Embedded Fusion & Isotope Production in the UW IEC Device

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Outline

- Evidence of Embedding
- $D^+$ vs. $^3\text{He}^+$ Embedding
- Non-Transparent Cathode Experiments
- Isotope Production
- Summary
D-\textsuperscript{3}He Proton Peak Evident In D-D Runs Following D-\textsuperscript{3}He Runs

MCA Proton Energy Spectrum

- X-ray noise
- D-\textsuperscript{3}He protons
- D-D protons
- Initial D-\textsuperscript{3}He Run
- Subsequent D-D Run

100 kV, 30 mA
2.1 mTorr

Proton Counts (400 s) vs. Energy (MeV)
Embedded Regime

(100 keV $^3\text{He}^+$ ions penetrate 0.3 μm in tungsten)

Cathode  Grid Wire
D-³He Fusion Rates Increase With Run Time After Installing Virgin Grid

D-³He Proton Rate vs. Time

- R_{PLASMA} + R_{EMBED}
- 80 kV
- 70 kV
- 60 kV

30 mA
2 mtorr

Total Proton Rate (p/s)

Run Time (s)
D-$^3$He Fusion Rates Appear To Saturate

- Exponential saturation equations were fit to the curves
- \[ R_{\text{TOTAL}} = R_{\text{PLASMA}} + R_{\text{EMBED}}(1-e^{-\lambda t}) \]
- For the three voltages, \( \sim 2/3 \) of the maximum rate was due to embedded reactions.
D-D Fusion Rates Are Generally Constant With Run Time

D-D Neutron Rates vs. Run Time

Run Time (min)

Rate (n/s)

40 kV

50 kV

60 kV

70 kV

80 kV

90 kV
Non-Transparent Cathode Experiments

- A large fraction of D\(^{-3}\)He reactions occur at the cathode
- The 14.7 MeV proton flux is higher at that location
- A non-transparent cathode forces only embedded reactions to occur
Tungsten, Titanium, & Molybdenum Targets Were Fabricated
D-D Neutron Rates With Targets Are Low Compared to Grid Runs

D-D Neutron Production (30 mA)

- Grid Run
- W Target
- Mo Target
- Ti Target

Production Rate (n/s)

Voltage (kV)

(700-800 °C)
(1200-1300 °C)
D-$^3$He Fusion Rates Depend on D$^+$ and $^3$He$^+$ Implantation

Deuterium vs. Helium Embedding
(W Target-30 mA)

- **Exp 1)** D-D Plasma
- **Exp 2)** $^3$He Plasma
- **Exp 3)** D-D Plasma
- **Exp 4)** D-$^3$He Plasma

Voltage (kV)

D-$^3$He Proton Rate (p/s)
Isotope Production

- Can a solid cathode be used to produce isotopes?
- Reactions occur in the outer layer of the target, protons created isotropically
- Protons activate the target material below the surface
- Initial studies concentrated on $^{94}\text{Mo}(p,n)^{94m}\text{Tc}$ reaction
$^{94}$Mo Has A Significant Cross-Section For 14.7 MeV Protons

$^{94}$Mo(p,n)$^{94m}$Tc Cross Section

$^{94m}$Tc: Positron Emission
52 Minute Half-Life

www.nndc.bnl.gov/nndc/exfor
Molybdenum Irradiation Experiment

- Both deuterium and helium-3 were run in the chamber
- Voltage was increased from 40 to 110 kV, keeping current constant at 30 mA
- Voltage was held at 110 kV for 15 minutes
- On average, about $5 \times 10^6$ p/s were created at the cathode surface for 20 minutes
- Then, chamber was vented, target was removed and counted (NaI detector)
About 1 nCi of $^{94\text{m}}\text{Tc}$ Was Created

Moly Target Activation Spectrum
(Background Subtracted)

Run 684
9-16-02

Counts (in 1 hour)

Channel Number

511 keV ($^{94\text{m}}\text{Tc}$: $t_{1/2}=52$ min.)

871 keV ($\gamma$ released after positron)
Summary

- Retention of $^3$He$^+$ seems to be higher than D$^+$ in W, Ti, Mo
- Metals with low hydrogen diffusivities seem to hold more implanted ions (W>Mo>Ti)
- Embedded reactions can be used to produce isotopes in an IEC beam-target setup