Lattice Confinement Fusion Gas Cycling Experiments

ARPA-E Workshop on Low-Energy Nuclear Reactions

October 21–22, 2021

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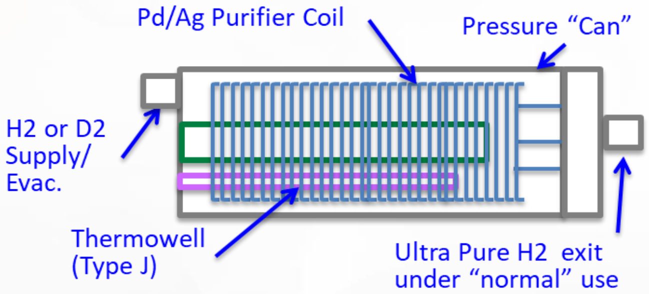
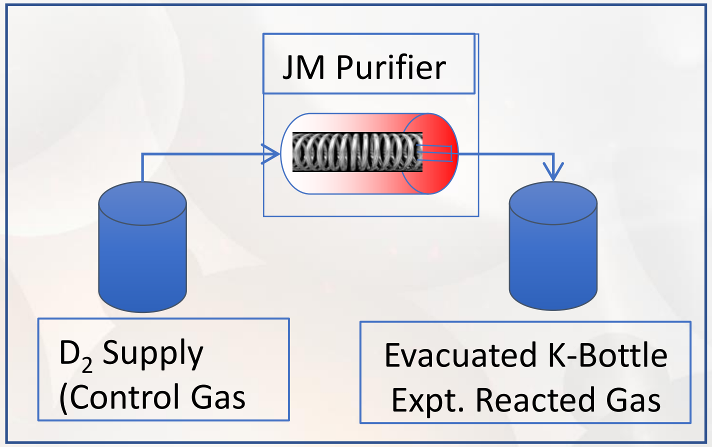
J-M Gas Cycling Experiments: Description

<u>High flux of D through Pd/Ag hydride system:</u>

- Test Article: Johnson-Matthey (JM) hydrogen purifier
  - Hydrogen purification accomplished by gas diffusion across Pd/Ag Tube
- Inspired by electrolytic wet cell experiments and LENR claims, G. Fralick (1989) used JM purifier to load Pd with D_2 since it's easier than loading D_2 during a wet cell experiment; looked for neutrons and heat release
  - Very little neutrons above background observed
  - Observed temperature rise of 17 °C in 15 sec unloading D_2 but not with H_2
- Experiments in 2014 & 2018: pressurized cycling of D_2 gas produces heat & surface transmutations on PdAg tubing; evidence of LENR
- Experimental protocol:
  - Heat JM purifier tube bundles to < 400°C (ideally between 375°C & 400°C) to maintain structural integrity of Pd/Ag tubing and heal cracks on the tube
  - Load with D_2 gas to given pressure on inner/outer sides of Pd/Ag coils
  - Unload: Rapidly evacuate to vacuum sink, resulting in high flux of trapped D
- Inputs/Outputs:
  - Resistance heater used to raise temperature of the Pd/Ag tubing
  - Thermocouples placed on parts of PdAg coil, the inner SS can, and heater
  - Pyrometer aimed at sapphire window to monitor overall temperature
  - Materials analyses of unexposed and exposed PdAg tubing



<u>Schematic of H2 Purifier</u>
Anomalous Heat observed: flux of Deuterium (D2);
Temp Rise: 2009: °5 C; 2012: 25°C during unload



Initial work during original 1989 gas cycling experiments inspired other researchers such as Bin Liu and J. P. Biberian to investigate the excess heat anomaly.

- B. Liu excess heat (2006): 3.5 W
- Biberian excess heat (2007): 3 W (calorimeter)

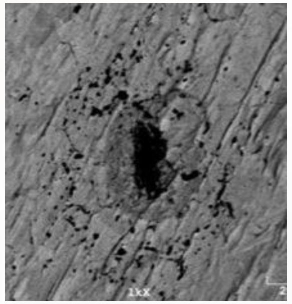
B. Liu, X.-Z. Li, Q.M. Wei, N. Mueller, P. Schoch, H. Oehre, "Excess Heat Induced by Deuterium Flux in Palladium Film", *Condensed Matter Nuclear Science*, pp. 75-79 (2006).

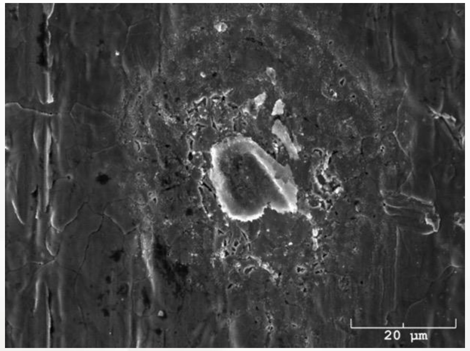
J. Biberian and N. Armanet, "Excess Heat during Diffusion of Deuterium Through Palladium", *Proc. ICCF13*, Sochi, Russia (2007) pp. 170-180

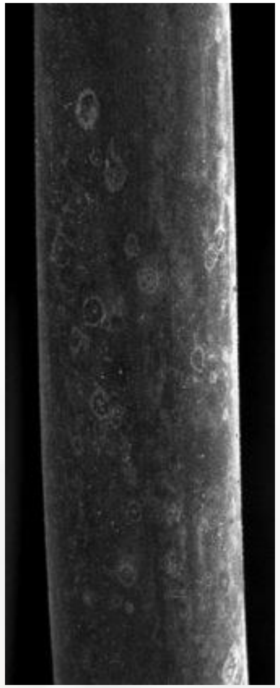
J-M Gas Cycling Experiments: Data (2014)

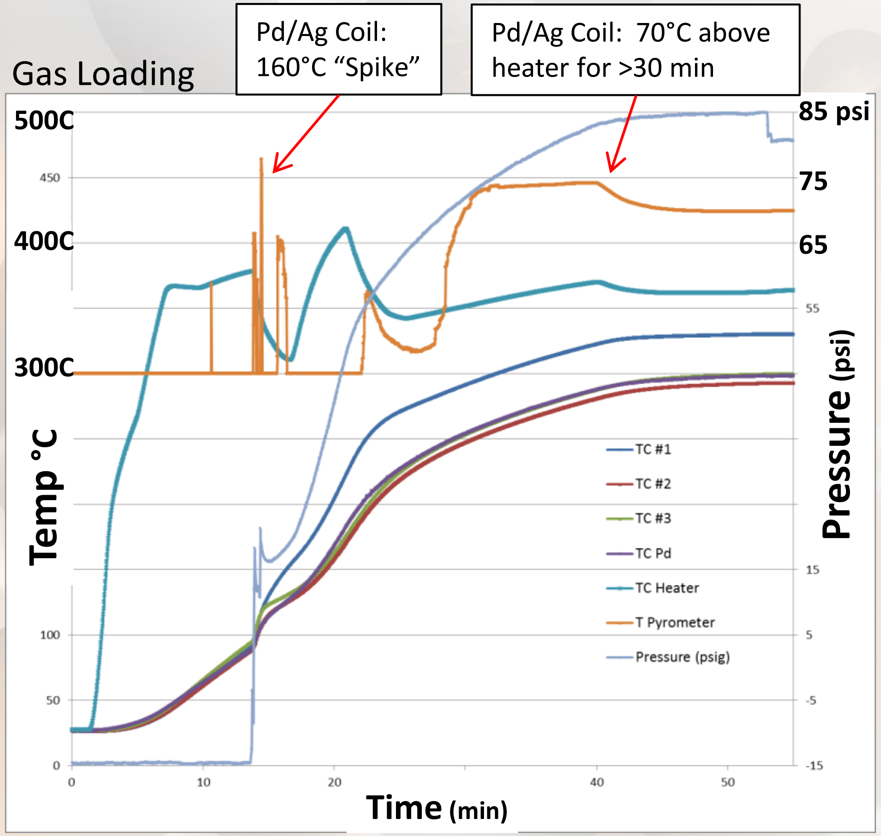
<u>High flux of D through Pd/Ag hydride system:</u>

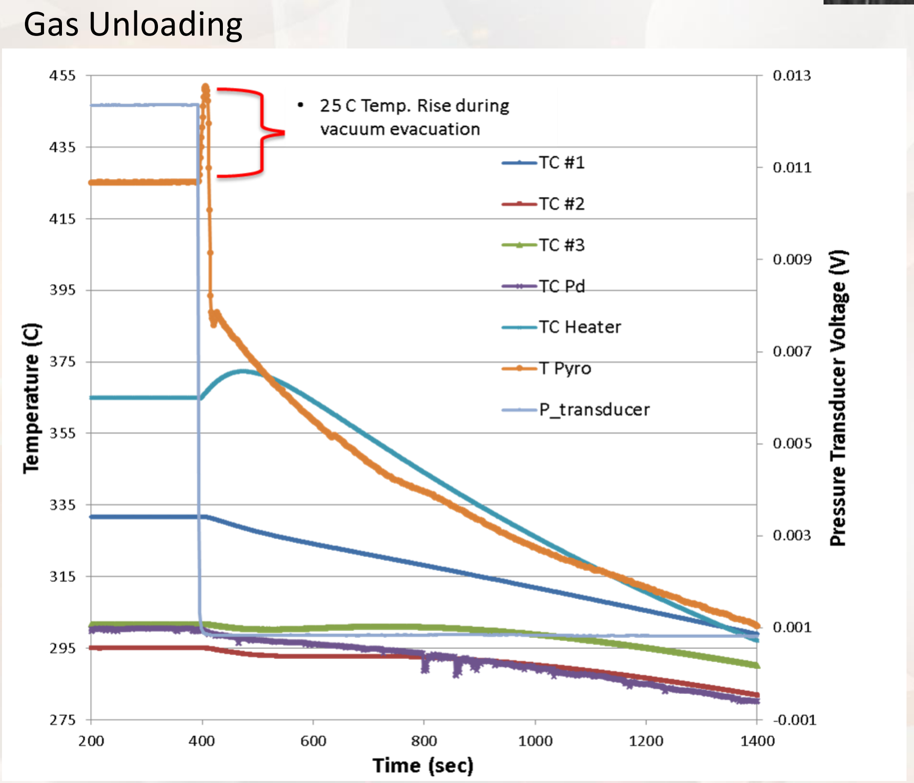
- Thermocouples showed anomalous heat release during experiment
  - During D_2 cycling, temperature rise occurred almost 100% present
  - During H_2 cycling, temperature rise less often than during D_2 cycling
  - During He cycling, temperature rise never occurred
- Scanning Electron Microscopy showed areas of molten looking spots and craters
  - Palladium melts at 1560 °C and silver melts at 962 °C yet system heater was kept under 425 °C











Joule-Thomson effect would induce cooling during gas evacuation instead of a 25 °C temperature rise

Repeat of temperature rise during D_2 gas unloading

- 1989: 17°C temp rise in 15 s
- 2014: 25°C temp rise in 4 s
- 2018: 12 °C temp rise in 45 s

Note: Pyrometer was not used in the 2018 experiment.

G. Fralick, R. Hendricks, W. Jennings, T. Benyo, F. VanKeuls, D. Ellis, B. Steinetz, L. Forsley, C. Sandifer, “Transmutations observed from pressure cycling palladium silver metals with deuterium gas," International Journal of Hydrogen Energy, vol. 45, no. 56, pp. 32320-32330, 2020.

J-M Gas Cycling Experiments: Data (2018)

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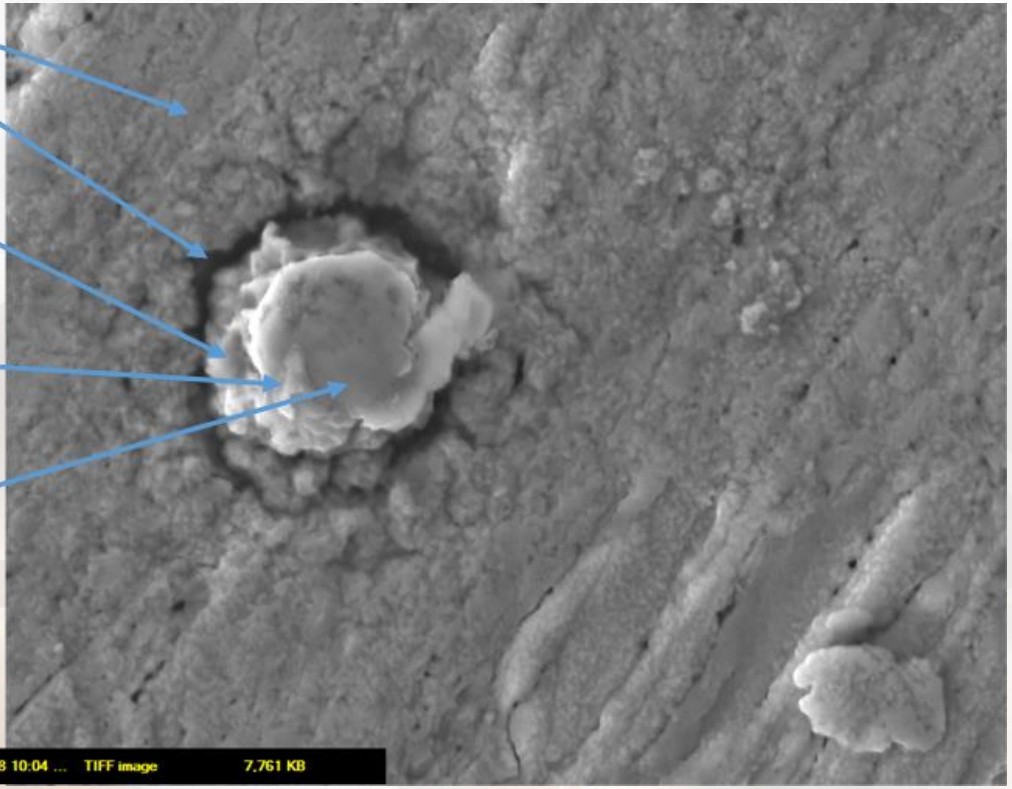
Striations Band

Outer Edge of Dark Band

Outer Edge of Doughnut Shell
Often Zn and/or wide field of scattered Zn spots

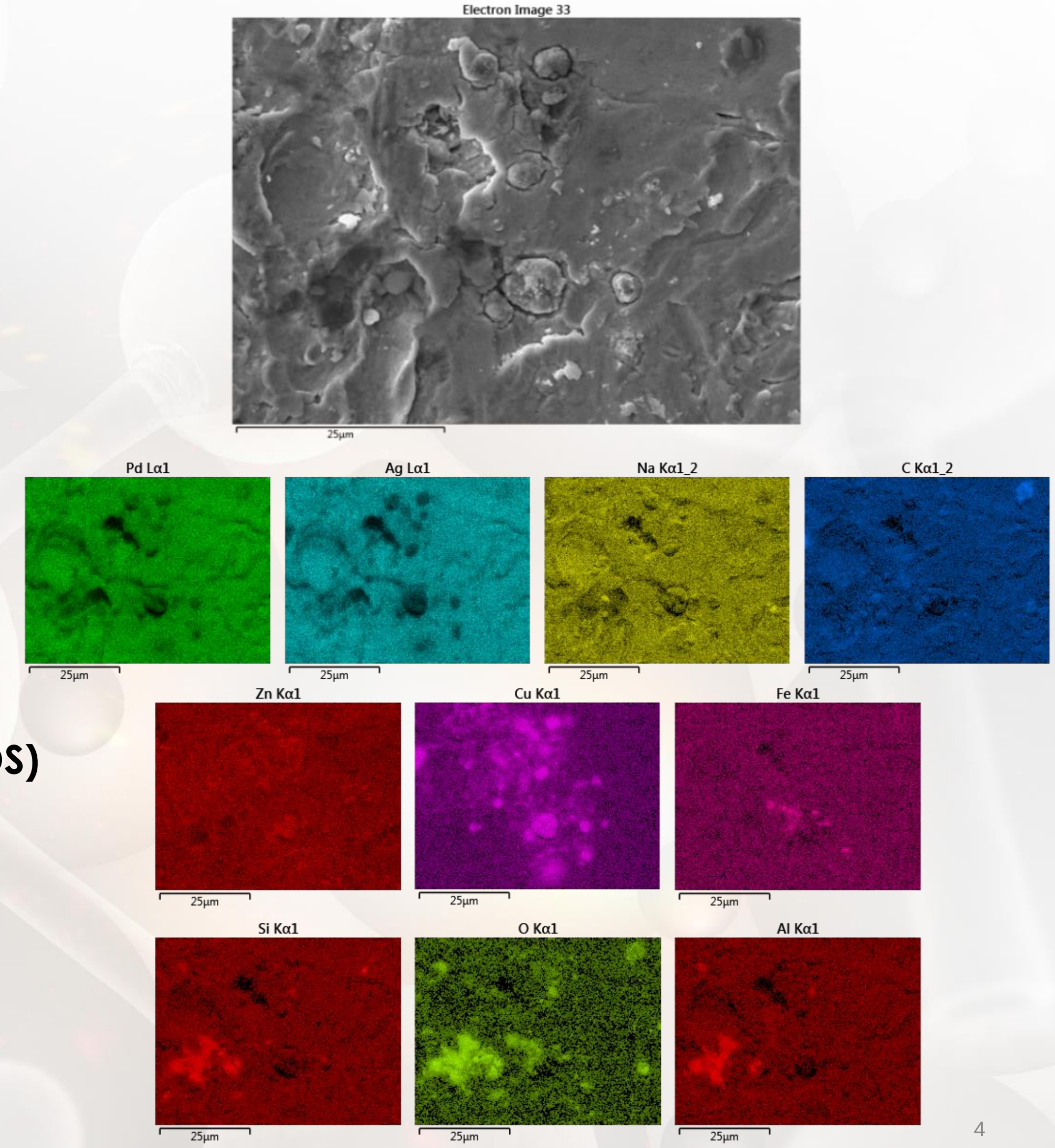
Outer Edge of Doughnut Band
Zn melts at 420°C
Cu melts at 1085°C

Copper Core



No Copper or Zinc was found on
1. Pristine virgin JM-3 coil
2. Pre-test JM coil
3. Coil tube section cut from JM

AEC-PdAg-GL-D-20180802-001-01 8/6/2018 10:04 ... TIFF image 7,761 KB



Scanning Electron Microscope/Energy Dispersive Spectroscopy (SEM/EDS)

Observed areas that look melted or crystalized.

J-M Gas Cycling Experiments: Data (2018)

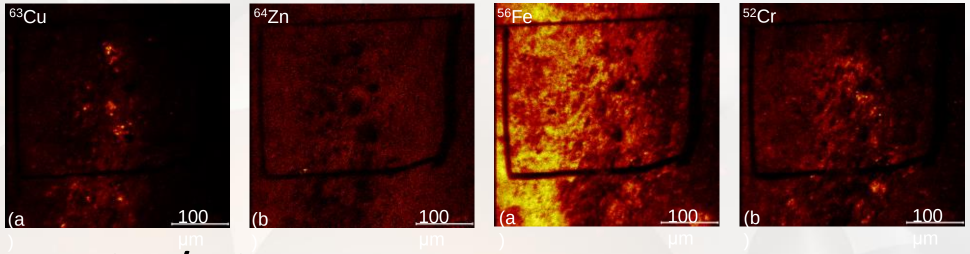
High flux of D through Pd/Ag hydride system:

- ICP-AES: Elemental bulk analysis of PdAg tubing
  - Elevated levels of Cr, Cu, Fe, Mn and Zn detected in the exposed PdAg tubing
- SEM/EDS: Elemental surface analysis of PdAg tubing
  - Spots of Fe, Cr and Cu on top of the PdAg alloy with overall spread of Zn on exposed PdAg tubing compared to unexposed PdAg tubing with mostly Pd, Ag and trace of Fe present.
- ToF SIMS: Isotopic surface analysis of PdAg tubing
  - Areas of ^{63}Cu, ^{64}Zn, ^{56}Fe, and ^{52}Cr

Inductively Coupled Plasma Atomic Emission Spectroscopy

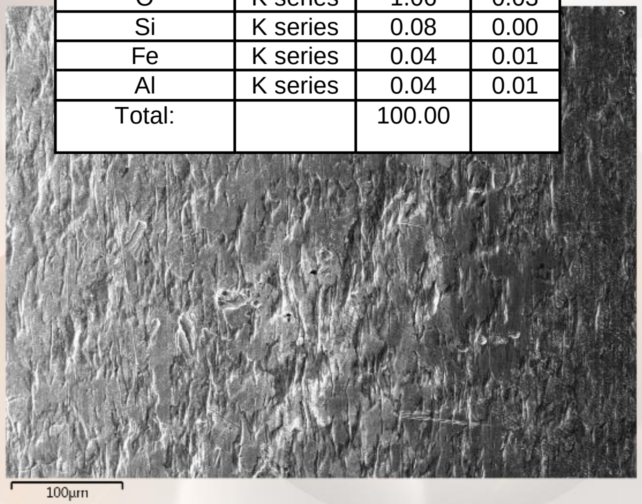
Element	Pd25Ag Bulk Results			Units
	Control/Unexposed	Exposed	Δ	
Ag	25.0	24.9	–0.1	wt%
Pd	75.0	75.1	+0.1	wt%
Al	30	30	0	ppm
Cr	**Not detected**	**2**	**+2**	**ppm**
Cu	**20**	**140**	**+120**	**ppm**
Fe	**20**	**40**	**+20**	**ppm**
Mg	1	1	0	ppm
Mn	**Not detected**	**0.5**	**+0.5**	**ppm**
Na	2	2	0	ppm
Pt	105	105	0	ppm
Si	40	30	–10	ppm
Zn	**Not detected**	**285**	**+285**	**ppm**

Time-of-Flight Secondary Ion Mass Spectroscopy

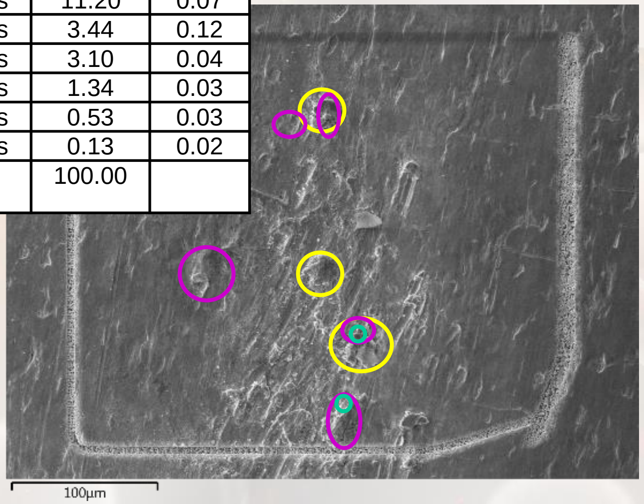


Scanning Electron Microscope/Energy Dispersive Xray Spectroscopy

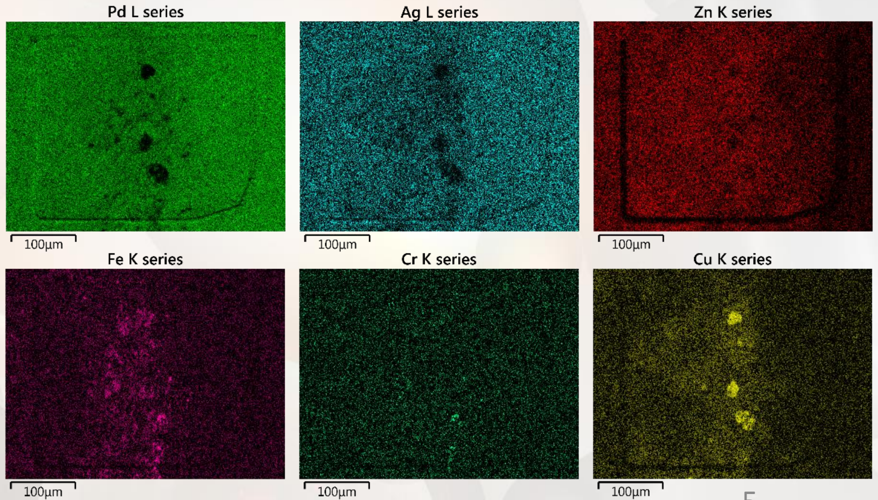
Element	Line Type	Wt%	Wt% σ
Pd	L series	72.47	0.04
Ag	L series	26.31	0.03
O	K series	1.06	0.03
Si	K series	0.08	0.00
Fe	K series	0.04	0.01
Al	K series	0.04	0.01
Total:		100.00	



Element	Line Type	Wt%	Wt% σ
Pd	L series	62.95	0.14
Ag	L series	17.32	0.12
Zn	K series	11.20	0.07
O	K series	3.44	0.12
Cu	K series	3.10	0.04
Fe	K series	1.34	0.03
Ni	K series	0.53	0.03
Cr	K series	0.13	0.02
Total:		100.00	



SEM/EDS



Assessment of needs

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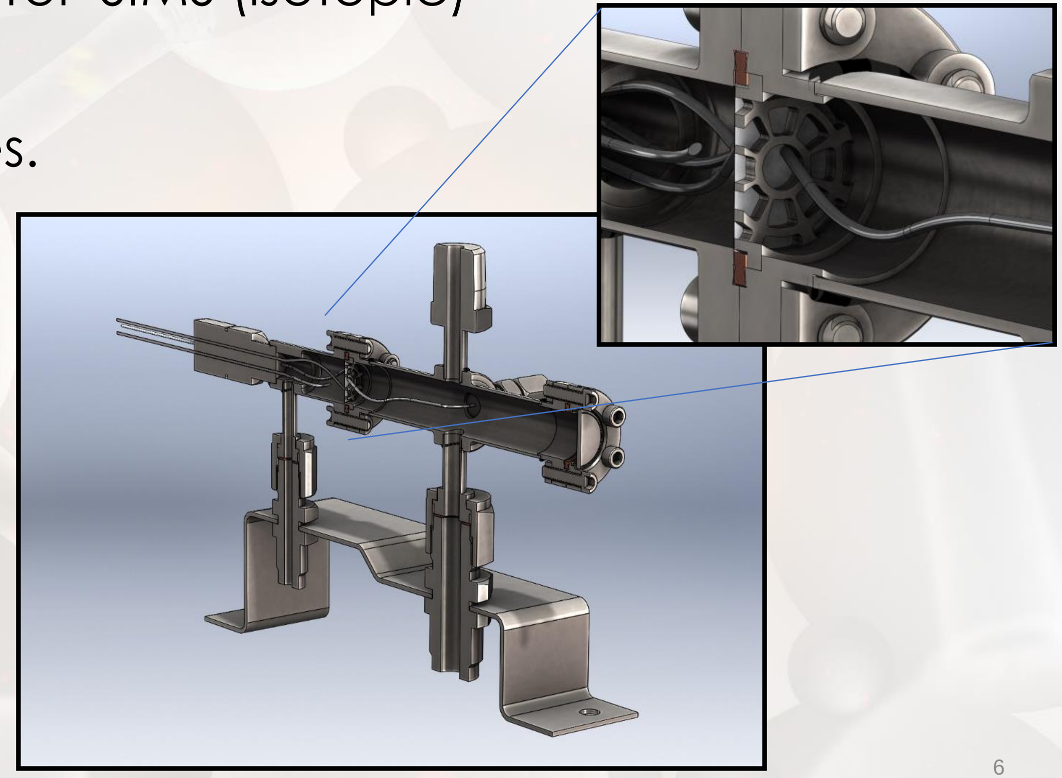
- Need to rule out contamination of PdAg tubes with other materials within the JM gas cycling system; stainless steel being transferred?
- JM system really designed for hydrogen purification
  - Need pressurized system specifically designed to track material changes and allow for other materials to be cycled with reaction gases
- Need more data of before vs after condition of PdAg
  - Continue ICP-AES (bulk), SEM/EDS (surface), and ToF-SIMS (isotopic)
- Need better measurement of excess heat
  - Run with calorimetry in addition to thermocouples.
- Repeatability and Scalability
  - Need to have multiple runs with same conditions
  - When repeatability mastered, begin scaling up
- Further investigation of d-Pd fusion-fission theory
  - Gas analysis of captured/cycled D_2 gas
  - Additional SEM/EDS and ToF analysis of samples



B. Liu, Z. M. Dong, C.L. Liang, and X. Z. Li, "Nuclear Transmutation of a Thin Pd Film in a Gas-loading D/Pd System", *J. Condensed Matter Nucl. Sci. 13* (2014) pp. 311-318

Backup

Temperature vs Time Data from 2018 JM experiment

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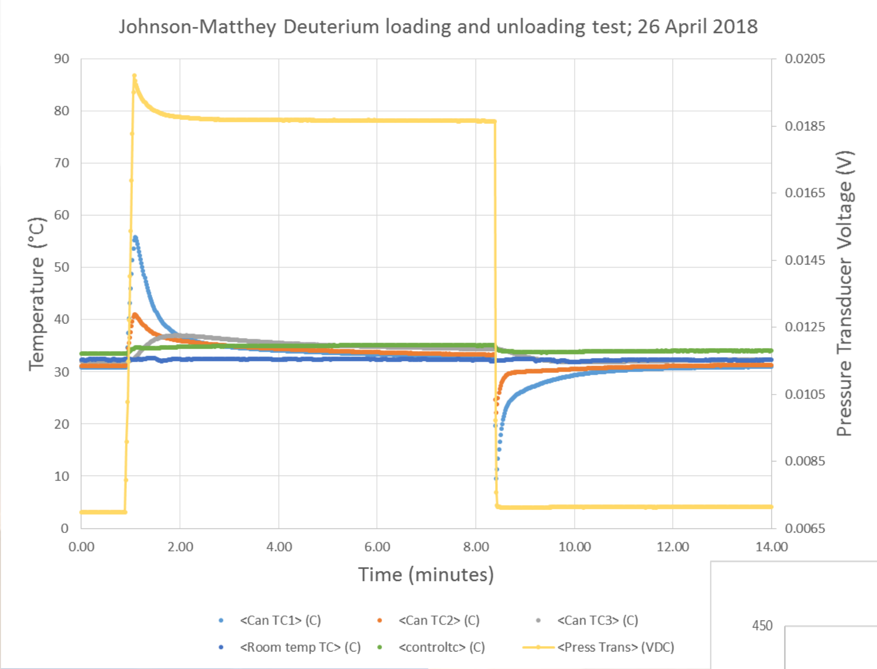
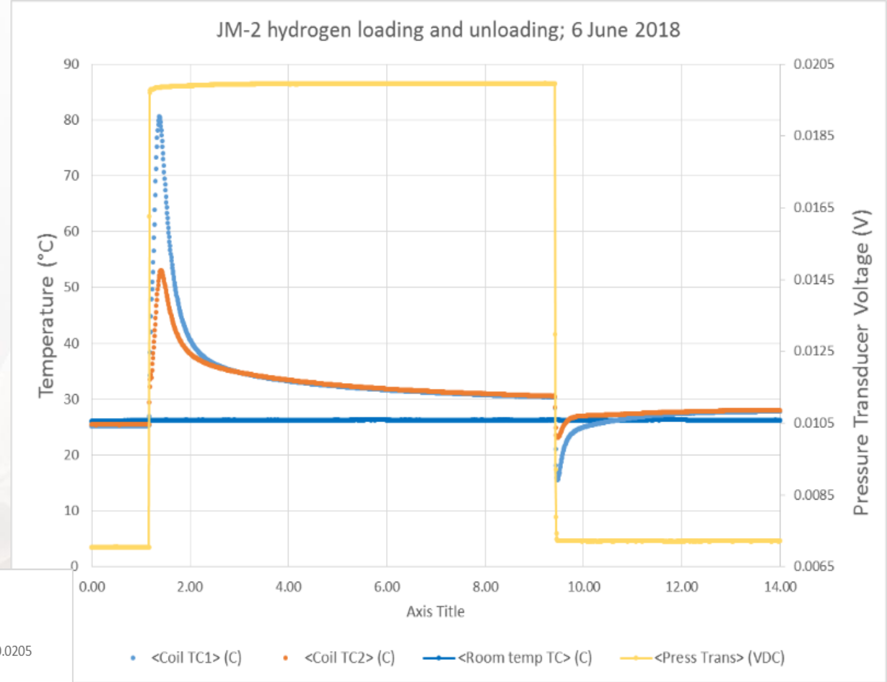
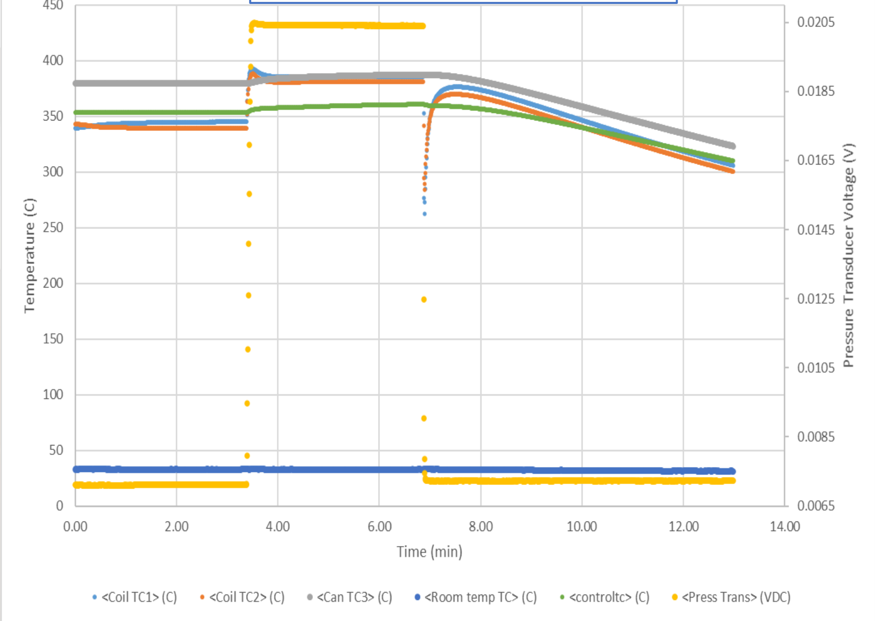


D_2 loading/unloading



H_2 loading/unloading

He_2 loading/unloading



Additional area with transmutations (2018)

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