Investigation on Cs dispersion and Mo coating on SPIDER components

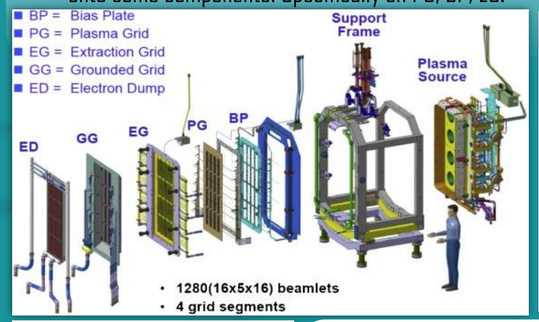
Candela V. [1, 2] *, Cavallini C.[1, 3] *, Gasparrini C.[3, 4], Arlmelao L. [5, 6], Candeloro V.[3], Dalla Palma M.[3,7], Fadone M.[3], Marcuzzi D.[3], Pavei M.[3], Pouradier Duteil B.[3,8], Rancan M.[5], Rizzolo A. [3], Sartori E. [3,9], Segalini B.[3], Serianni G.[3], Spolaore M.[3], Zorzi. F.[10], Sonato P.[3,9]

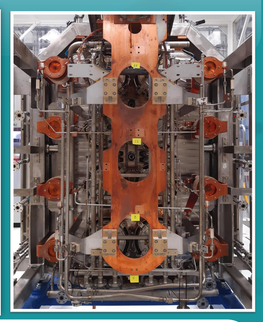
1) Centro Ricerche Fusione, Università degli Studi di Padova, Corso Stati Uniti, 4, 35127 Padova, Italy; 2)Istituto Nazionale di Fisica Nucleare (INFN) - Sezione di Padova, Via Marzolo 8, 35131 Padova, Italy; 3) Consorzio RFX (CNR, ENEA, INFN, Università di Padova, Acciaierie Venete SpA), Corso Stati Uniti, 4, 35127 Padova, Italy; 4) Department of Materials & Centre for Nuclear Engineering, Imperial College London, London, SW7 2AZ, UK; 5) Department of Chemical Sciences, University of Padova, via F. Marzolo 1, 35131 Padova, Italy; 6) Department of Chemical Sciences and Materials Technologies (DSCTM), National Research Council (CNR), Piazzale A. Moro 7, 00185 Roma, Italy; 7) CNR - Istituto per la Scienza e Tecnologia dei Plasmi, Padova, Italy; 8) Swiss Plasma Center (SPC), Ecole Polytechnique Fédérale de Lausanne (EPFL), CH-1015 Lausanne, Switzerland; 9) Dipartimento di Ingegneria Industriale, Università degli Studi di Padova, via Gradenigo 6°, 35131 Padova; 10) Centro di Analisi e Servizi Per la Certificazione (CEASC), University of Padua, 35121 Padua, Italy.

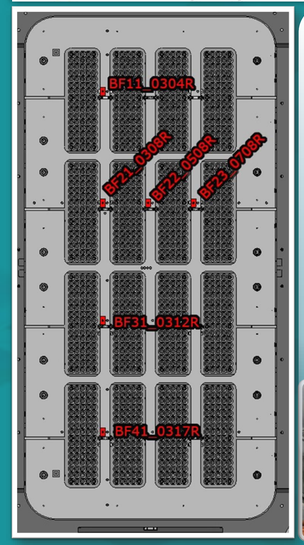
Corresponding authors: *valentina.candela@igi.cnr.it ** caterina.cavallini@igi.cnr.it

INTRODUCTION

- SPIDER is the low energy 100 keV ITER full-size Ion Source [1].
- Plasma is produced in the plasma box.
- A thin **molybdenum** layer covers the plasma box components, the Plasma Grid (PG) and the Bias Plate (BP).
- **Caesium** spread onto BP and PG to enhance H- production via Cs ovens [2].
- **SHUTDOWN 2021**: dismantling of the source → non uniform coatings revealed onto some components! Specifically on PG, BP, EG.







MATERIALS and METHOD

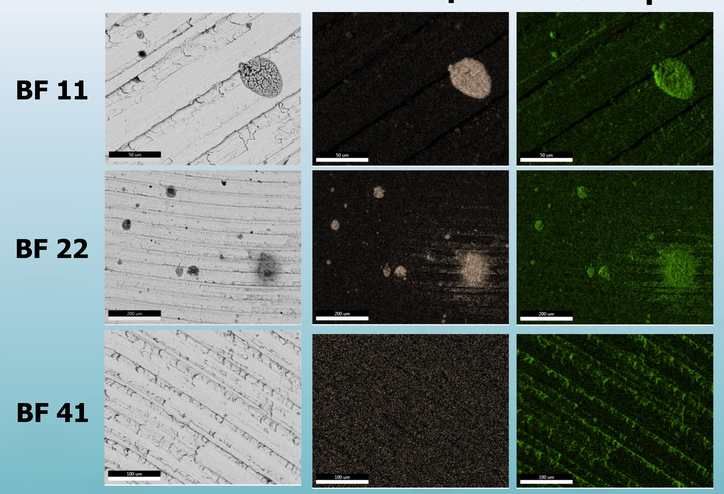
1. **Samples** of the Mo coating that covers the BP and the PG taken scratching the surface with a flat end metallic spatula.
2. **BF Probes** removed and analyzed. They are bulk Mo platelets fastened to the Bias plate with a screw.

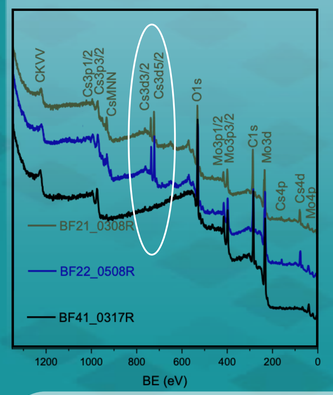
→ **SEM-EDS, XRD** and **XPS:** on both BP probes and powder residues taken from SPIDER components.

REFERENCES

[1] https://www.igi.cnr.it/en/research/negative-ion-neutral-beam-injection/spider/
[2] Okuyama T., Mori Y., Cesium catalysis effect of H- ion production in volume production type of H- ion source, Review of Scientific Instruments 63 (1992). Doi: https://doi.org/10.1063/1.1142831
[3] https://www.webelements.com/caesium/chemistry.html
[4] https://www-nds.iaea.org/relnsd/vcharthtml/VChartHTML.html
[5] L. R. Greenwood, D. G. Doran, H. L. Heinisch, Production of 91Nb, 94Nb and 95Nb from Mo by 14.5-14.8 MeV neutrons, Physical Review 35 (1987).
Doi: https://doi.org/10.1103/PhysRevC.35.76

BF PROBES ANALYSES

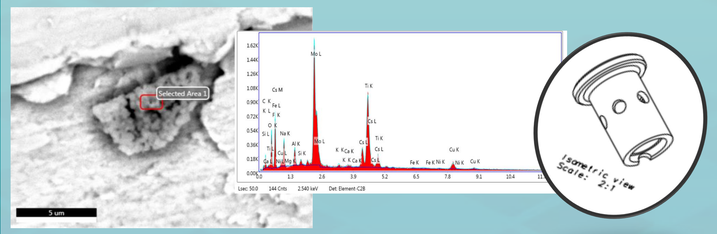




BF21_0380R	Cs % at.	Mo % at.	Mo/Cs
Low R	18.3	81.7	4.5
Low L	19.5	80.5	4.1
Top R	18.7	81.3	4.3
Top L	19.3	80.7	4.2
BF22_0508R	**Cs % at.**	**Mo % at.**	**Mo/Cs**
Low R	22.0	78.0	3.5
Low L	19.1	80.9	4.2
Top R	16.5	83.5	5.1
Top L	23.0	77.0	3.3

- Caesium traces found on **BF Probes**.
- **Oxygen** is always *strongly combined with caesium*.
- **No** caesium was found on **BF 41.**

Ti-Cs CHIPS

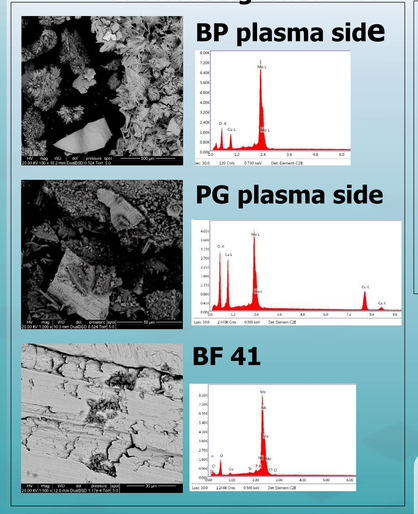


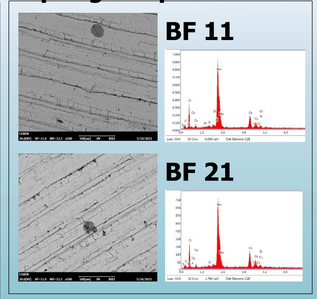
Porous **Ti-Cs** chips were found especially on BF21.

Cs nozzle is made of TMZ alloy! Cs strips Ti from the alloy.

RESULTS and DISCUSSION

CAESIUM AND WATER

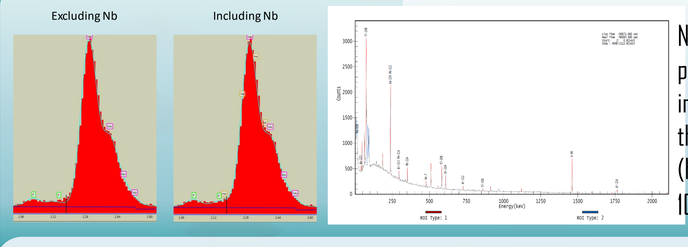




- **No caesium** found on the bottom part of each component.
- A **water leak** occurred in SPIDER vessel at the end of 2021.
- ***Caesium reacts with water*** by an exothermal and explosive reaction:

$$2Cs(s) + 2H_2O \rightarrow 2CsOH(aq) + H_2(g)\ [3]$$

GAMMA SPECTROSCOPY for Nb



No evidence of Nb. The 94Mo (usually present for ~9.18% [4]) do not decay into 91Nb m/g species by a (p, alpha) no threshold reaction. Moreover, 91Nbm (half-life of 61 days) produces peaks at 105 and 1205 keV [5], not detected.

CONCLUSIONS

So far, the only evidence of caesium evaporation is its heterogeneous distribution across SPIDER surface. Cs is present on the top half, but no evidence of Cs on the lower part: water leakage occurred and water strongly reacted with Cs. Due to atmospheric exposure, oxygen is most probably bonded to Cs. Further investigations need to be carried out to establish if Cs droplets are hydroxides and/or oxides. Moreover, it was assessed that there is no evidence of Nb due to nuclear reactions on the BF probes. Ti-Cs porous chips, found on the BF probes surfaces are fragments of Cs-ovens nozzles that have been distributed around the source. The nozzles should be observed to confirm the statement. Further investigations need to be carried out on other SPIDER components to analyze both the chemical composition and the Cs dispersion: a test bed is under design and construction at Consorzio RFX to study the effective monolayer caesium distribution on SPIDER grids. TEM analyses will be performed to assess Cs monolayer and its morphology.

This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European commission can be held responsible for them.

- *This work has been carried out within the framework of the ITER-RFX Neutral Beam Testing Facility (NBTF) Agreement and has received funding from the ITER Organization. The views and opinions expressed herein do not necessarily reflect those of the ITER Organization*