Investigation of H/He Isotope Separation via Pd Foil

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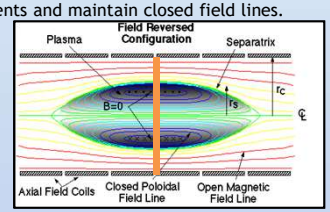
GOALS

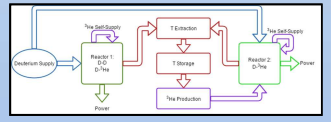
- **Test permeability of Hydrogen and Helium in Palladium foil for isotope separation.**
- **Focus on the effects of temperature and pressure in permeability.**
- **Apply to reducing tritium inventory in ITER or an exhaust stream of an FRC.**

BACKGROUND: PFRC-2 SELECTIVE PERMEATION

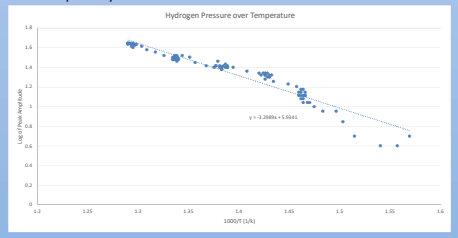
- The PFRC-2 is a magnetic confinement device that utilizes odd-parity rotating magnetic fields to induce currents and maintain closed field lines.



- A reactor would use D-^{3}He fuel, which is aneutronic. However, deuterium (D) atoms in the plasma can fuse with each other to produce either tritium (T) or ^{3}He particle of mass m, charge q, and canonical angular momentum p_φ moves in the effective potential:
- The T must be extracted in order to have a low radioactivity plasma, and to limit D-T reactions resulting in high energy neutrons. By introducing a material with selective permeability (such as palladium) we can separate Hydrogen and Helium isotopes.



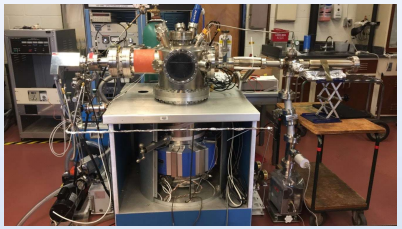
- Deuterium, upon entering the reactor, has a 50-50 probability of fusing with itself and creating tritium. To remove tritium from the exhaust stream of the reactor it must be separated from the plasma via a permeation barrier and stored separately.

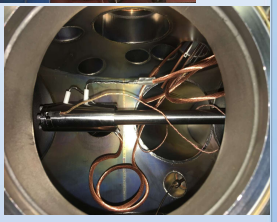


$Q=.3125ev$

EXPERIMENTAL SET-UP

- Two separate vacuum chambers connected by a holding pipe with the 1cm diameter palladium foil sealed in between two mini-conflat flanges. The flange extended ~10 centimeters into chamber 1 and faced the plasma source.
- Two ion gauges were attached to the chamber to measure pressure, one on each chamber.
- An RGA was attached to each chamber to measure partial pressures.
- An integrated pump was connected to the bottom of chamber 2 and a turbo and rough pump were connected to chamber 1 to create the vacuum conditions required for the experiment. Chambers were pumped down to 10^{-7} torr.
- An ECR plasma source was attached to chamber 1 and could be supplied using argon or deuterium gas for future plasma experiments. The role of the ECR plasma source is still under investigation.
- Nichrome wire inside a heat shield with 10-200 watts of power warmed the palladium foil.

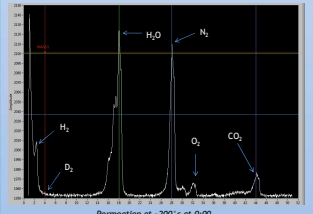




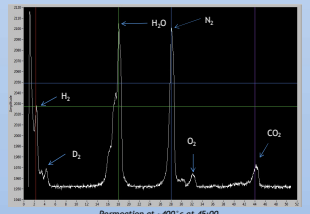
PERMEATION EXPERIMENT RESULTS

PROCEDURE

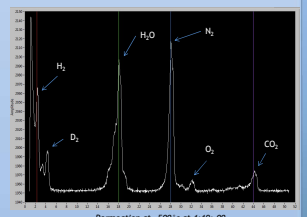
- **Preliminary experiment tested permeation using an argon plasma and deuterium gas.**
- **Data from the mass spectrometer, ion gauge, and thermocouple were recorded every minute for 2 hours to watch for changes in pressure, temperature, and electron signals**
- **The temperature was raised in 25˚c increments, and then each held steady for 15 minutes while data was recorded**
- **The maximum temperature reached was 500˚c**



Permeation at ~200˚c at 0:00



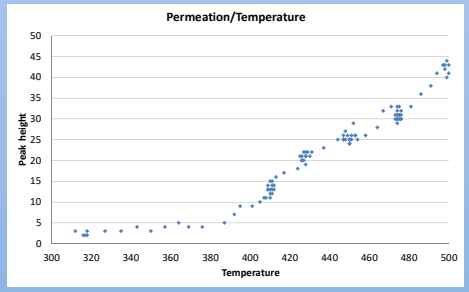
Permeation at ~400˚c at 45:00



Permeation at ~500˚c at 1:19:-00

RESULTS

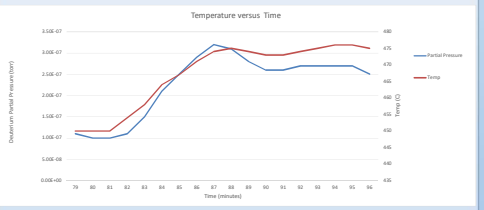
- **As temperature increased, the amount of deuterium detected by the RGA probe in chamber 2 rose.**
- **No presence of argon was detected with the chamber 2 RGA probe. This suggests that there was no leak from chamber 1 to chamber 2 and that the deuterium permeated through the palladium foil.**



CONCLUSIONS

$$D = D_0 * \exp(\frac{-Q}{T})$$

- The rate of permeation through a palladium is proportional to the temperature of the foil.
- Palladium has shown to be a strong choice for a high-z material.



From the rate of rise
T = 60 seconds
$D_o = 3.9 * 10^{-7}$ +1.29 -0.6 m^2/s

FUTURE WORK

- Test permeation using a Deuterium and He-4 plasma source.
- Implant permeation barrier using an ion beam.
- Determine and compare the percentage of Tritium permeating through the palladium foil to the percentage in the main chamber.
- Vary palladium foil thickness to confirm transportation rate.
- Test experimental chamber design in the exhaust stream of a Field-Reversed Configuration (FRC) reactor
- Determine viability in reducing the tritium inventory in ITER.

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REFERENCES

- FRC image from http://depts.washington.edu/rppl/images/frcintropict.gif.
- N. Kishimoto “Hydrogen Diffusion and solution at high temperatures…” (1985)

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