# TiN coating on coupler window

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Coupler collaboration meeting
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A Partnership of:
US/DOE
India/DAE
Italy/INFN
UK/UKRI-STFC
France/CEA, CNRS/IN2P3
Poland/WUST

# TiN coating of ceramic hints

- 7-14 nm kind of optimal thickness of TiN. If thickness < 4nm – high SEY, >15nm – high electrical conductivity – losses/heating

- Advantages:
  - Reduce SEY from  from 8 to 1 ➔ suppress MP activity in window
  - electrical conductivity help for charge removal to prevent sparks, discharge, breakdown (operation with beam)

- Disadvantages/Issues
  - Extra Cost: estimation 5-10% of coupler cost (CPI,…)?
  - Control uniformity, thickness, resistivity of TiN - samples
  - Effect of Oxidation (exposure to air)
  - Possible degradation during processing and operation (bursts, breakdown)

# Questions

Today TiN (TiO, Cr2O3) coating of coupler ceramic is using in many couplers (pulse and cw)

- How stable and reproducible the technology?
- Optimal thickness, what typical thickness variation vendor can provide? CPI/Thales/RI/…
- Existing experience; including processing and beam operation
  - Are any difference between Electron and Proton machines?
  - Performance with and without DC bias?
  - Most common failures of the ceramic (crack and vacuum leak), increase ceramic heating (MP start, electrical conductivity, ceramic loss)?

# Some experience with TiN coated window

- **Positive**
  - EXFEL, ESS, SNS, …  - easy processing?, working w/o DC bias in operation?
- **Negative**
  - FNAL RFQ coupler; grey color and high bias current (high electrical conductivity) after few ~ 1 month of operation.
  - China ADS front-end (HWR): in 2 months 4 couplers (out of 12) were broken (10kW) ➔ replaced with 2-window design

# Experience with TiN coating-free ceramic

- KEK/STF-2 coupler, no bias. Processed w/o bias (?), no MP. - ILC R&D
  - New development: conductive ceramic (cost reduction ILC R&D)

- FNAL;
  - SSR1 coupler was processed with DC bias ➔ no MP (few bursts during processing) – few windows developed leak after processing (brazing issues), 1 leak (out of 10) after cold test
  - 650 MHz coupler was processed with and w/o DC bias (4 couplers). No MP after processing (bias), small residual activity after processing w/o bias
  - Euclid Techlab (SBIR project)– conducting ceramic development (650MHz coupler) will be tested in August

# Summary

- TiN coating of ceramic is challenging but known technology, many coupler vendors do this.
  - Helps to suppress MP, also remove charge from ceramic due to electrical conductivity
  - Used for many built couplers (vacuum side), but
    - can be destroyed by bursts during conditioning/operation (China ADS).
- Positive experience with TiN coating-free ceramic:
  - KEK/STF-2 coupler (no bias?),
  - FNAL: SSR1 coupler with bias (warm and cold). 650MHz coupler (processing with and without bias). No beam operation yet.
- DC bias suppress MP completely, but
  - Vacuum bursts during conditioning/operation are possible - vacuum leak (design issue?)
  - Ceramic charging during operation may cause discharge/arc and destroy ceramic
  - More data will be available after testing modified designs (325 and 650)

# Plans for TiN coating studies for PIP-II couplers (under discussion)

Use existing SSR1 ceramic disc (~10) for TiN coating and measurements:

- TiN thickness and resistivity, deposition contents (vs. thickness)
- Loss factor measurements
- Charge removal rate (electron microscope)

- CPI – interested to do TiN coating, we are discussing details (meeting)

- Euclid Techlab: has experience, qualified personnel, TiN coating chamber, tools (electronic microscope, thickness measurements, etc.)