Progress in Coating on Inwall of the Ceramic Vacuum Chamber for the Collider Ring's Kicker of CEPC

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Collider Ring's Kicker of CEPC and Ceramic Vacuum Chamber

Design parameters of Collider Ring's Kicker of CEPC	
Configuration of Kicker	Window Frame
Rising Edge	200 ns
Flat Top Time	0 ns – 1980 ns
Length	1000 mm

- Configuration of Kicker → A ceramic vacuum chamber can be used.
- Rising Edge → Extremely strong eddy-current shielding effect.
- Flat Top Time → Maintaining the magnetic field waveform is important.
- Length → Loops of eddy currents are long.

Design parameters of Ceramic Vacuum Chamber	
Length	1200 mm
Section Shape	Racetrack
Section Dimension	75 mm(W) × 56 mm(H)
Material	Alumina - 99

- Length → One of the longest integrated ceramic vacuum chambers.
- Section Shape → Limitation of firing ceramic technology. Not an ellipse.
- Section Dimension → Keep the ellipticity of the aperture consistent.
- Material → Good sealing, high temperature and wear resistance, etc.

Pattern coating trades off eddy currents and impedance. → Select the coating pattern from the perspective of the eddy-current shielding effect. **Page 2** → Analyze the beam impedance of a ceramic vacuum chamber with pattern coating. **Page 3** → Progress in coating experiments. **Page 4**

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The finite element simulation software COMSOL is used to calculate the effect of the pattern coating on the fast-pulsed magnetic field.

There are a few points to note:

- The structure of the kicker is very complex. To simplify the model, a relatively simple magnet model was constructed. The rising edge (falling edge) of the magnetic field is 200 ns, the flat top time is 400 ns, and the peak magnetic field is about 550 Gauss.
- The eddy current loop is related to the length of the metal coating, so the ceramic vacuum chamber in the model is the same as the real thing, rather than calculating a short sample.
- Meshing the coating is very difficult. Considering that eddy currents are only sensitive to the conductivity of metallic materials, the coating is treated with an equal square resistance, that is, the thickness increases and the conductivity decreases.

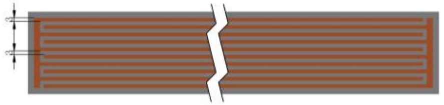
How to come up with coating patterns?

For eddy currents:

- No DC connection upstream and downstream of the coating.
- Short loop for eddy currents.

For Impedance and SEY:

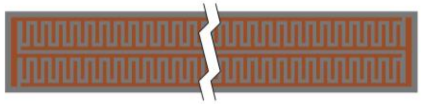
- Cover the ceramic surface as much as possible.
- Form capacitive structures, that is, pass high frequency, block low frequency.



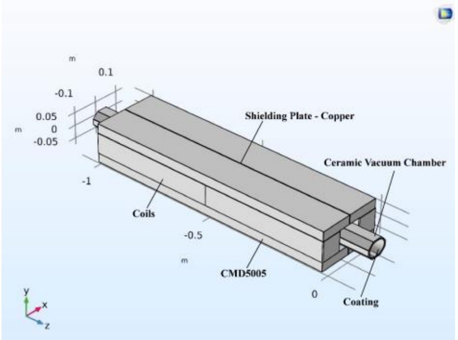
comb3

comb5

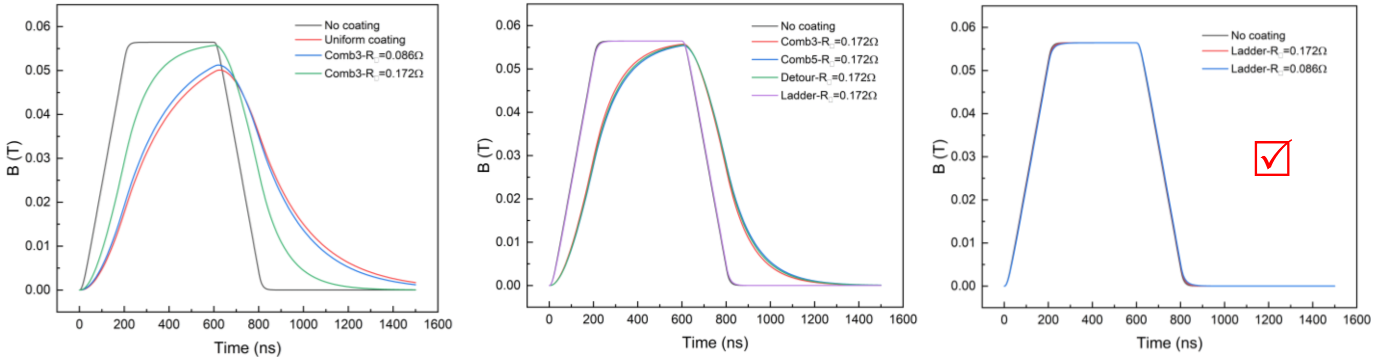
detour



ladder



Model in COMSOL



The effect of different square resistance of pattern coatings on the magnetic field waveform.

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There are some difficulties in calculating the impedance of a ceramic vacuum chamber with pattern coating:

•For multilayer wall resistances, IW2D gives an analytical solution with highly confident results. However, IW2D can only define a two-dimensional aperture, which means that it **can** calculate the impedance of a uniform coating, but it **cannot** calculate the impedance of a pattern coating.

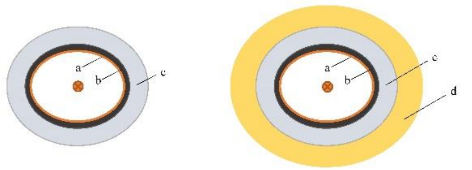
•CST can calculate 3D models. However, CST is a finite element simulation software, which is very difficult for the meshing of coatings. Due to the complexity of electromagnetic fields, simple equal square resistance methods can no longer be used. And CST results may be distorted at too low or too high frequency.

A workable solution:

•**IW2D** calculates the wall resistance of uniform coating as a reference.

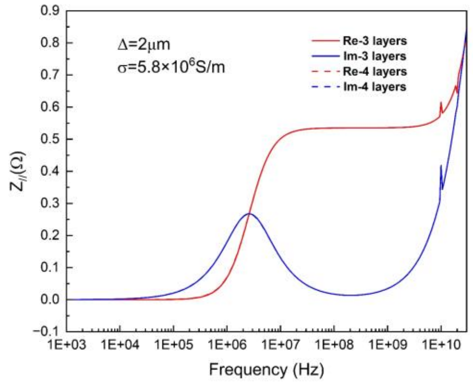
•Select the suitable modeling method for uniform coating in **CST** to bring the results close to IW2D.

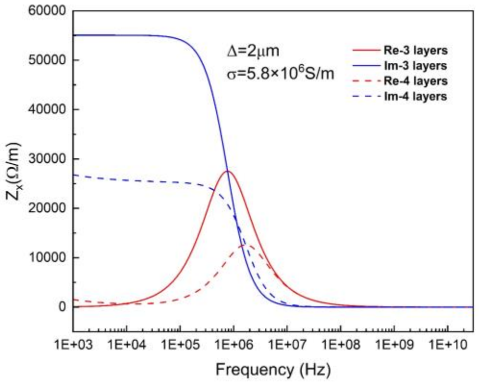
•Model pattern coatings in CST to calculate impedance.

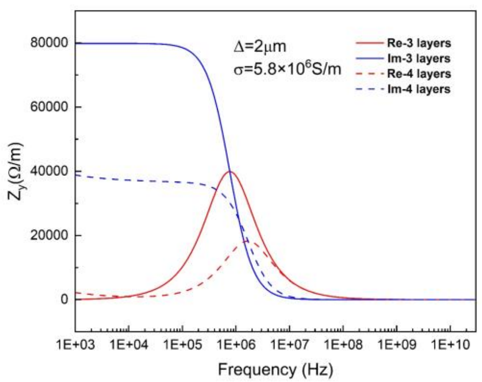


IW2D a:2 μm TiN, b: 5 mm Ceramic chamber, c:5 mm Air, d:PEC

The impedance of a kicker using a uniformly coated ceramic vacuum chamber should be somewhere in between.



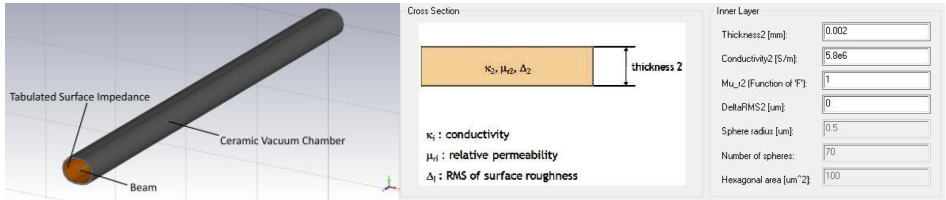


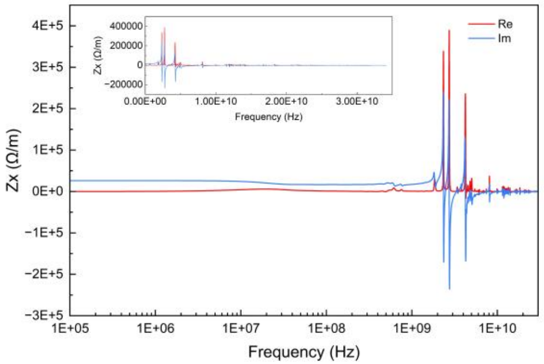


Modeling methods for coatings in CST:

Tabulated Surface Impedance

The coating is a component without thickness in the model, but its properties can be set by creating a new material.





☜ Calculation results of transverse impedance Zx of ladder pattern coating by CST.
More results are still being calculated...

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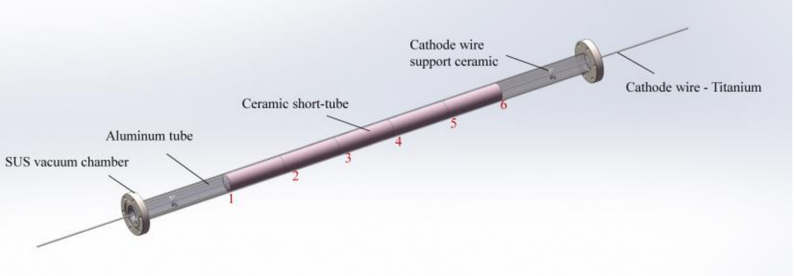
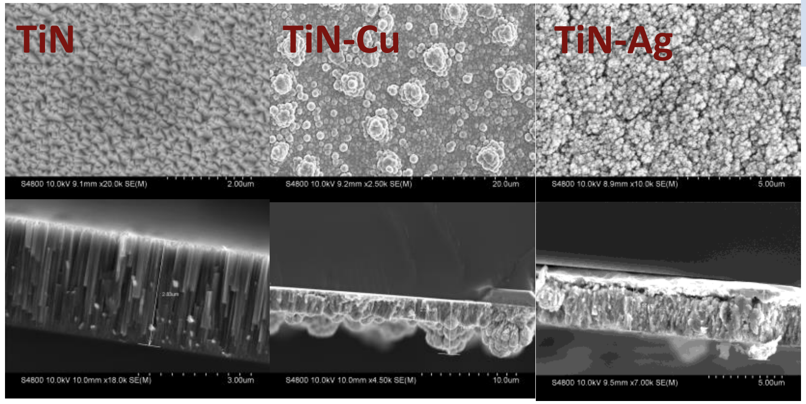
Based on the coating of the circular vacuum chamber, the coating process is explored.

- The development process is from simple to complex.
- The vacuum chamber used for the spare parts of the HEPS pre-dump beam kicker is a 500 mm-long circular ceramic vacuum chamber.
- The magnetic field waveform is a 4 μs half-sine wave.
- The magnetic field changes slowly and the eddy current loop is short. Therefore, uniform coating can already meet the requirements of maintaining the magnetic field waveform.
- After the circular vacuum chamber coating is completed, the coating of CEPC's racetrack-shaped ceramic vacuum chamber becomes easy.





coating	conductivity	roughness
TiN	376000 S/m	smooth
TiN-Cu	1807000 S/m	rough
TiN-Ag	6230000 S/m	smooth

Adjusting different parameters, the conductivity of pure TiN coating is always lower than expected.

Doping silver or copper in TiN to improve conductivity.

From the perspective of surface roughness, TiN coating with silver doped is a better choice.

A rendering of coating system for racetrack-shaped ceramic vacuum chamber.

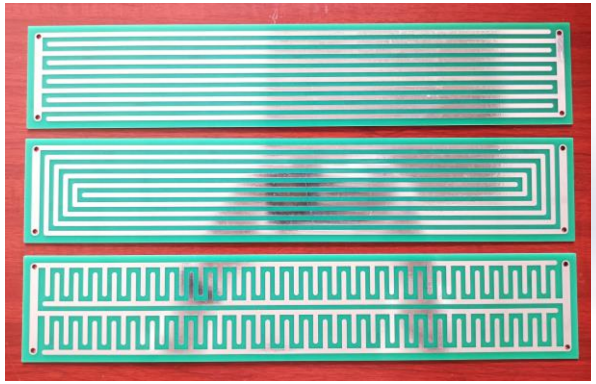
The coating parameters refer to the circular ceramic vacuum chamber. The difference is that in order to make the coating thickness distribution on the cross-section more uniform, the "double cathode wire" method will be used.

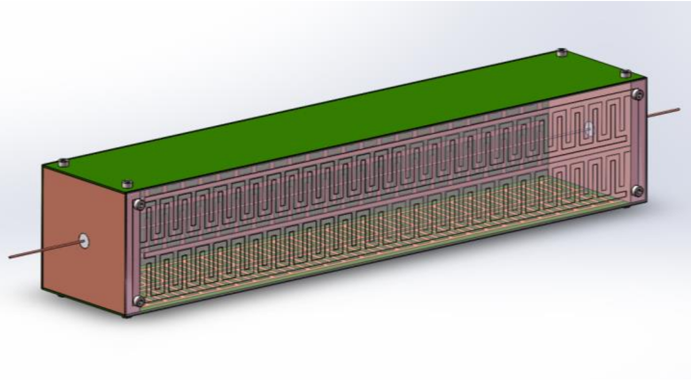
What to do NEXT?

For Impedance:

•Continue to optimize the model in CST to calculate the impedance of the pattern coating.

•The coating patterns are printed on the PCBs, and the transmission characteristics of the patterns will be compared using the coaxial line.





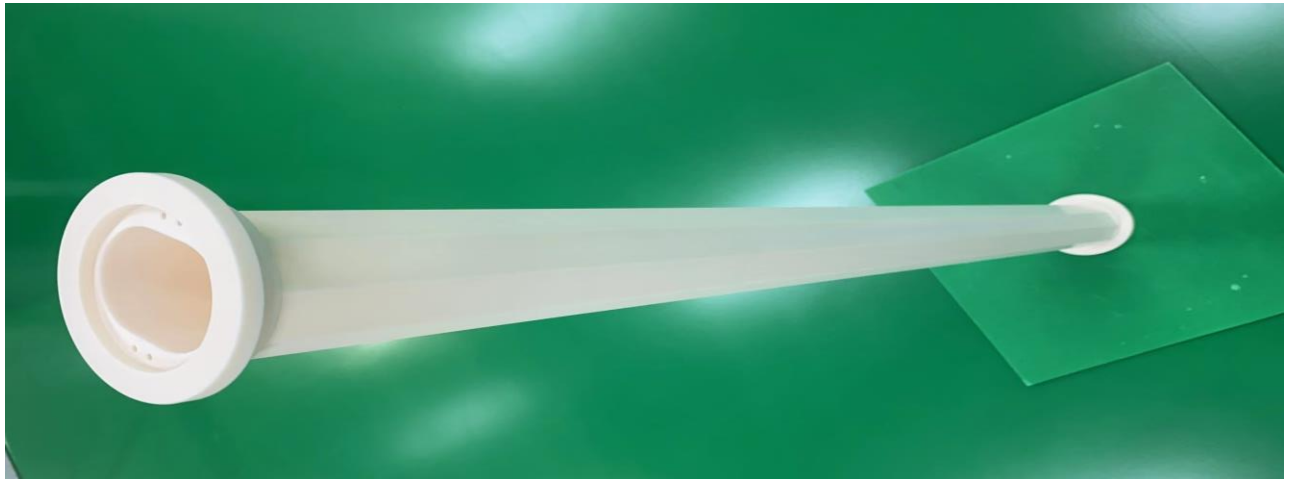
For Coating Experiment:

•The secondary electron yield (SEY) of TiN coating with silver doped will be tested.

•A 1200 mm-long integrated ceramic vacuum chamber is about to leave the factory.

•This ceramic vacuum chamber wall is coated with ladder pattern.

•Complete the measurement of magnetic field and impedance.



THANKS!