Sonofusion Produces Tritium That Decays to Helium Three

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Abstract. Three main points are covered that are unique to Ti sonofusion target foils. These are surface modification to TiO_x shown by photos and scanning electron microscope, SEM, photos, and the decay measurement of tritium, T, by mass spectrum analysis, MS, to ^3He, the Ti target foils, and the unexplained production of 1μm Ti hollow tubes shown in SEM photos.

1. Introduction

A collection of D^+ implanted Ti sonofusion data, $D_2O \rightarrow 2D^+ \rightarrow T + H + 17$ MeV, are measured and described as $T \rightarrow {}^3He$. The cavitation bubble jet implants into a Ti target foil producing fusion and heat. Along with T some ^4He was also detected but will not be covered here. This work was spread over several years of sonofusion laboratory work. All experiments described here used 100 μm Ti target foils in M II and M III reactors. Experiments show some fusion products, the observed small but high temperature events in the foil, ejecta sites, and induced MHz acoustic standing waves in the target foils. The Ti foil behaves differently than most other target foils in that it forms a bonded hydride that stops the deep loading found in mobile D^+ lattices. The Ti shows very colorful markings due to thin film build-up of TiO_x on its surface. The unique formation of hollow Ti 1 μm tubes, atoms thick, were observable by SEM photos.

2. Experimental and data

Two Ti target foils are described, one exposed to 20 KHz, foil Ti 3A (4-2) and the other to 46 KHz, foil Ti 17. Ti 3A was run at Los Alamos National Lab., LANL. The other foil, Ti 17, was run at the EQuest laboratory on 2/09/95. The Ti 3A run in the MII reactor was a dual cavitation system, Fig. 1,2,3. The configuration of the dual concentric cavitation reactors was powered by a 5cm diameter Ti horn. The top reactor circulated D_2O; the bottom reactor H_2O. The reactors were separated by 0.6 cm thick x 7 cm diameter stainless steel reactor volume. The acoustic energy was transferred through the disk producing the transient cavitation bubbles that implanted plasma jets into these foils. The experiments were run with the assistance of Tom Claytor, Dale Tuggle, and Russ George, The gas sample was collected from over the circulating D_2O in the MII reactor by gas transfer to an evacuated 50 cc sample volume on 4/29/94. Fig. 2.

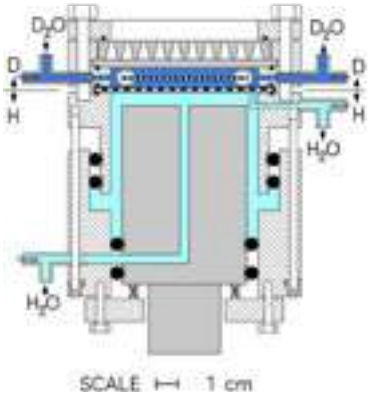

Fig.1- MII, reactor 20 KHz was used in the tritium and ^3He experiment with a heater for calibration.

Fig.2 - 50 cc sample volume was used for MS analysis.

Fig.3 - MIII, 46 KHz reactor, had two opposing piezos with a calibration heater.

Table 1. The table of mass spectral, MS, data produced by Brian Oliver. Days represent days after gas collection.

Sample Volume 4-2.	Analysis Date.	Days.	T in Volume, atoms.	3He in Volume, atoms.
2-0	4/29/94	0	Leak ?	0+
2A	9/14/94	139	1.13E+15	1.71E+13
2B	9/14/94	139	1.10E+15	1.67E+13
2C	9/14/94	139	1.08E+15	1.63E+13
2D	2/06/95	285	1.03E+15	3.89E+13
2E	2/06/95	285	1.00E+15	3.80E +13
2F	2/08/95	287	9.76E+14	3.73E+13

Shown in table 1 is the experimental sonofusion data, Ti 3A (4-2) tritium, analyzed for T via the evolution of ^{3}He that was identified by mass spectrometry, MS. From this experiment at LANL, the 4-2 sample was chosen. The exposed Ti target foil, 5x5x0.01 cm, in a controlled flow of D_2O and Ar at 200 ml/min was cavitated for 18 hours. The 200-watt acoustic input into a 35 cc reactor volume was driven at 20 KHz by a Heat Systems 5 cm diameter Ti horn. The steady state temperature was 61^{o}C, the external pressure of Ar at 30 psig. The lower H_2O reactor was pressurized by N_2 gas to reduce the population of cavitation bubbles (high pressure stops the formation of cavitation bubbles). The dual sonofusion reactor MII was vacuum tight. The gas samples were collected by vacuum transfer in evacuated 50 cc stainless steel sample volumes. Sample 4–2 was collected at the end of the run on 4/28/94. All these dates are very important for measurements as T $\rightarrow$ ^{3}He + β + ν at a decreasing rate of ^{3}He production in the sample volume. T has a half-life of 4475 days and $\lambda = 1.56\text{x}10^{-4}$/days. The MS data is shown in column 5 in atoms. Brian Oliver of the DOE using his tested methodology for ^{3}He analysis performed the mass spectrometry. Column 2 shows 3 dates and column 3 shows days between measurements. These measurements show a disintegration constant that was consistent with the decay of T to ^{3}He. A plot of this data shows the T decay rate in the sample volume to be $\Delta(\text{To} - {}^3\text{He})/\Delta t$ is λ and To - ^{3}He = T, where To is initial tritium. The calculated decay of T is shown as circles in Fig. 4 a,b (4b shows expanded scales).
In the experiment the hypothetical addition of less than $0.66\text{x}10^{13}$ atoms to the initial ^{3}He alters the To, initial titanium atoms, and corrects the data for a possible storage leak. The data in the graph shows that there is a good fit that incorporates the day the gas sample was collected, See table 1. The date produced by the uncorrected data was 30 days later and is shown by the squares in Fig. 4a. With this correction there is a good fit to Brian Oliver's data (in Fig. 4b the circles are calculated data). Brian's data has the right slope but the wrong intercept. Correction for a leak remedies that problem.

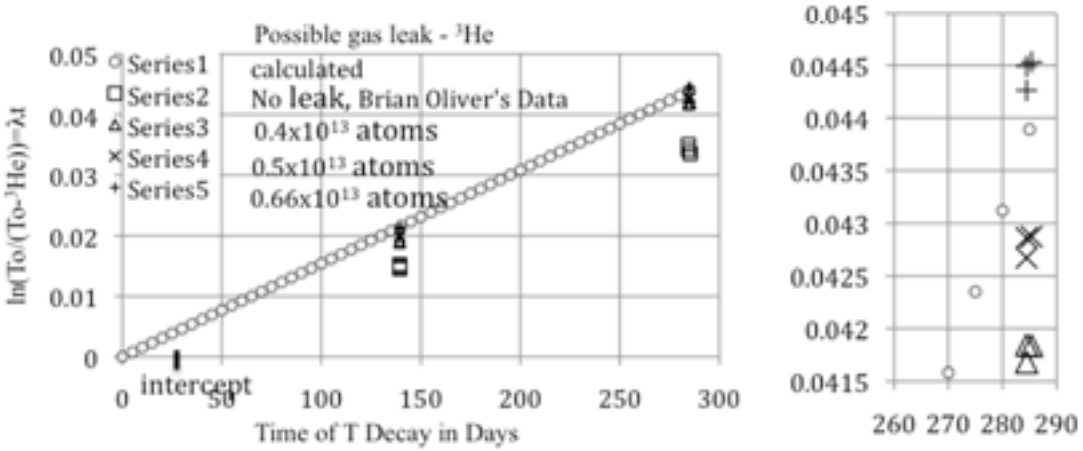

Fig. 4a,b - Graph of the MS data. Leak of gas during storage of 139 days (leaked atoms of ^{3}He corrects the data)

The 50 cc sample volume shown in Fig. 2 may have had a slow leak in its valve, a Nupro (SS 4BK TW-VA), during its storage.
Ti target foil Ti 17 was run at EQuest Laboratory in Mountain View, CA. USA at 46 KHz. The reactor MIII consisting of opposing dual piezo ceramic disks produced smaller cavitation bubbles, same energy density, in circulating D_2O. The configuration of the concentric dual piezo stacks bonded to opposing stainless steel disks held about 0.5 cm gap with 5x5x.01 cm Ti target foil centered in the 6 cm diameter reactor. A controlled flow of D_2O passed through the 14 ml reactor volume at a rate 60 ml/min. Cavitation bubbles formed at the target foil surface were implanted via the plasma jets of deuterons and electrons into the target lattice. The MIII reactor run was pressurized with 3 atmospheres of Ar. The calorimetry was a flow through type calibrated by a variable resistance heater and measured at steady state temperatures and D_2O flow rates. Most of the acoustic activity occurred in the center 50% of the target foil.

3. Discussion

The graph, Fig. 4a, of the MS data was gathered over a period of 284 days with an assumed 0 atoms of ^3He on the day the 50 cc gas cylinder 4-2 was filled via vacuum transfer with the gas from the reactor. This transfer effectively removed 50% of the reactor gas. The gas in the sample volume was flown from LANL to the EQuest laboratory where it spent most of the 139 days in storage. The sample volume was mailed to Brian Oliver at the Rocketdyne DOE facility for the 4-2 mass spectrum analyses. Table 1 of the data from the MS of Brian's gas analysis from sample volume Ti 3A (4-2) was on the 9/14/94 for samples A, B, and C and was repeated 145 days later on the 2/06/95 for samples D, E, and F. The intercept of these two points with the timeline in Fig. 4a should be the time the sample was collected, 4/27/94. However, this is not the case. Brian Oliver's calculated sample volume collection date shows an intercept 30 days later; data shown by squares, Fig. 4a. The intercept should be moved to the earlier collection date, 0 days, not 30 days later. The initial storage time was 139 days. This can be done if one assumes a small leak of gas, T and ^3He, from the sample volume during that period. It is enough to identify T decay as a straight line from the two MS measurements shown in Fig. 4a, at 139 days and 285 days, that has the slope of the disintegration constant λ for T. But it is better to show that the intercept point was on the day of the gas collection. A leak during the initial storage period, valve later closed at 139 days, can explain the shift in the timeline intercept. Or possibly doping of the sample volume with DTO might be the explanation for Brian Oliver's intercept date. Tritium is obviously there in the sample volume. If the sample was spiked, it happened before the sample was mailed to Brian Oliver about 30 days after the sample collection. In any case Brian Oliver's data is a good example showing the presence of T in the sample volume Ti 3A (4-2).
The photo Fig. 5 of the Ti 3A target foil shows interesting colorful visual modification of its surface produced by the sonofusion process. Similar observations in Ti 17 are shown in Fig. 6. These colorful standing wave patterns are produced by thin layers of TiO_x deposited during cavitation that is unusual in an apparent reducing environment of D^+. These standing waves appear to be associated with the Ti target foil's mass and thickness producing an induced MHz resonance frequency via the primary 20 KHz resonance reactor frequency. The Ti surface lattice and D^+ form stable bonds and the surface is covered with thin layers of mostly TiO_x and TiD_x [1,2]. The jets that implant leave their bulky ionic oxygen atoms combined with the surface Ti of the target foil. The D^+ and e^- are implanted into the Ti lattice and form the transient imploding cluster, the cluster model [3,4,5]. Surface color and erosion patterns are not unique to Ti target foils [6].
The SEM of the surface of the two Ti target foils, Ti 3A and Ti 17, are very informative via SEM photos, Fig. 7 and Fig. 8. The two are almost indistinguishable from each other. The 20 to 50 nm nodule surface of sonofusion Ti target foils are different from those foils that have mobile D^+ in their lattice [5]. The very mobile D^+ ejecta from the lattice matrix as found in Pd and Ag target foils [3,5,6]. The SEM of the surface of Ti 3A shows the presence of very small hollow 1 μm diameter tubes of Ti. They appear as a complex network of black lines on the target foil surface, see Fig. 9. SEM photos discovered these several years after Ti 3A foil removal from the M II reactor. Further SEM magnification shows that these tubes are only a few Ti atoms thick and about a micrometer in diameter, Fig 10. The Energy Dispersive X-ray Spectroscopy, EDS analysis, shows a degree of transparency and perhaps shadows, Fig. 10. These tubes were thought to be fragile and certainly would not last long in the cavitation environment so their existence would be limited to a time period just before the reactor was turned off. The SEM photos, Figs. 7, 8, and 9, were taken by Jane Wheeler of Evans Lab, Sunnyvale, CA, and six months later Ti 3A was reanalyzed by Lorenza Moro of SRI, Menlo Pk., CA., Fig. 10.

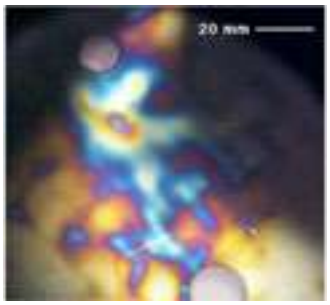

Fig. 5 - surface Ti 3A (20 KHz).

Fig. 6 - surface Ti 17 (46 KHz).

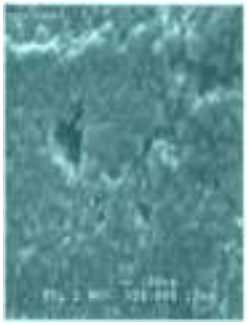

Fig.7 - SEM photo of Ti 3A.

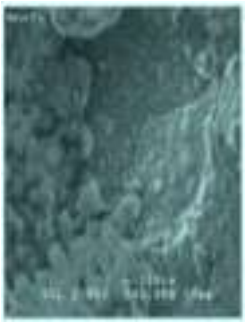

Fig. 8 - SEM photo of Ti 17

Fig. 9. - SEM; tube network

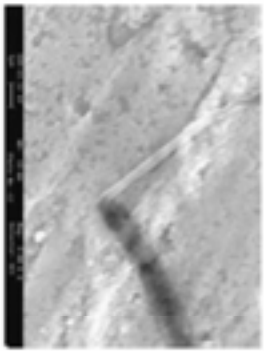

Fig. 10 - SEM of 1 μm

4. Summary

The Ti experiments are worth repeating and the many unanalyzed foils are worth analyzing [6]. T was measured and definitely decaying in the sample volume. The MS analysis showed a 30-day shortfall of the true collection date that can be corrected by assuming a small initial leak from the sample volume before the first MS measurement. Introducing a phantom leak improves the data to the correct time line. The TiO_x and TiD_x surface appearance for the two Ti target foils at different frequencies were the same except that the pattern was larger for the 20 KHz foil. The Ti tubes defy explanation at this point. Collapsing bubbles, their implanting jets, and D^+ clusters produce heat and nuclear products and exist in other systems [5].

Acknowledgements

Tom Passell of EPRI funded Brian Oliver's DOE MS analysis, T → ^{3}He and 2D+ → ^{4}He.

5. References

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