Analysis of surface chemistry of boronized TZM in NSTX-U between plasma exposures

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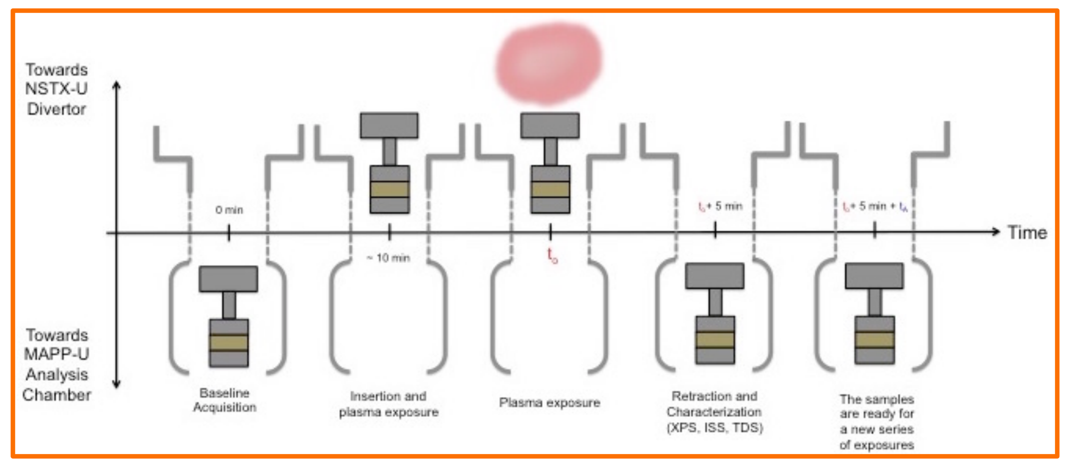
Introduction

- MAPP is a new materials characterization technique used in NSTX-U to study the evolution of the surface chemistry of the plasma-facing components.
- It has the capability of conducting X-ray Photoelectron Spectroscopy (XPS) *in vacuo.*
- The probe is not exposed to atmospheric conditions, and can take measurements on a day-to-day basis.



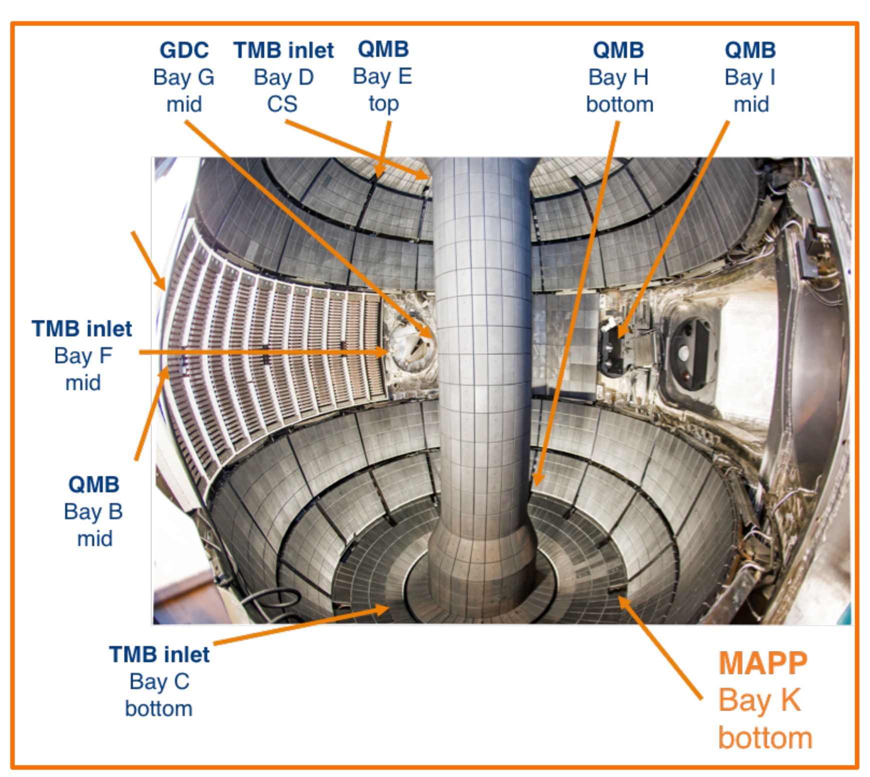
Schematic of the exposure sequence of MAPP

Plasma Facing Components

- NSTX-U currently has graphite (carbon) walls.
- The next upgrade will feature TZM tiles in the lower divertor region.
- TZM is 99% Molybdenum, 0.5% Titanium, 0.08% Zirconium.
- High-Z materials have better resistance to heat loads and lower erosion and chemical sputtering rates than carbon.

- PFC conditioning is used to minimize the emission of impurities, fuel recycling, erosion, and redeposition.
- During the 2015-2016 campaign, deuterated-trimethlyborane (d-TMB; chemical formula $B(CD_3)_3$) was used to condition the PFCs.

- This study shows the chemical composition of TZM as it is exposed to plasma and boronization with d-TMB.

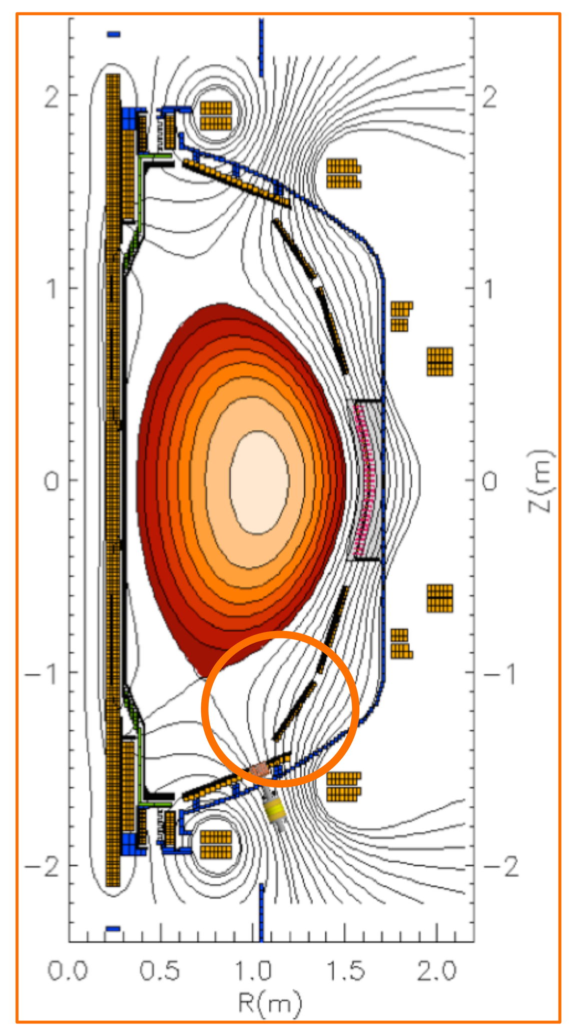


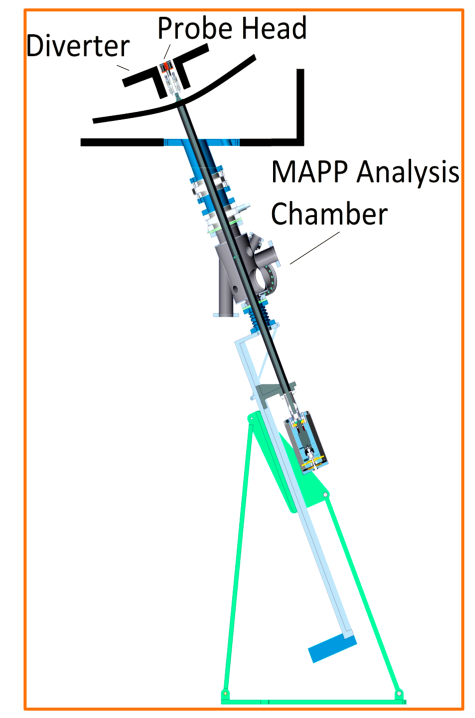
Above: Inside of the vacuum vessel. MAPP is located in Bay K (lower divertor region). The TMB inlets are located in Bays D and F.

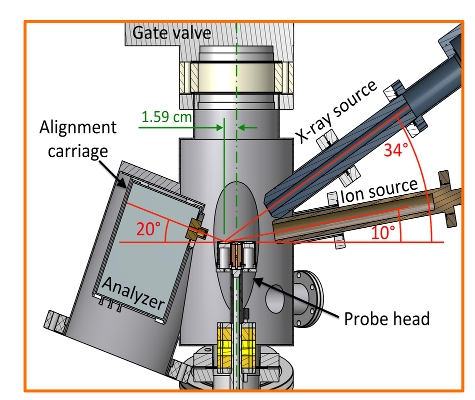
Right: Probe head. Here, the samples are (1) ATJ graphite, (2) TZM, (3) ATJ graphite and (4) gold. (2) and (3) were changed periodically. (1) was kept in place for the entire campaign. (4) was used for calibration

MAPP: The Materials Analysis and Particle Probe

- MAPP is located in the lower divertor region.
- The samples are not exposed to air in between plasma exposures, making the data obtained using MAPP is an accurate representation of the PFCs in the lower divertor region







Left: Cross section of NSTX-U Bay K. The probe is highlighted with the circle. Upper right: MAPP probe and analysis chamber location with respect to the divertor. Lower right: Detailed schematic of the MAPP analysis chamber and diagnostic tools.

XPS and data fitting

- The photoelectric effect is the basic working principle of XPS. X-rays hit the surface and cause electrons to be emitted. The energy distribution of the electrons is determined by the elements and concentrations present in the surface.

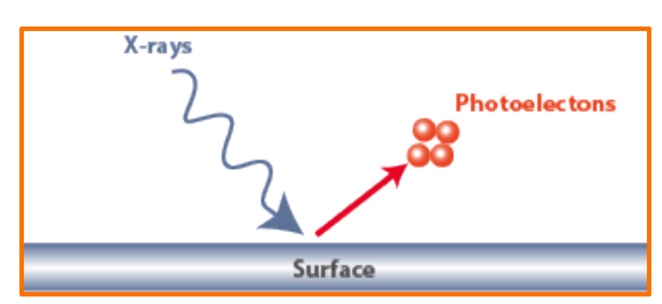


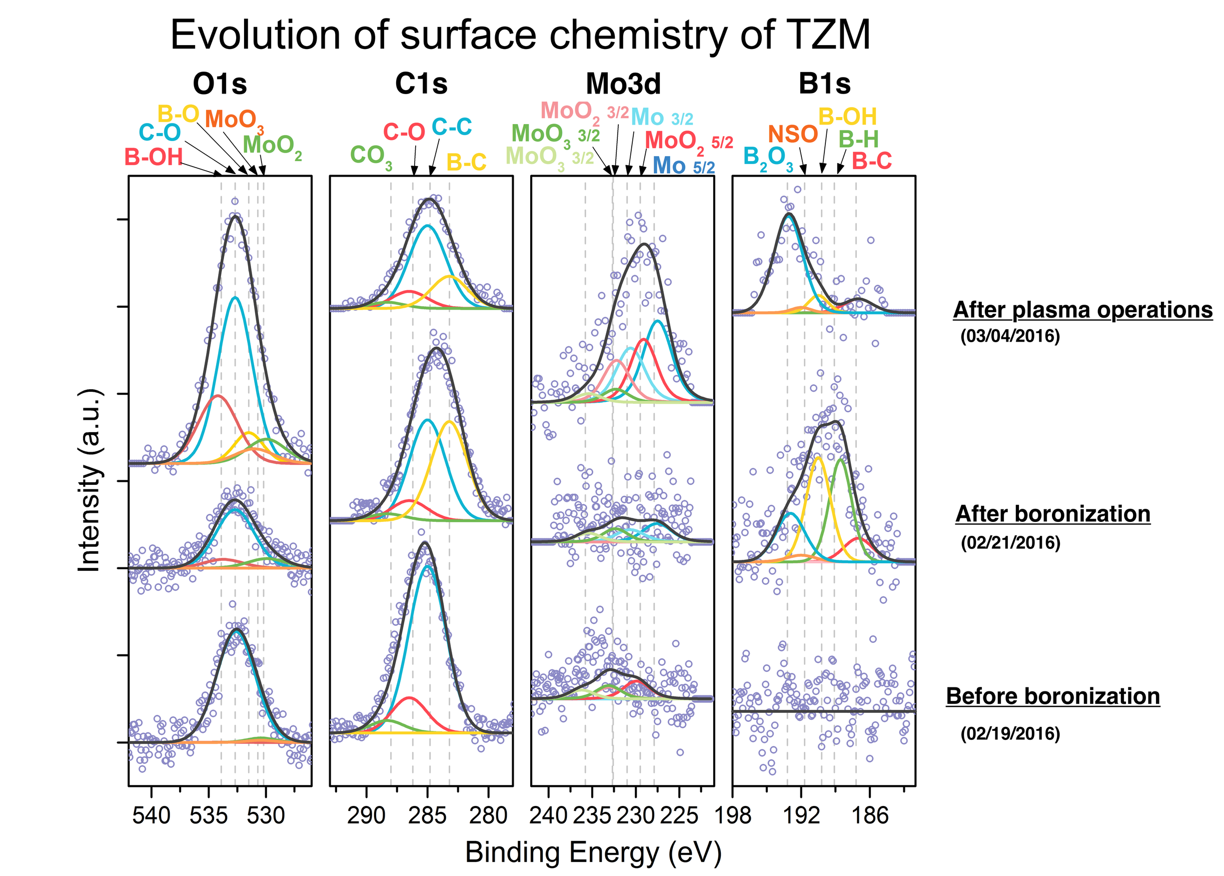
Diagram of the photoelectric effect

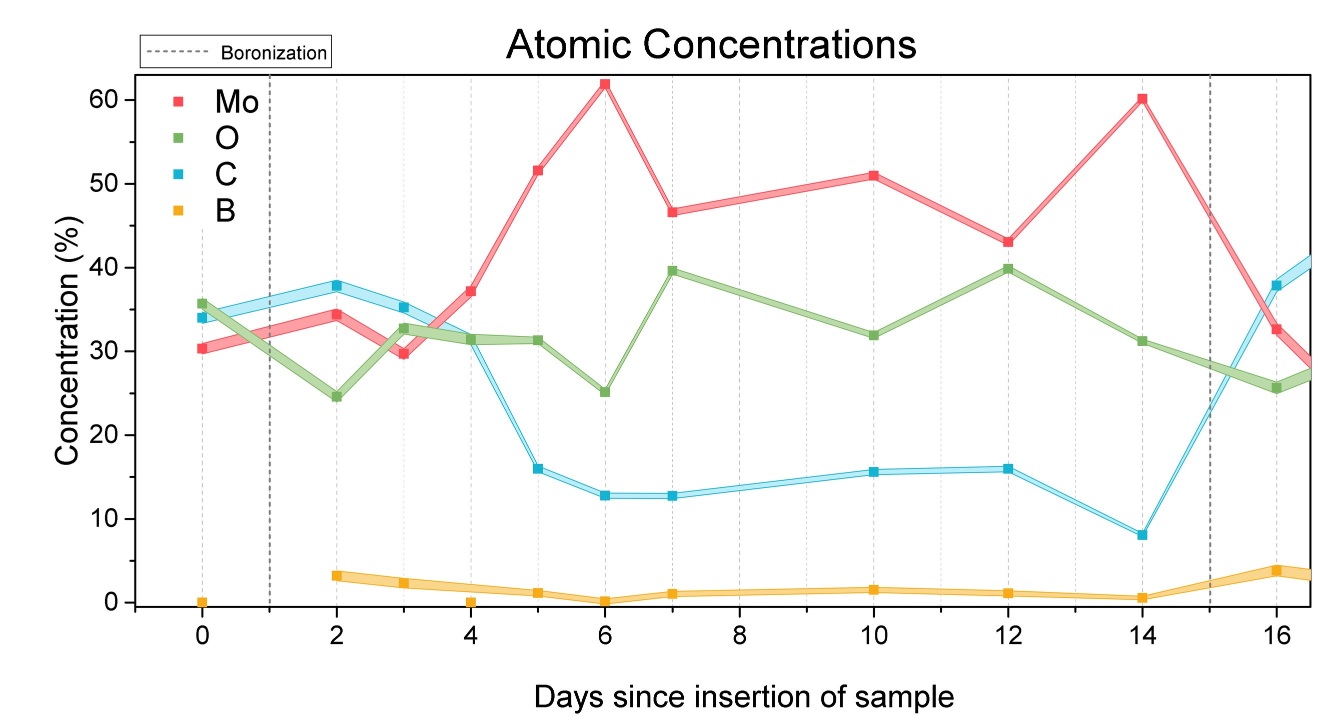
- The XPS data obtained using MAPP gives information on the chemical composition of up to 5 nm of the surface of the samples.
- The samples were scanned in four regions (B1s, Mo3d, C1s and O1s).
- The data peaks were deconvoluted and fit according to the following constraints:
  - Position/Binding energy: obtained from previous controlled experiments [1-3].
  - FWHM of the spectral fits
  - Area relation between doublets (in Mo3d 5/2 and 3/2)

Results

- XPS data of TZM samples was taken with MAPP.
- The data shows the following trends:
  - Before boronization: Adventitious carbon present in the sample. No B peak, low intensity Mo peak.
  - Immediately after boronization: concentration of boron increases, oxygen decreases.
  - After plasma operations: concentration of molybdenum increases. Oxides form in Mo and B region.

Right: Deconvoluted XPS data. Purple dots indicate raw data, lines indicate fits.





Left: evolution of atomic concentrations of boron, carbon, molybdenum and oxygen, as a function of time. Data was taken after each boronization, and after each day of plasma operations.

Summary

- With MAPP, PFC material evolution can be studied in ways not previously possible.
- The data is representative of the TZM tiles that will be put into the lower divertor region.
- The variations in the atomic concentrations could be the result of migration, sputtering, and redeposition during plasma shots between boronizations.
- The data shows that boron is deposited on the surface following boronization with d-TMB. The boron layer, however, is <5% of the chemical composition of the surface.
  - Controlled experiments will be conducted at UIUC to further investigate boron layers on TZM substrates.

Acknowledgments

Work supported by US DOE Contract No. DE-AC02-09CH11466, US DOE Contract No. DE-SC0010717, Award Number DE-SC0012890, and the DOE Science Undergraduate Laboratory Internship (SULI) Program.

References

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