Outlines:

1. Tritium Plasma Experiment (TPE) capability
2. First result of tritium plasma campaign:
   - Imaging plate technique (IP) surface/depth tritium profiles
3. Deuterium retention in tungsten and molybdenum
   - Thermal desorption spectroscopy (TDS) analysis in W
   - Characterization of surface morphology and retention in W
     (next talk by Rob Kolasinski)
4. Summary and future plans
   - Deuterium/tritium retention in neutron irradiated tungsten

Acknowledgements: all FSP support staff and ATR RadCons:
Role of TPE in fusion/PFC community:
- "Tritium" behavior in various PFCs (Mo, W, CFC, Be, n-irradiated materials)
  - Tritium use (T inventory: 15000 Ci ~1.5g)
  - Handling of "neutron irradiated materials"
  - D/T retention in PFCs.
  - T permeation through PFCs
  - T surface/depth profiling in PFCs

Tritium Plasma Experiment:
- Linear type plasma
  - LaB$_6$ source and actively water-cooled target
  - Steady state plasma up to high fluence ($\sim 10^{26}$ m$^{-2}$),
  - High flux ($\sim 10^{22}$ m$^{-2}$s$^{-1}$), surface temp. (300~1000K)
- Tritium use: (0.1 ~ 3.0 %) T$_2$/D$_2$
- Double enclosures for tritium use
  - System piping as primary confinement
  - Glovebox as a ventilation hood (second enclosure)
  - PermaCon box as a third enclosure
  - Ubeds as tritium getter
Tritium Plasma Experiment (TPE) capabilities

**Diagnostics and collaborations**

**in-situ plasma diagnostics:**
- Langmuir probe (single probe, PMT)
- Spectrometer (Ocean Optics HR-4000)
- RGA (residual gas analyzer)

**ex-situ PSI material diagnostics:**

**At site (INL - STAR)**
- TDS (thermal desorption spectroscopy)
- IP (imaging plate analyzer)
- Optical microscope

**In town (INL – Idaho Research Center)**
- SEM (scanning electron microscope)
- XPS (X-ray photoelectron spectroscopy)
- AES (Auger electron spectroscopy)

**University of Wisconsin, Madison: IBA (ion beam analysis)**
- ERD (elastics recoil detection)
- NRA (nuclear reaction analysis)

**Sandia National Laboratory, Livermore**
- Laser Profilometry for blister height/size
- SEM/AES etc.

**Plasma parameters:**
- $n_e$, $T_e$, $V_s$, $V_p$, $p_{\text{impurity}}/p_{\text{D2}}$, $I_{D\alpha}$, $I_{D2}$

**PSI parameters:**
- D/T retention
- D depth profile
- T Surface/depth profile
- Grain size
- Element composition (depth profile)
- Chemical states of element
- Blister size/height

**Use of tritium (even in trace amount <1 %)**
- Enhance the detection sensitivity significantly (by ion chamber or LSC)
- Trace the surface profile easily (by IP)

Sensitivity: $\sim 10^{-12} = \text{ppt}$ (part per trillion)
First result of tritium plasma campaign:

(0.1~0.2 %) $T_2/D_2$ plasma on Mo and W

(Preliminary results)

- **Tritium profiling by Imaging plate (IP) technique**
  - Surface profile of plasma exposed front surface
  - Depth profile using split sample
    - Polish to remove deposition after TPE exposure

**Sample preparation:**
- Cut-in-half cylinder sample (split sample)
  - (6 mm diameter and 10mm length)
- Polished:
  - Mirror finished: front surface
  - 1200 grit paper: cross-sectional surface
- Cleaning: Ultra-sonic bath
  - Acetone, Ethanol, DI H$_2$O for 5min/each
- Annealed at 873K for 1 hours (<1x10$^{-7}$ Torr)

**TPE exposure conditions:**
- Ion flux: ~ $5.0 \times 10^{21}$ m$^{-2}$s$^{-1}$
- Ion fluence: ~ $3.5 \times 10^{25}$ m$^{-2}$
- Ion energy: ~ 70 eV
- Sample temperature: 393K and 573K
- 0.2 % $T_2/D_2$ plasma

**Samples:** (W and Mo)
- Pure (polycrystalline) tungsten
  - 99.99 at. % purity from Allied Material Corp.
- Pure molybdenum
  - 99.95 wt. % purity from Nilaco Corp.

After polishing

Samples provided by Teppei Otsuka (Kyushu Univ.)

2009 July 9
First result of tritium plasma campaign: (cont’d)

(0.1~0.2 %) $T_2/D_2$ plasma on Mo and W

(Preliminary results)

- **Front surface**
  - Surface T distribution after 2h TPE @ 573 K
  - PSL intensity ~ Relative T concentration
  - Difficult to quantify T concentration
  - Penetration (detection) depth depends on material/impurity/surface oxide etc..
  - Penetration depth: < 1 µm
  - Resolution: 25 µm/pixel

- **Cross-sectional surface**
  - IP intensity ~ Relative T concentration
  - Sample: 8Cr2W, SS316, Mo, W
  - W mask

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2009 July 9
PFC meeting@ MIT

Provided by Teppei Otsuka (Kyushu Univ.)
Deuterium retention in tungsten and molybdenum

Sample Preparation / Plasma Exposure Conditions

**Sample preparation:**
- Pure (polycrystalline) tungsten
  - 99.9999 wt. % purity from PLANSEE
- Pure molybdenum
  - 99.95 wt. % purity from Eagle Alloy Corp.
- 1 inch diameter disc (1mm thickness)
- Polished: Mirror finished
- Cleaning: Ultra-sonic bath
  - Acetone, Ethanol, DI H₂O for 5min/each
- Annealed at 1273K for 1 hours (<1x10⁻⁷ Torr)

**TPE exposure conditions:** D₂ plasma
- Ion flux: ~ 1.1x10²² m⁻²s⁻¹
- Ion fluence: ~ 8.1x10²⁵ m⁻²
- Ion energy: ~ 70 eV
- Sample temperature: (400~1000) K
Deuterium retention in tungsten and molybdenum (cont’d)
Thermal desorption spectroscopy (TDS) analysis in W 

\[ D\text{ retention peaks around } T_{\text{sample}} \sim 500 \text{ K} \]
- 770 K peak (1.6~1.7eV trap: vacancy cluster) is responsible for higher retention
- Blistering occurs at lower temperature (400~700K)
- Very small retention with 920K peak (2.1eV trap: void)
Summary and future plans

TPE will be focusing on “Deuterium/tritium retention in neutron irradiated sample”

- Completed first tritium plasma campaign (<0.2 % T<sub>2</sub>/<D<sub>2</sub>)
  - Plan to operate higher concentration T plasma (a few % T<sub>2</sub>/<D<sub>2</sub>) in late 2009

- Continue on D/T retention in Mo and W
  - Setup dual mode TDS retention measurements (both deuterium/tritium)
  - Investigate surface morphology in single crystal W
  - Investigate surface profiling in He-D<sub>2</sub> exposed W (W fuzz) by IP
  - Obtain T depth profile by cutting Mo and W in half after TPE exposure

- Deuterium/tritium retention in neutron irradiated tungsten
  [TITAN US-Japan collaboration]
  - Irradiate the samples (W, Mo, Ni) at HFIR (High Flux Isotope Reactor), ORNL (0.1, 1.2, 9.6 dpa @ 80, 300, 650°C )
  - Completed first set of W samples (at 0.1 dpa, 80 C)
  - Plan to test first neutron-irradiated W (0.1 dpa, 80 C) in Dec. 2009
  [with US domestic collaboration]
  - Could irradiate sample at ATR (Advanced Test Reactor), INL as NSUF

- T retention/permeation experiment (new design)