Materials Analysis and Particle Probe (MAPP-U): Progress Status and Future Plans

J.P. Allain, C.N. Taylor, F. Bedoya, B. Heim, S. Gonderman, Z. Yang

[1]School of Nuclear Engineering, Purdue University, West Lafayette, IN 47907

Update meeting PPPL
July 26, 2012

RSSEL

PURDUE ENGINEERING

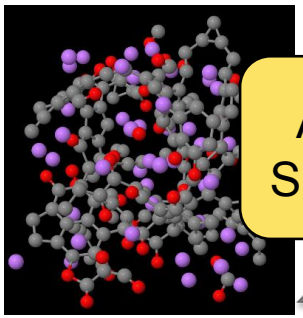
Outline

- MAPP motivation, design and capabilities
- MAPP operation
- Current Status
- Short Term Plans
- Long Term Plans

Motivation

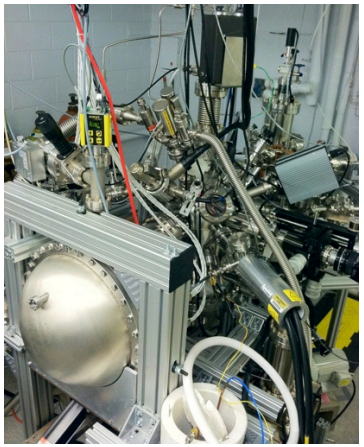
Approaching the problem

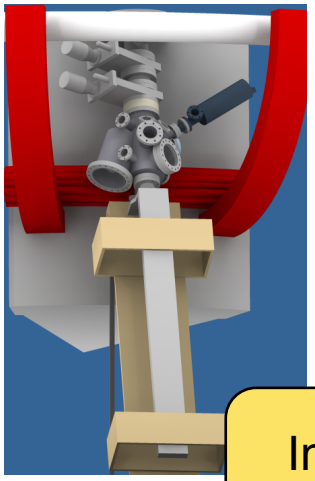
- Investigating the Plasma-Surface Interface



Atomistic Simulations

What is going to happen?





Controlled Laboratory Experiments

What is happening?

In-vacuo Probe

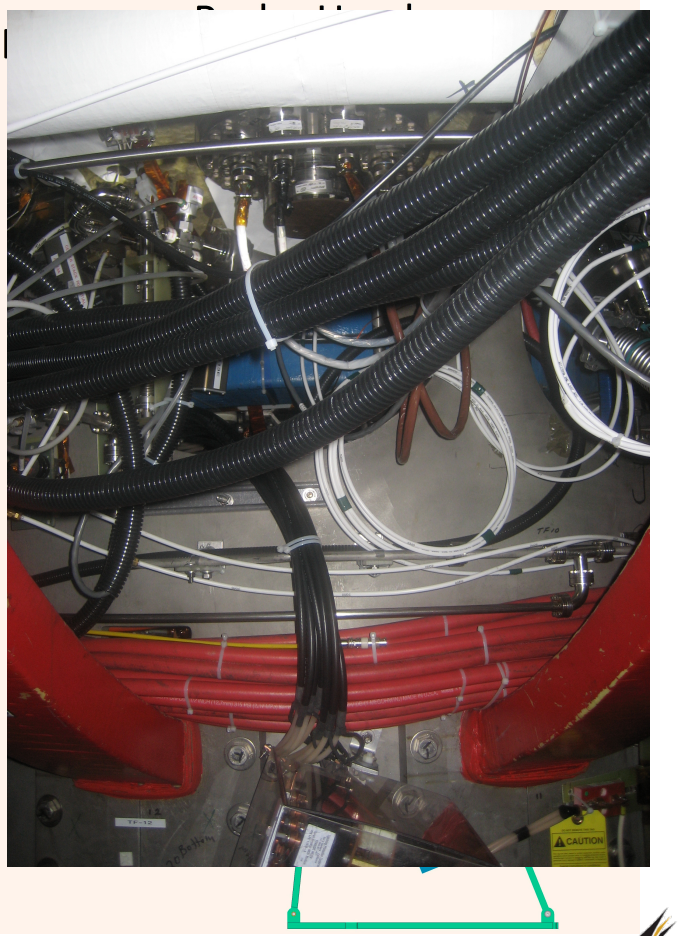
What happened?

Post-Mortem Tile Analysis

MAPP design
Overview

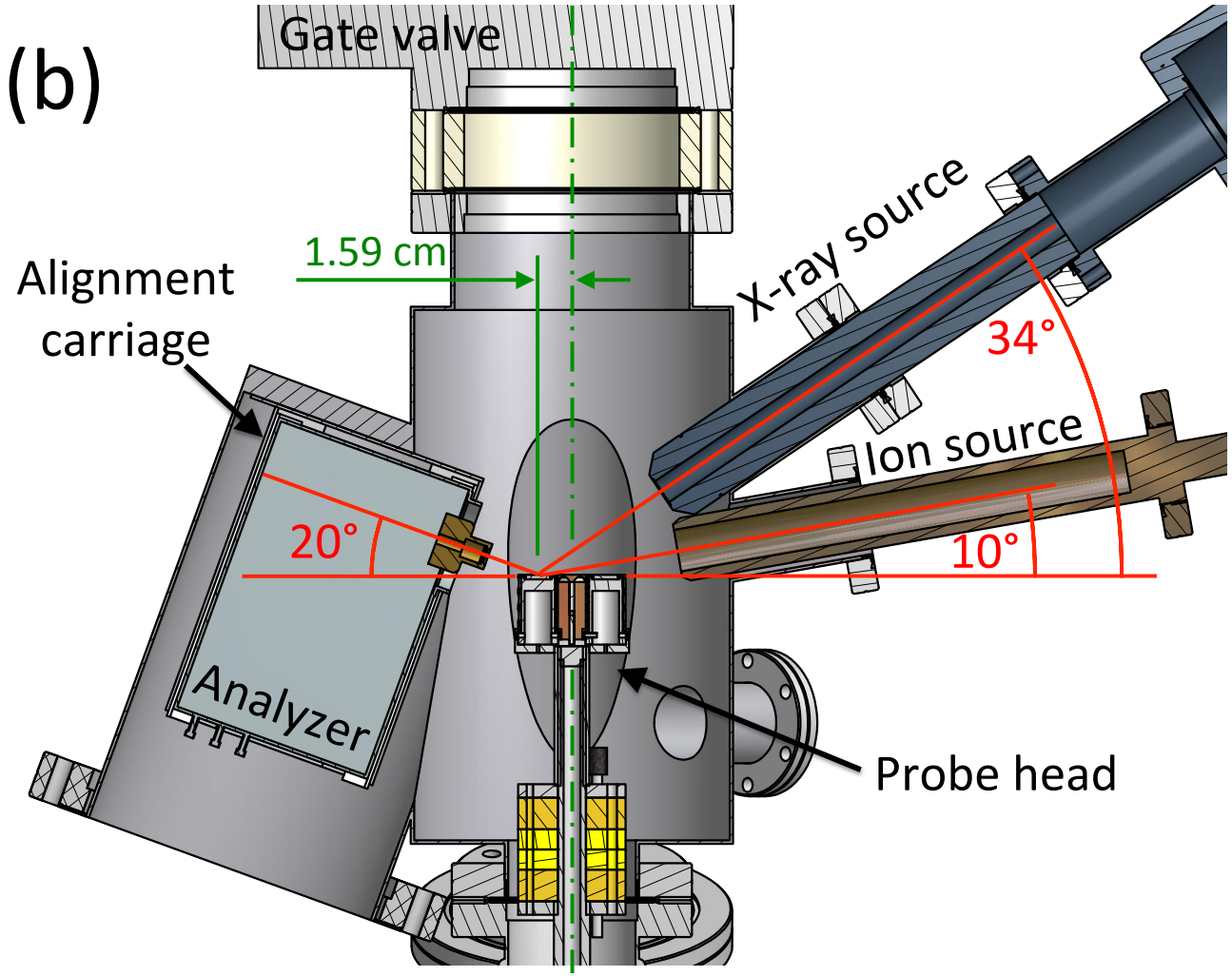
MAPP: Materials Analysis Particle Probe

- Scientific objective
  - Correlate plasma performance to state of the plasma-facing surface
- Design objectives
  - Develop diagnostic to accomplish scientific objective!
  - *In-vacuo* analysis of materials exposed to plasma discharge
  - Provide immediate, shot-to-shot analysis
  - Operate within 12 min minimum between-shot time window
- Capabilities
  - X-ray photoelectron spectroscopy (XPS)
  - Thermal desorption spectroscopy (TDS)
  - Ion scattering spectroscopy (ISS)
  - Direct recoil spectroscopy (DRS)



MAPP design

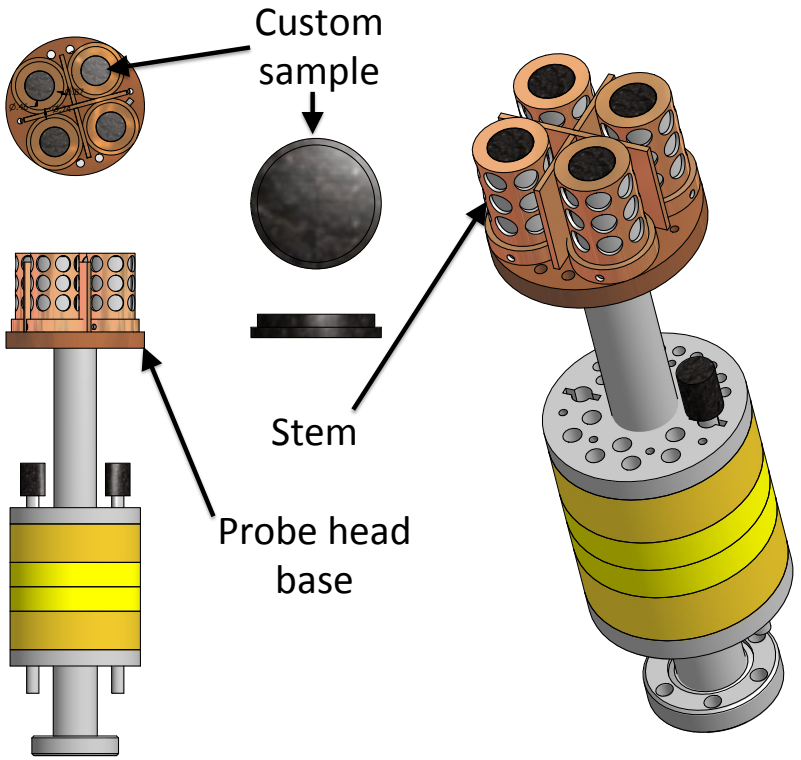
Mechanical – chamber



MAPP design

Mechanical – probe head

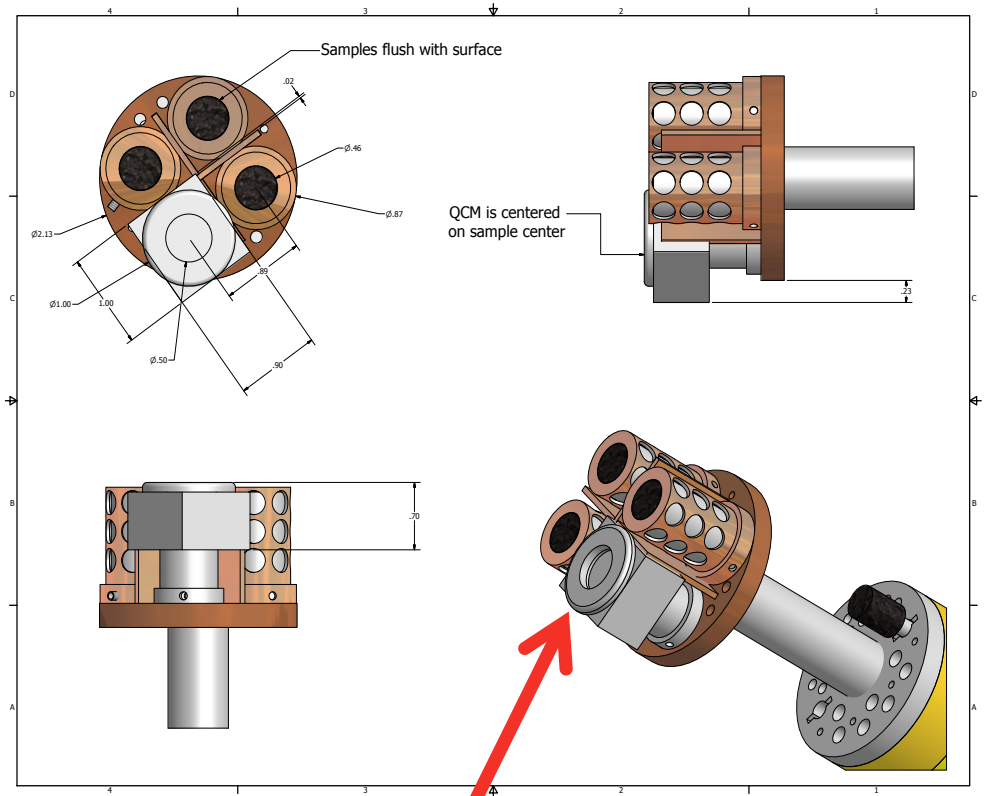
- Hold four samples
- Independent heating of each sample
  - Radiation shields
  - Perforated stems
- Geneva gear to position samples for analysis
- Quick release probe head



MAPP design

Upgrade system

- Received 40% of funding request.
- Primary MAPP-U diagnostic upgrade will be a QCM-DCU
- Quartz crystal microbalance (dual crystal unit) can measure net erosion during exposure of MAPP probe to incident plasma
- Surface characterization on the QCM crystal surface can help us correlate erosion to surface chemistry



QCM-DCU

MAPP capabilities

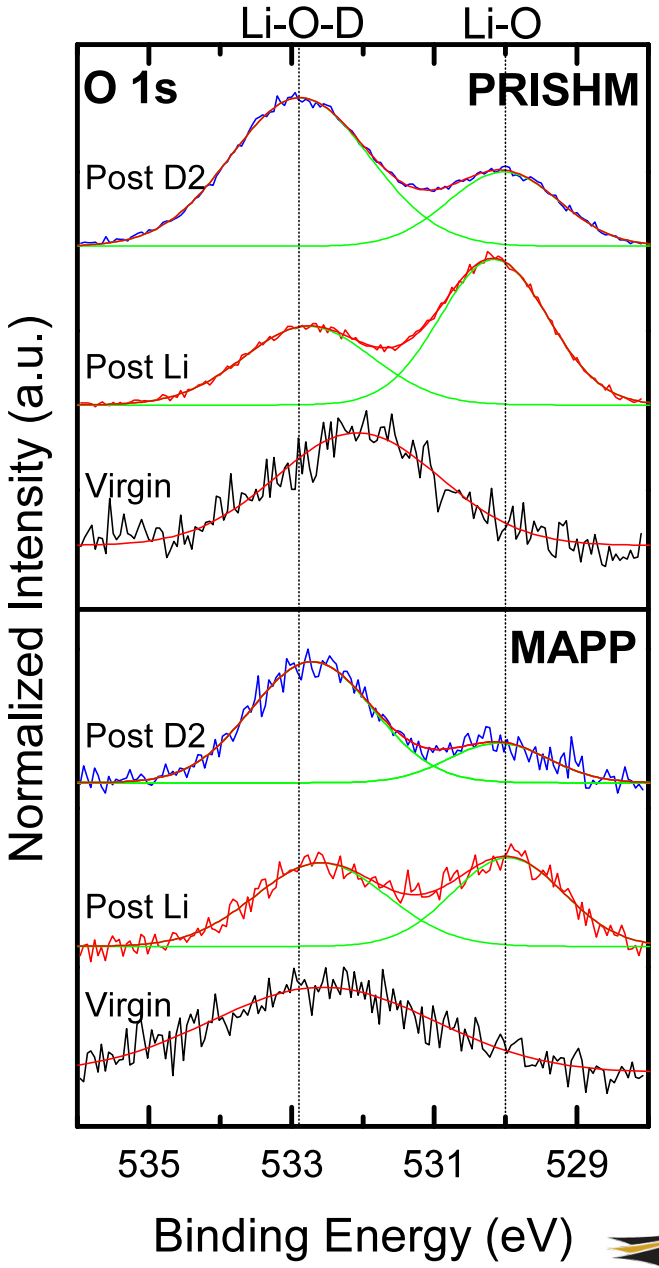
X-ray photoelectron spectroscopy

Initial calibration

- Comparison with PRIHSM (Particle and Radiation Interaction with Hard and Soft Matter) facility at Purdue.

Results

- Depositing lithium results in new chemistry: Li-O (~530 eV)
  - Difference in relative intensities depends on lithium dose, sample morphology, and time after deposition.
- Subsequent deuterium irradiation enhances Li-O-D peak (~533 eV)



MAPP operation

Operation modes

1. Dedicated NSXT-U Experimental Proposal:
   - *Influence of outer strike-point location on lithium-deuterium chemistry observed in MAPP*
     - Aim: Use MAPP to develop a direct correlation between PFC surface chemistry/surface D retention and strike-point location.
     - Milestone
       - R(12-1): Investigate the relationship between lithium-conditioned surface composition and plasma behavior.
       - "Correlations between the surface composition and plasma behavior will be explored and compared to laboratory experiments and modeling…. The results will deepen the understanding of plasma-wall interactions and inform the plans for particle control in NSTX-Upgrade."
2. Run in 'piggy-back' mode
   - Use routinely as a diagnostic to correlate plasma performance to individual plasma discharge conditions.

MAPP operation

Example remote control sequence

NSTX	MAPP	
Shot ends		
Open TIVs, insert LiTER	Open TIV insert MAPP	
Evaporate	Evaporant received on MAPP samples	
Retract LiTER, close TIV	Retract MAPP, close TIV	Leave MAPP inserted
Plasma shot		MAPP samples exposed to shot
Shot ends		Retract MAPP, close TIV
Open TIVs, insert LiTER	Power up diagnostics	
Evaporation	*Analyze samples (details on next slide)*	
Retract LiTER, close TIV	Power down diagnostics, open TIV, insert MAPP	Power down diagnostics
Plasma shot	MAPP samples exposed to shot	
Shot ends		
Open TIVs, insert LiTER	Power up diagnostics	

MAPP operation

Analysis procedures

Diagnostic	Energy range	Step size	Dwell time	Scan time
XPS – survey scan	~600 eV	0.5 eV	0.1 sec	2m0s
XPS – high res	10 eV	0.05 eV	0.8 sec	2m40s
ISS	1500 eV	1 eV	0.1 sec	2m30s
DRS	1500 eV	1 eV	0.1 sec	2m30s

One-of-each total: 9:40 min

XPS survey scan, 3 high-resolution region scans: 10:00 min

Requirement: Complete operation within 12 minute minimum between-shot window

(TDS performed end-of-day)

<table>
<tr><th colspan="3">MAPP</th></tr>
<tr><td colspan="3">Retract probe from NSTX/
Power up diagnostics</td></tr>
<tr><td>ISS scan</td><td rowspan="4"></td><td></td></tr>
<tr><td rowspan="2">Remotely change gas in ion gun</td><td>XPS survey scan</td></tr>
<tr><td>XPS region scan(s)</td></tr>
<tr><td>DRS scan</td><td></td></tr>
<tr><td colspan="3">Insert probe into NSTX/
Power down diagnostics</td></tr>
</table>

Current Status

- Bryan Heim visited PPPL for ~ 2-3 weeks in May 2012 to re-calibrate MAPP system in C128 with help from Bob Kaita and Mike Jaworski
- May meeting discussed possible uses of MAPP including integration into LTX
- Remote control systems updated
- Vacuum systems were not adequate for proper diagnostic operation of MAPP
- MAPP is now integrated with new Thermionics probe drive
  - Need to integrate geneva gear
- Alignment issues also identified
- Heim graduated with MS in May; new grad students, Sean Gonderman and Felipe Bedoya to take over

Short Term Goals for MAPP

- Installation of MAPP probe head components
  - Heaters, wiring, TCs, sample holders
  - Design and fabrication of new samples for testing
- Complete testing and calibration of MAPP system
  - All diagnostics, remote operation, ion source
- Use LTX as a test platform between 08/12 to 05/13
  - Collaboration with Dick Majeski
- Personnel
  - Bob Kaita coordinating PPPL activities including working with D. Majeski on LTX installation
  - Tyler Abrams and Matt Lucia to be involved in MAPP operations
  - Purdue U: Sean Gonderman and Felipe Bedoya on board starting August 2012

Long Term Goals for MAPP

- LTX MAPP operation
  - September 2012 through May 2013
  - Summer of 2013 have Purdue students at PPPL for transition of MAPP to NSTX-U
- Installation and testing in NSTX-U
  - Early 2013 need to identify tasks for MAPP integration (e.g. gas lines, electrical requirements, etc… same as summer 2011)
  - Purdue-PPPL task list to be generated once we have good experience with MAPP in LTX and also new NSTX-U configuration
  - Testing of MAPP-U through late Fall 2013 to be ready for 2014 campaign