layer



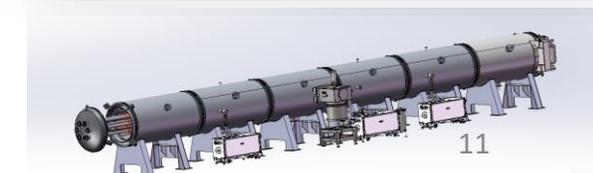
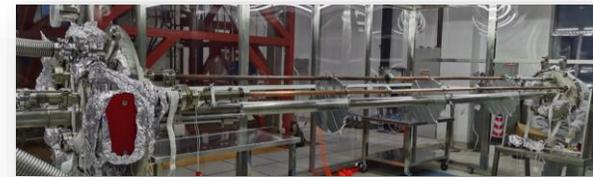
Function	Materials	Thickness/um
Transition-layer	MCrAlY alloy	50~100
Isolation-layer	Al2O3 ceramic	~200
Conductivity-layer	NiCr alloy	50~100
Isolation-layer	Al2O3 ceramic	~200
Contactor-layer	Copper	~50

## ■ Cleaning

- Outside
- Inside

## ■ NEG coating

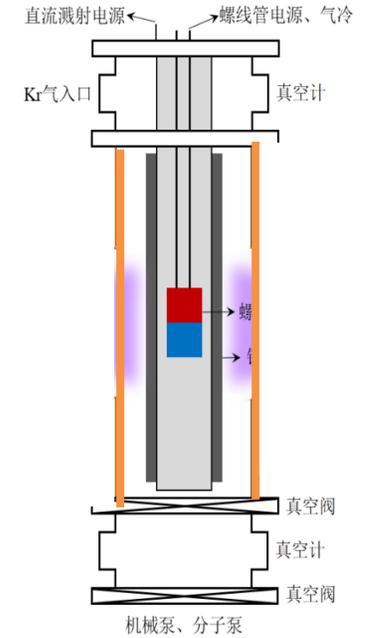
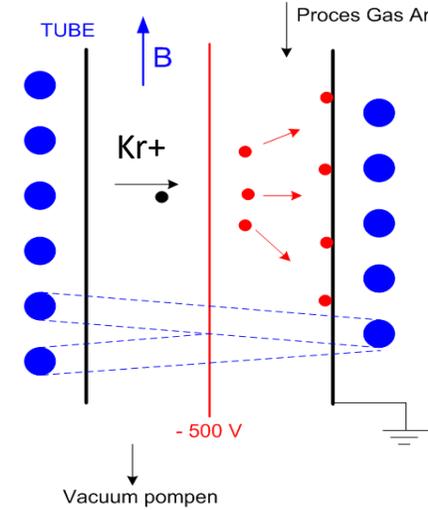
- vacuum chambers, cathodes assembling by mechanical arms (flanges sealing).
- Leakage testing.
- Deliver the assemblies to vacuum oven/ baking/ NEG coating;
- Disassembly the vacuum chambers



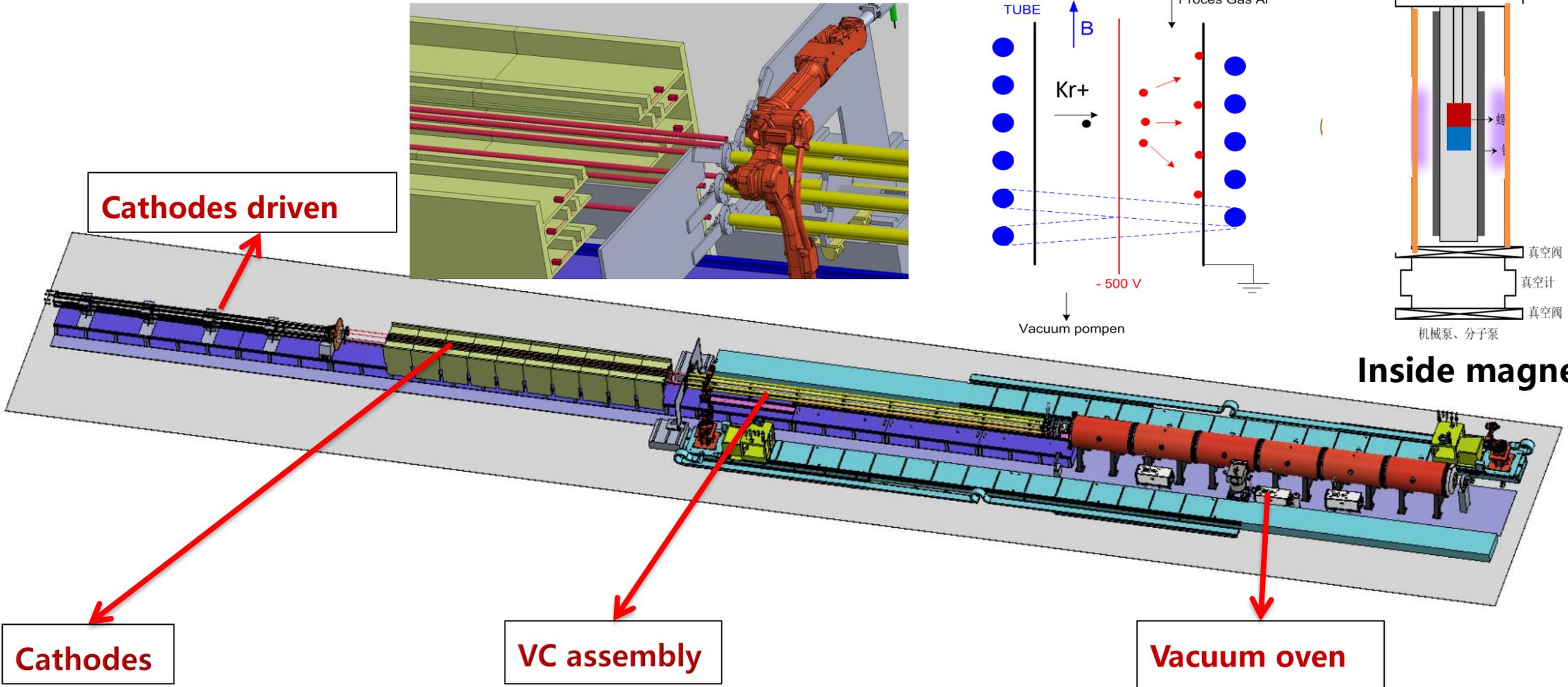
# Layout & composition of NEG coating facility

- NEG coating, VC assembly and disassembly with automatic robot arms.

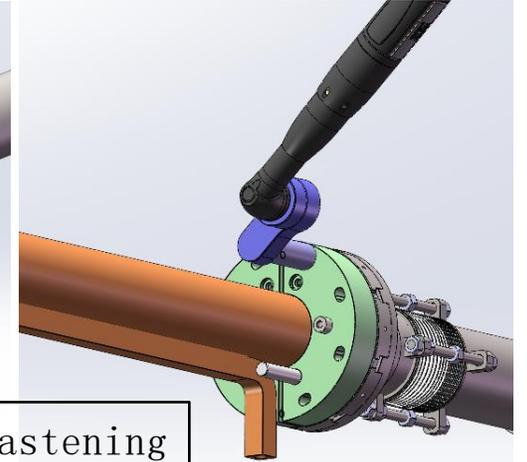
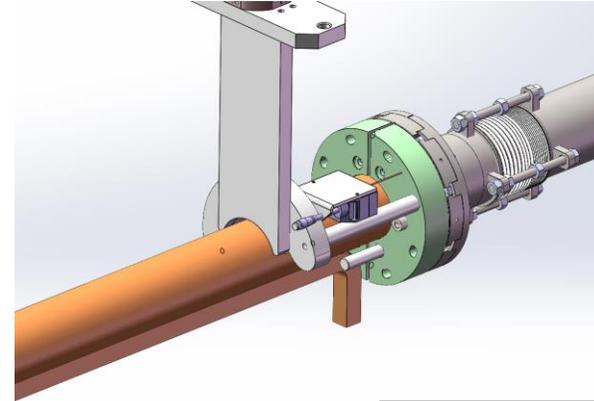
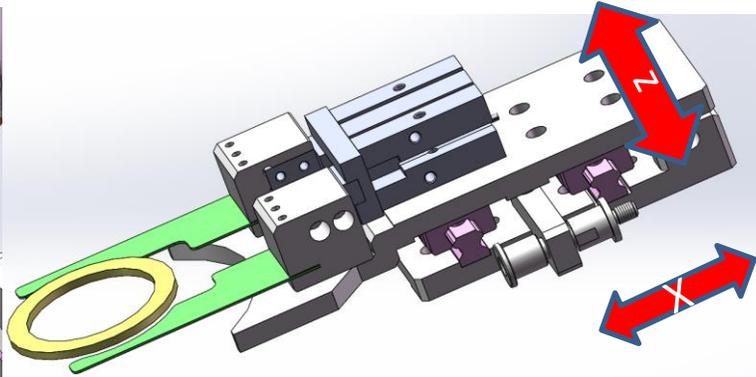
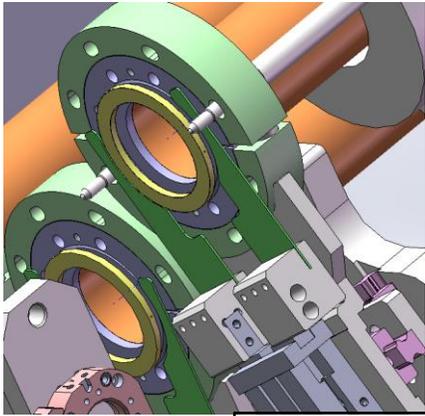
## DCMS for NEG coating



## Inside magnet

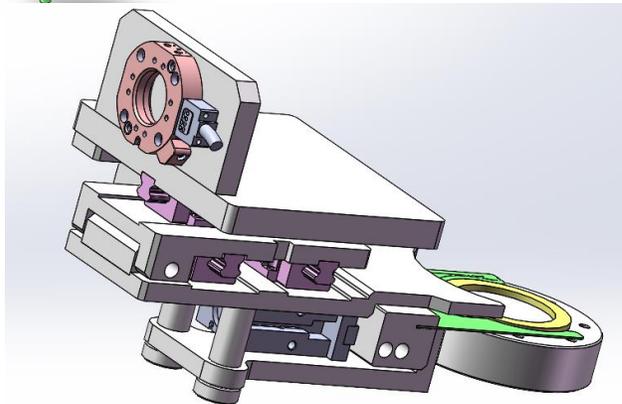
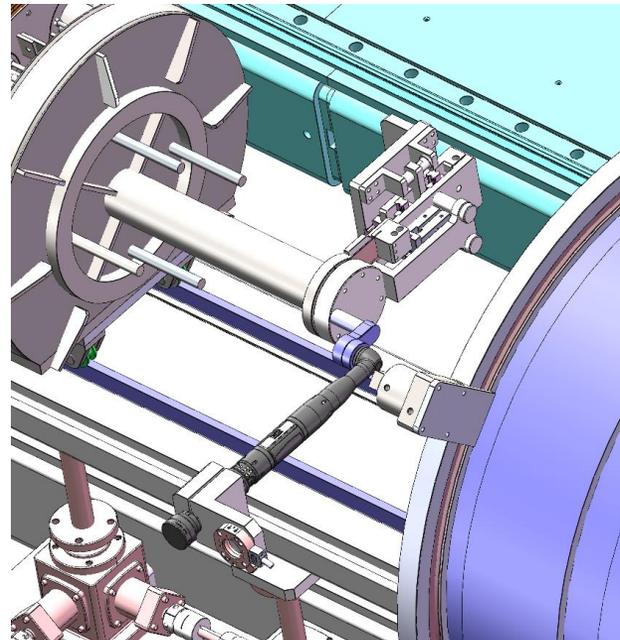
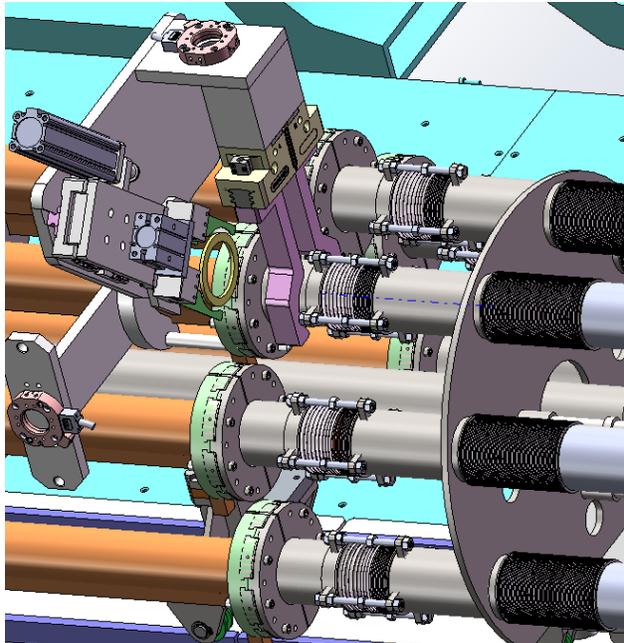


# Vacuum chamber automatic assembly



Sealing gasket installation

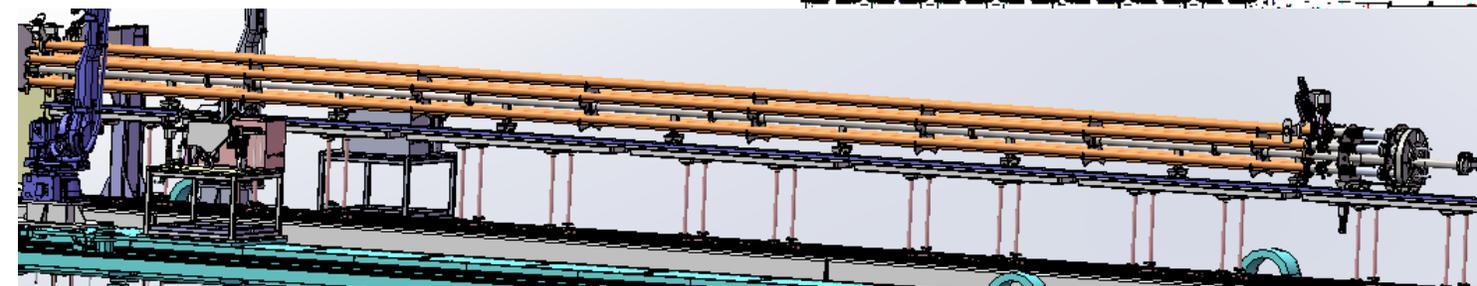
Flanges fastening



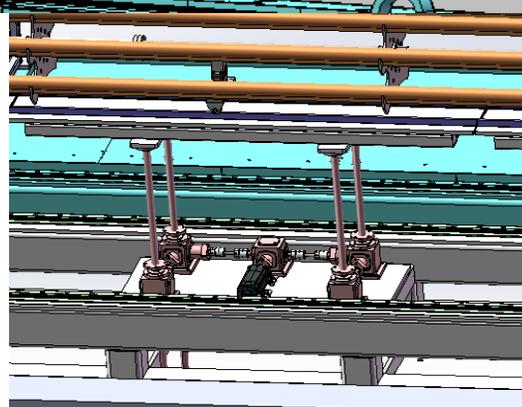
# Vacuum chamber automatic assembly

- Due to the diameter of CEPC is D56, we plan to replace the cathode wire with a magnetron sputtering cathode
- Permanent magnet instead of the solenoid which supplies magnetic field for DCMS;
- By combining the low vacuum chamber outside of the vacuum chambers to be coated with NEG, the high vacuum process is simplified;

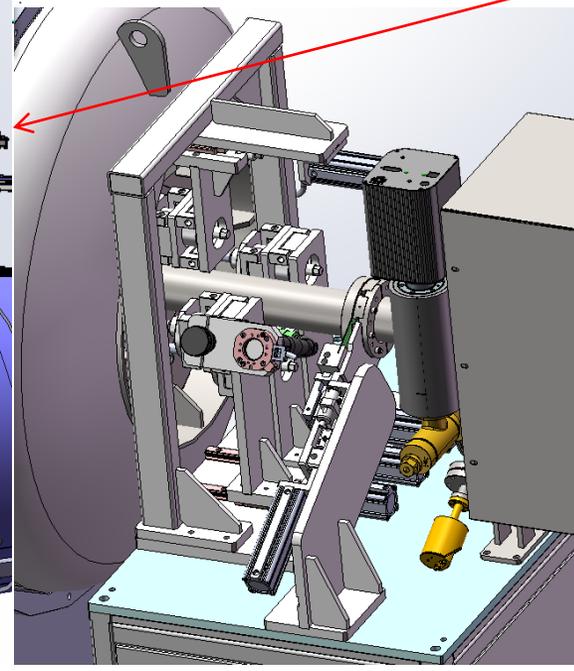
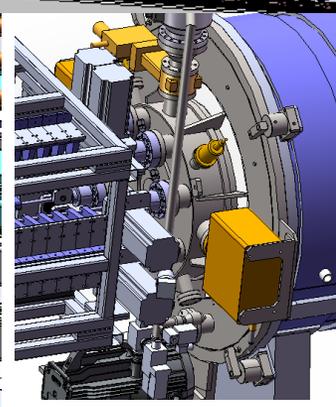
VC inserted into the oven



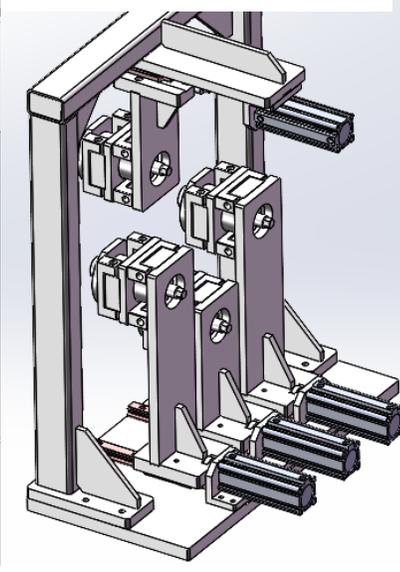
Safety insurance



VC & cathode support



UHV system for NEG coating

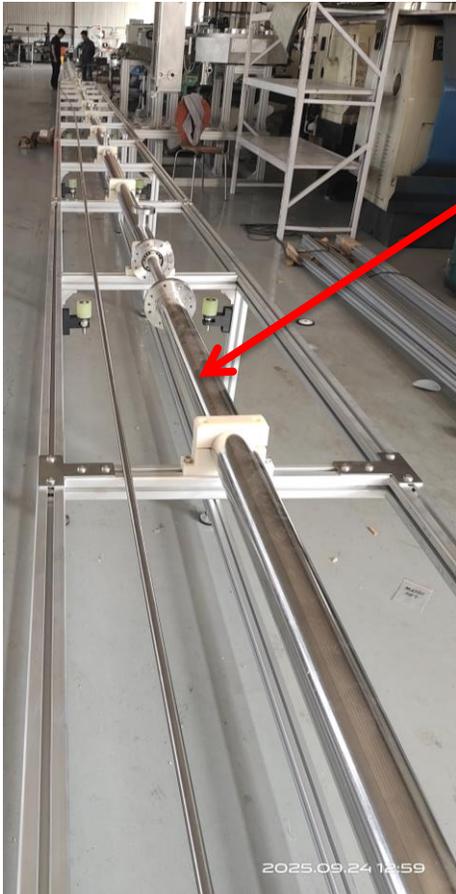


# Prototype of cathode for NEG coating

Motor for magnets driven



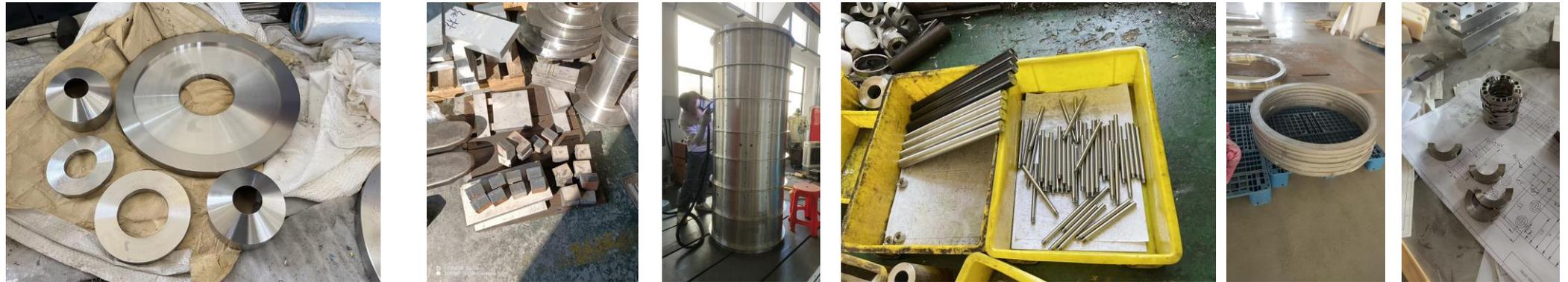
~12000mm(12 meters)



■ After testing and conditioning, the cathode achieves a stable DCMS plasma discharge under 367 V and 1.1 A.

# Manufacturing progress of production line

- The oven for NEG coating, which provides a low vacuum environment and baking capabilities, is under manufacturing.

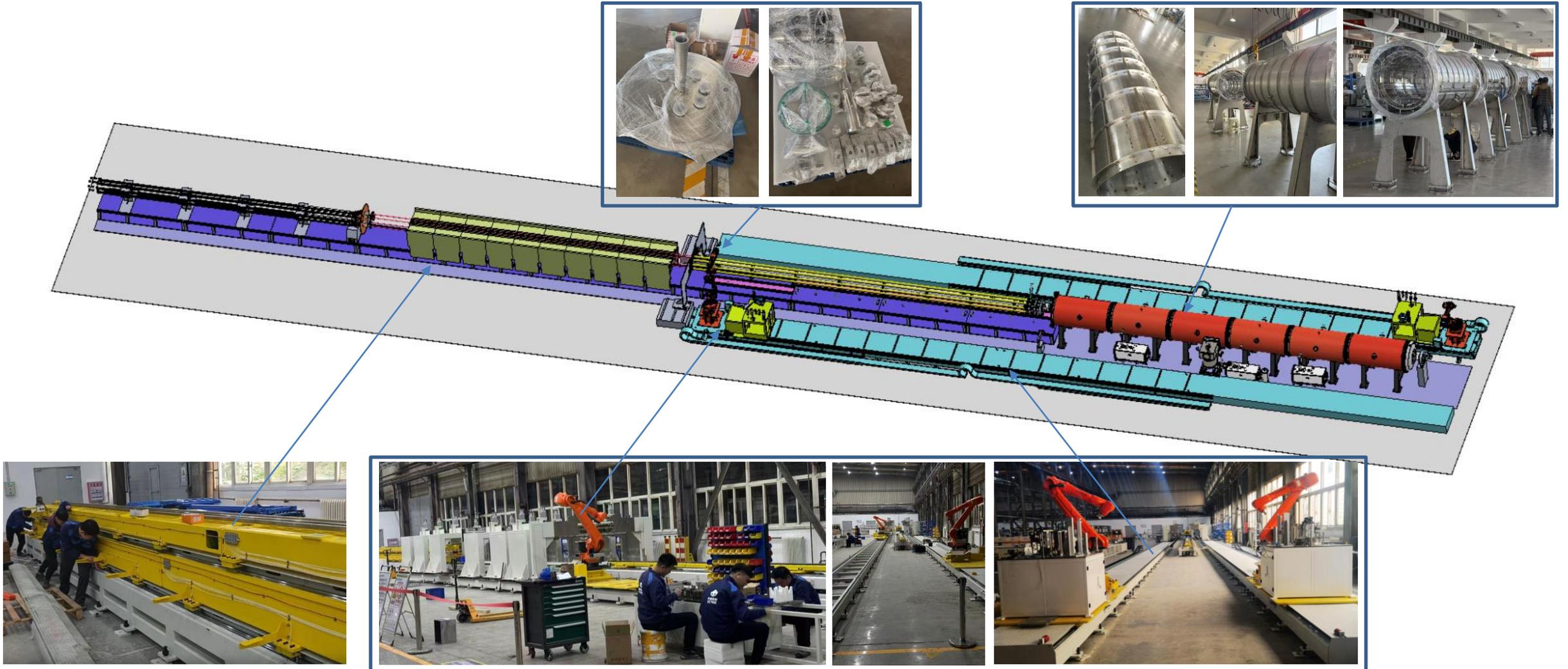


- The 12-meter cathode prototype for NEG coating is under manufacturing.

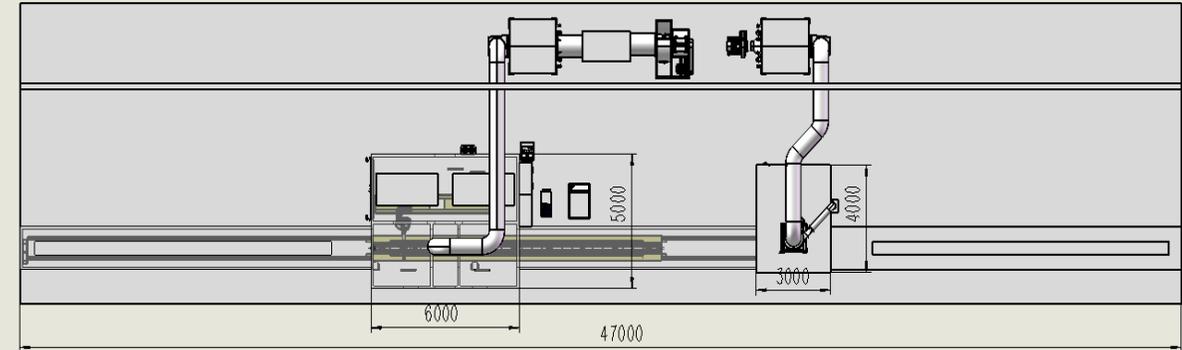
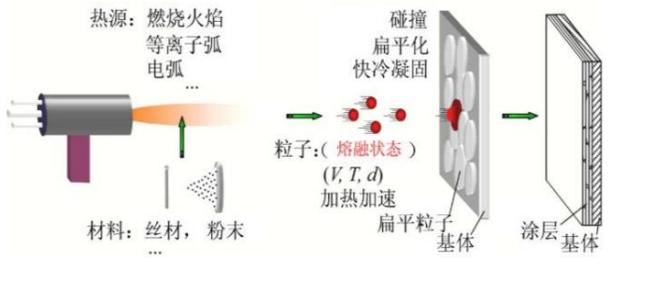


# Manufacturing progress of production line

- The main components of vacuum oven for NEG coating have been manufactured and under are now being assembled.



# Plasma Spraying system



Plasma Spraying  
& Laser etching room

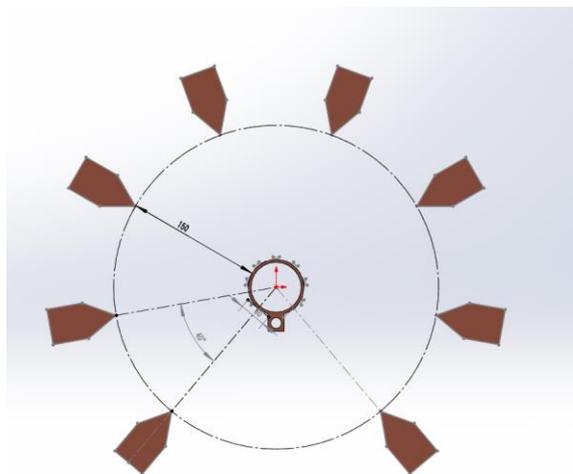
Sandblasting room

The vacuum chamber will be transferred by motorized conveyance to the coating station, where a robotic arm will execute multi-layer deposition using an automated spray gun.

# Heating coating spraying

◆ The processing step for the heating coating spraying

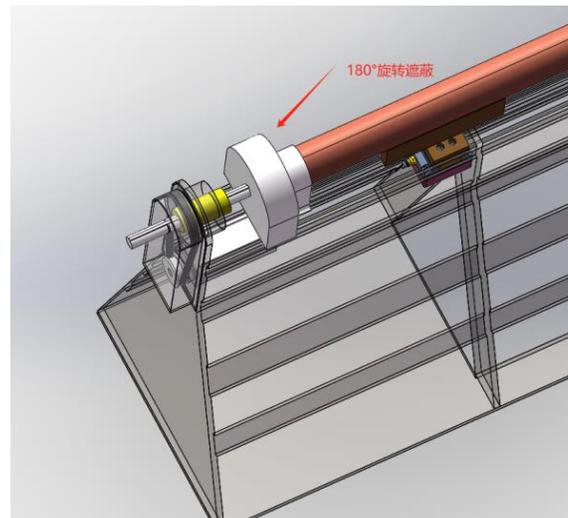
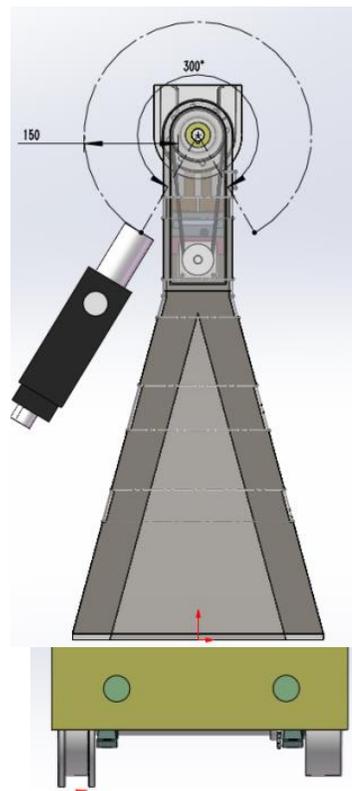
## Sandblasting



名称	参数
喷砂枪数量	8把
喷砂距离	150~180mm
喷枪喷砂有效区域	≤φ30mm
砂料	白刚玉或棕刚玉
喷枪口径	8mm
喷砂压力	0.25-0.6MPa (可调)
砂流调整范围	1~3KG/min



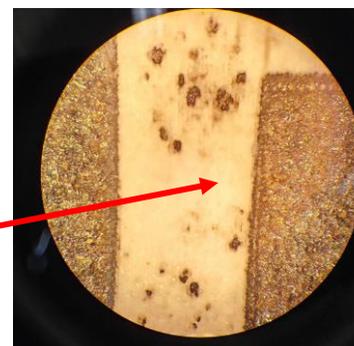
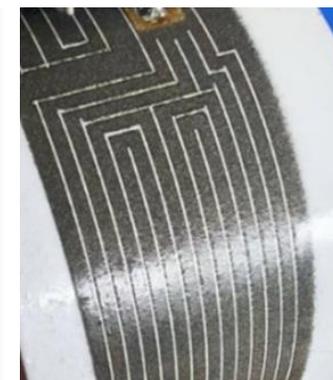
## Plasma Spraying



项目	参数
驱动方式	旋转气缸驱动
遮蔽材质	不锈钢
轴向可调节范围	100mm

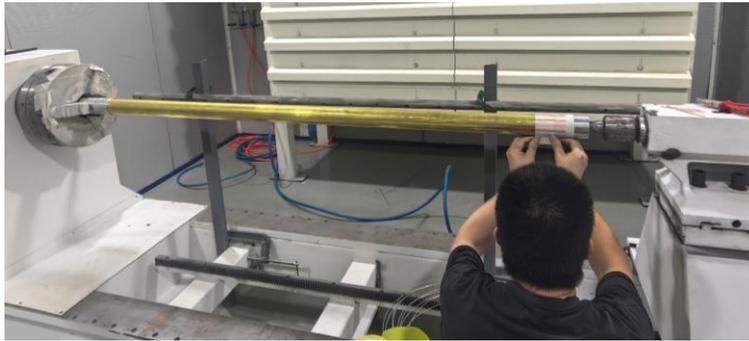


## Etching by laser

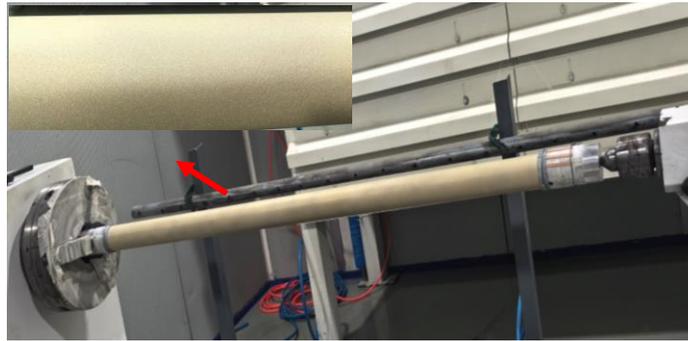


# Length of 1.5m prototype of Spraying

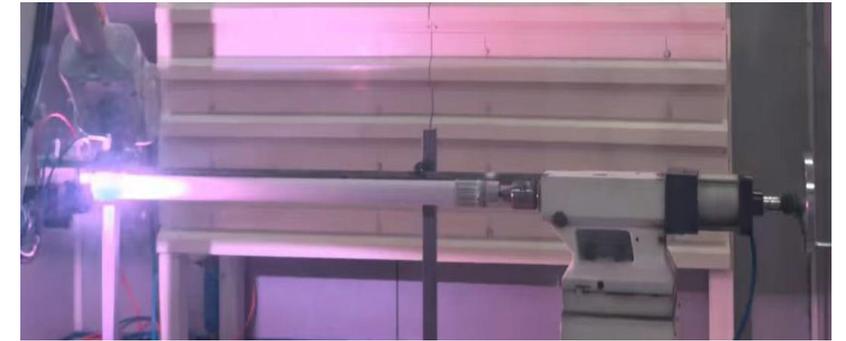
- ◆ A 1.5-meter prototype has been developed to validate key process steps that will be implemented in the production line.



Installation



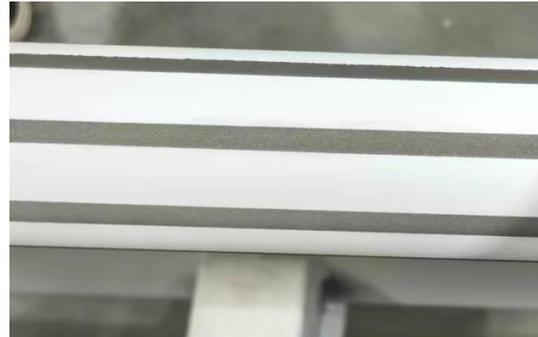
Sandblasting



Spraying



Spraying\_Isolation-layer

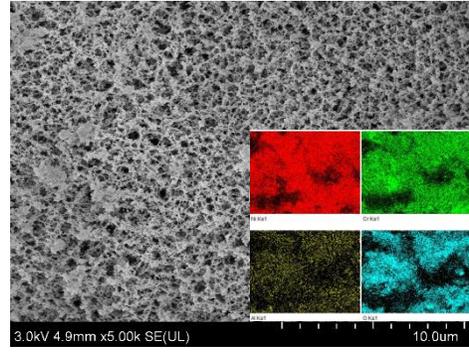


Spraying\_Conductivity-layer

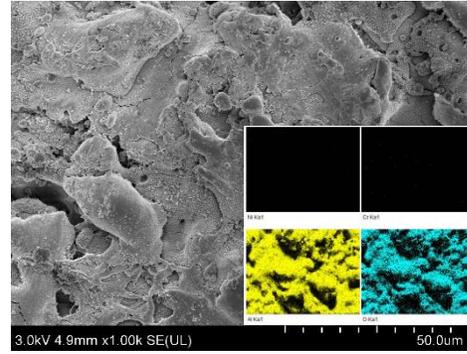


Spraying\_Isolation\_layer

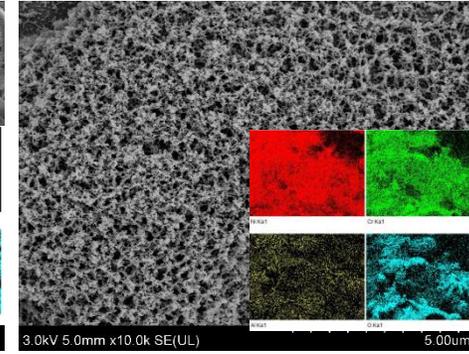
# Elements and thickness of thermal-spray heating layer



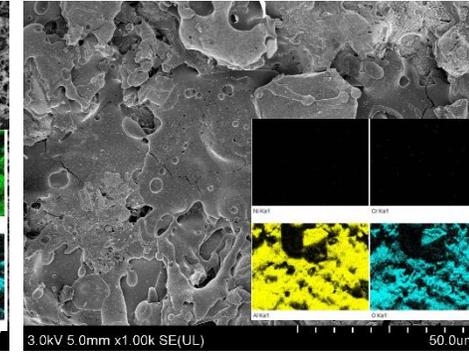
NiCr Conductivity-layer



Al<sub>2</sub>O<sub>3</sub> isolation layer

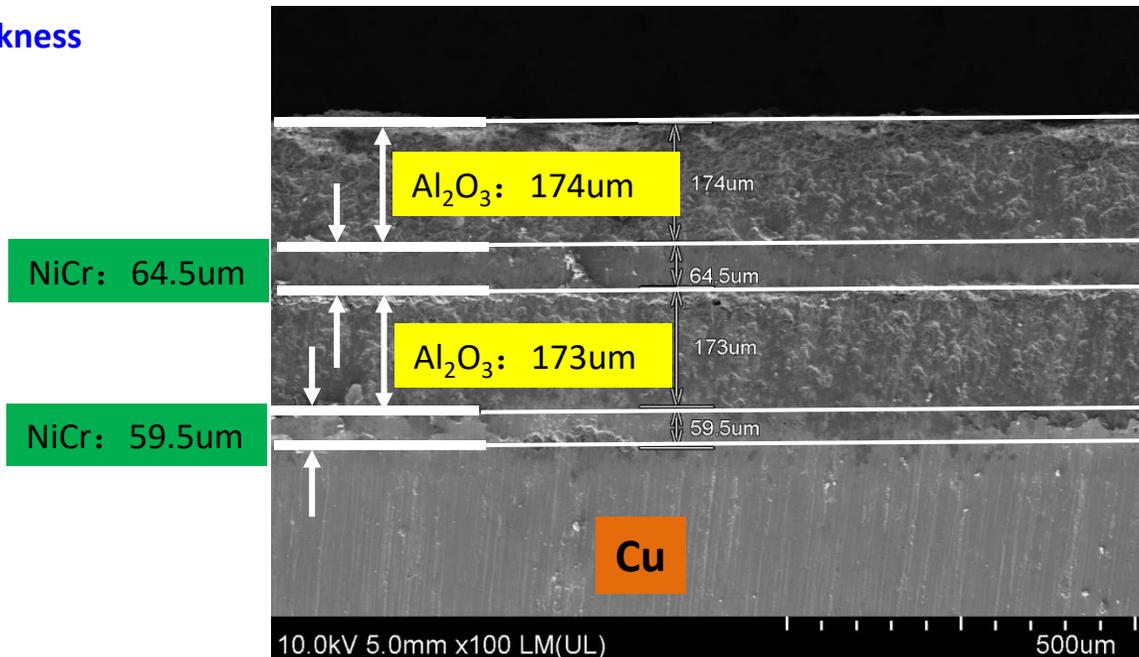


NiCr Transition-layer



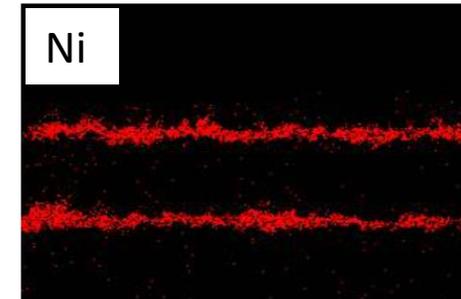
Al<sub>2</sub>O<sub>3</sub> isolation layer

## Thickness

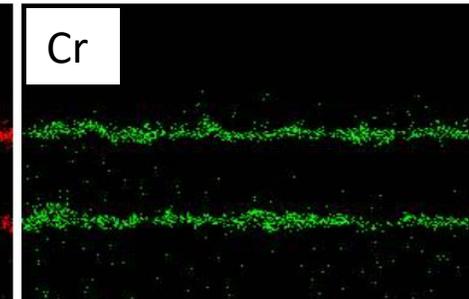


=471um

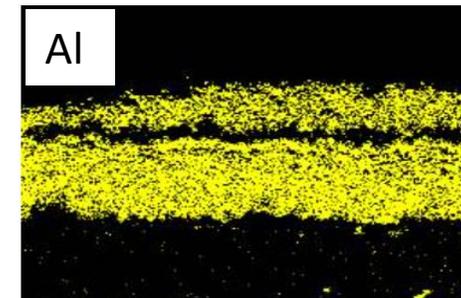
< 0.5mm



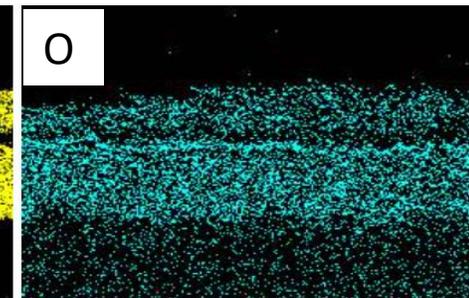
Ni Ka1



Cr Ka1



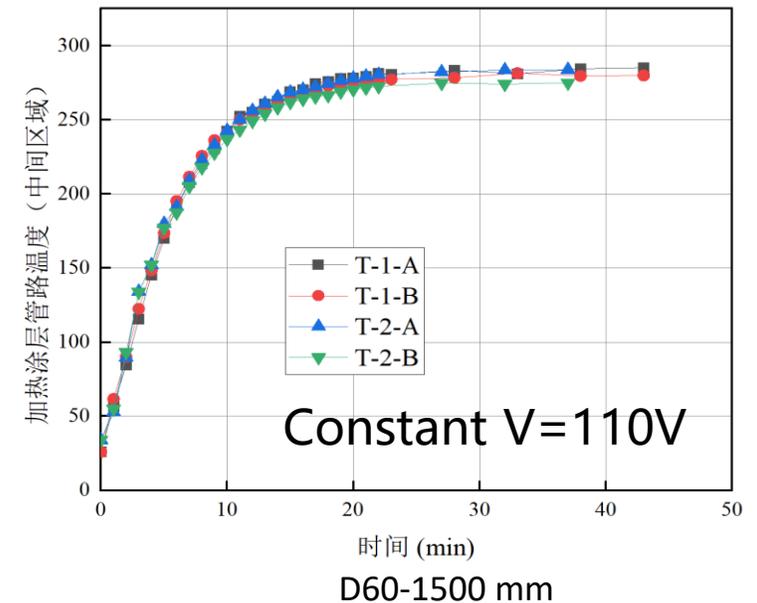
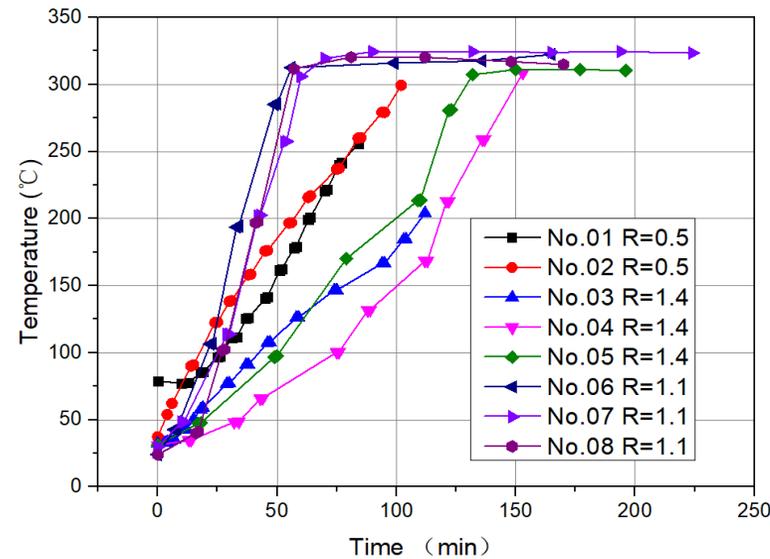
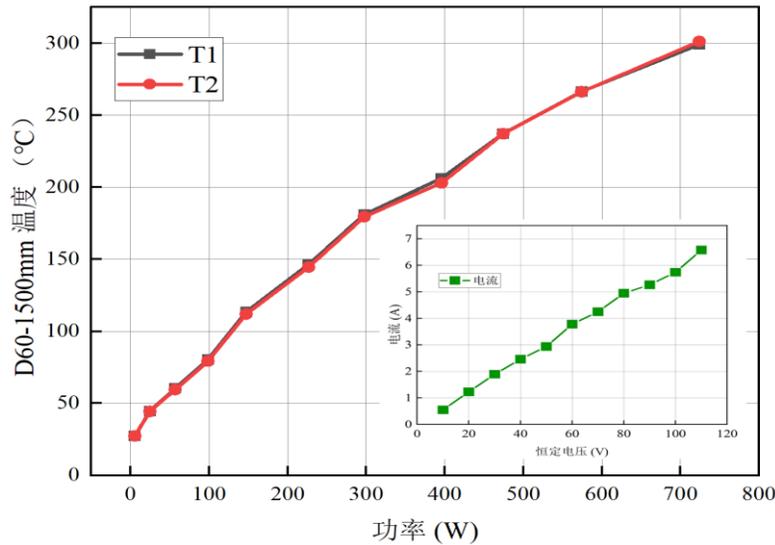
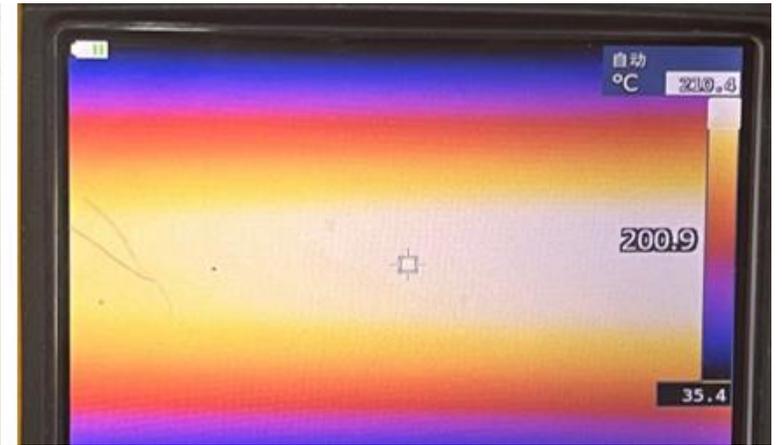
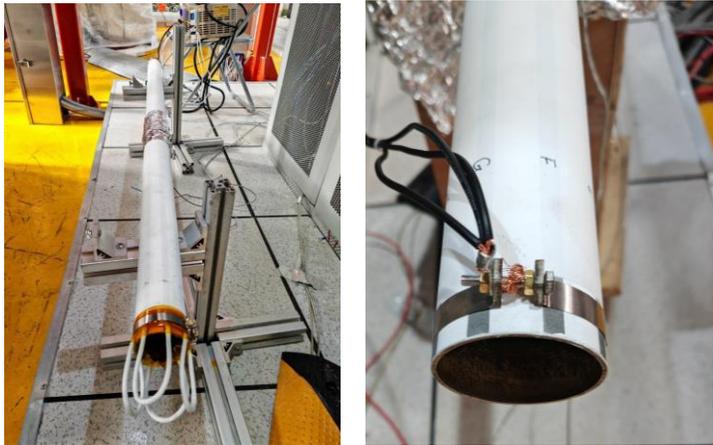
Al Ka1



O Ka1

# Prototype of thermal-spray heating layer and testing

Dimension: L1500\*D60 Substrate: copper



Several ten times reheating tests which shows a good lifetimes and performance

# Plasma spraying devices

- The spraying system is similar to the system detailed in the following pictures.



# Summary

- The production line for vacuum chamber NEG coating and thermally sprayed heating layers is currently under installation and will be commissioned by March 2026.
- It is capable of handling vacuum chambers with a minimum dimension of 56 mm and a maximum length of 11.5 meters for NEG coating applications. There are no dimensional restrictions for the thermal-sprayed heating layer process.
- This production line will be up and running soon—we're open for business and welcome collaboration on related manufacturing tasks.
- Additionally, a 1.5-meter prototype of the thermally sprayed heating layer has been fabricated, with relevant performance tests successfully completed.

**Thanks for your attention!**