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Research Article

Helium Measurements From Target Foils, LANL and PNNL, 1994

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Abstract

The alphas formed in Ti and Pd target foils were measured as ^{4}He in a mass spectrum, MS, analysis at the Pacific Northwest National Laboratory, PNNL, a lab that specializes in ^{3}He and ^{4}He measurements. The exposed bcc crystal lattice Ti target foil, TF, measured an average of $39 \times 10^{12} \pm 1.4$ trapped ^{4}He atoms. The fcc crystal lattices of Pd, Ag, Ni, and Cu target foils, particularly the two measured fcc Pd TF lattices produced $\sim 0.35 \times 10^{12}$ trapped ^{4}He atoms. This helium level was just above its background level, and 1/100 that of the bcc Ti TF. In the fcc palladium TF, SEM crater volume measurements show that most of the alphas are ejected into the circulating D_2O, where they were measured in the gas phase. In 1994 the samples were run at LANL and measured at PNNL. The helium was measured by melting small TF pieces cut from the active center zone. Then each piece was placed in a crucible, and melted under vacuum, releasing all gases including background helium. These collected gases from one piece were pretreated; then were measured. The data was converted to total ^{4}He atoms trapped in the active zone of the TF lattice. A total of 24 measurements for ^{3}He and ^{4}He on three TFs found no ^{3}He but ^{4}He in all 12 measurements. SEM photos of single ejecta sites were combined with calculations of old data that used knowledge gained from 23 years of cavitation experience that enhances the old data.
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1. Introduction

EQuest Science, a small research laboratory in California, USA, first visited Los Alamos National Laboratory (LANL) in 1993, with the MI 20 kHz reactor, and then returned the next year for further work with a new reactor, the MII 20 kHz, Fig. 1. The new reactor was the same except with an added calibration resistance heater. For three weeks, from mid-April into May 1994, EQuest [1], ran experiments day and night in a collaborative effort with Dale Tuggle and Tom Claytor and their staff in LANL's Tritium Lab and equipped with mass spectrum, MS. We had the support of LANL's scientific staff, including advice and instrumentation. Also, assistance from Naval Research Lab, NRL from George Chambers, and Dave Nagel. The three weeks of nearly constant experimental runs produced much data. A MS filament failure during the first experiment at the Tritium Lab, induced Tom Passel of Electric Power Research Institute, EPRI, to negotiate a contract with PNNL, for a delayed MS analysis [2,3] of the collected sample gases and

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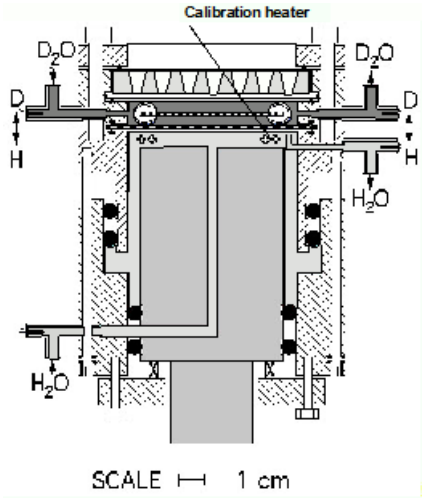

Figure 1. The M-II 20 kHz, a dual resonating reactor with two concentric flow systems.

metal TF stored at the EQuest facilities for 4.5 months after their collection. Among these stored gas samples and the corresponding TF were the samples the Ti 3-A, a 195-minute cavitation run (run at LANL 29 and 30 April 1994) from data recently found is highlighted, and was part of the PNNL report [2] along with 2 Pd TF samples. There were signs that the gas sample volumes were compromised, but the 3 TF were not affected by any problems before and after the experiment was shut down.

Power input to the above sonofusion reactor, Fig. 1, is similar to ion beam implantation experiments [4] and studies of the nuclear reactor containment materials damage studies from the 1980s to the present [5,6]. These papers discuss the swelling lattice and voids filled with D+ and/or ^{4}He. Analysis of collected samples show nm bubbles in grain boundaries at extreme pressures from irradiation of nuclear reactors containment [7,8]. This is similar to the damage measured by NRLs George Chambers's in his X-ray of diffraction study of an exposed Pd TF in 1994, that showed similar swelling and lattice changes compared to an unexposed edge piece from the same Pd TF [9]. The reactor in Fig.1 shows that it is divided into two co-axial reactors, one on top of the other. The driving horn powers the lower H_2O cavitation system at 20 kHz, and was coupled through the 40-mil stainless steel disk to drive the smaller D_2O TF reactor. This dual reactor set up was necessary because the Ti horn surface was damaged by the cavitating D_2O. Dividing into two systems by the separator allowed the horn powered H_2O system and an acoustic coupled D_2O system, to solve the problem. The collapsing bubble in the cavitating D_2O was adjusted to the correct resonance settings. *Argon Pressure, Temperature, and Cavitation power* are the working parameters producing a z-pinch jet in a magnetic squeeze by its accelerating sheath electrons [10] that implanted the TF with an accelerating micro ion plasma.

This paper is somewhat disjointed by time and circumstances. In 1993 R. George negotiated a working visit to LANL at Los Alamos, New Mexico. A year later in April, EQuest returned. Unfortunately, the MS in the tritium laboratory burned out a filament before the first sample was run, but we continued producing data at LANL for two more weeks. The samples were stored at the EQuest laboratory for 4.5 months, when Tom Passell made arrangements with PNNL in Richland, Washington to analyze some of our LANL samples. Many of the liquid and gas samples were contaminated during storage in the EQuest lab except for the TFs where ^{3}He and ^{4}He could be trapped for years. One year ago, data was discovered in a file that was never analyzed. The data was very revealing after so many years and was first presented at the ICCF-20 2016 in Sendai Japan, where Francesco Celani asked the question, "What was the

ratio between background and the measured ^{4}He"?

To make this cavitation make sense, a model was created many years ago to explain a path to the creation of an alpha in a TF lattice. The model is constantly changing. The model follows: Excess plasma electrons, where an electron–deuteron pinched jet plasma pulse approached the target foil. Where the plasma implanted first the plentiful more mobile electrons, followed by deuterons is in an atomic scale. Temperatures and time frames were drawn together as plasma particles M cluster implanted into the TF lattice. In the sub-picoseconds, the electrons surrounded the less mobile deuterons and squeezed clusters of 2–20 deuterons that were in the M cluster $\sim$ 25 nm below the surface of the TF. M cluster, the high-density cluster, compressed at 20 000 K preventing interaction between D+ and electrons. The interaction produces a D atom destroying the cluster. Before the M cluster's natural destruction, two deuterons will be forced together via the attractive image forces between like charges to produce an alpha with no gamma [11]. Or a BEC oriented boson containing D+ and Cooper pair, CP, where the deuterons occupy same energy level, behaving as a single atom, are squeezed to densities of muon fusion and no gamma. The speculation is that as the distance between deuterons decreases an alpha fusion occurs, and the expected gamma was not emitted [12]. These are two possible paths, one for the bcc Ti lattice and one for fcc lattice. The plasma particles involved, deuterons and electrons, were one fermion in radius, and the short time frame add to their possible existence as paths. Also, SEM photos show ejecta sites of the smallest size, from numerical study that form a minimum base size ejecta. The binding energy forming an alpha, $E = 3.83 \times 10^{-12}$ J, is close to the minimum base size energy that produces the smallest crater that has a diameter and depth of 50 nm, producing an ejecta of similar energy [13]. The M cluster is an entity that is the bridge to the alpha.

2. Experimental LANL

At LANL the MII dual reactor set up was constructed with two concentric flow systems. At the top of the dual reactor is a small, with a 36 ml volume, that was the reactor chamber that held the TF. The Ar saturated D_2O flowed through it, shown in Fig. 1. The bottom system, the larger of two systems, produced the cavitation in H_2O, with the heat systems 2-inch diameter Ti acoustic horn transducer in the 100 ml of flowing H_2O. It was discovered that the Ti horn was damaged by cavitating D_2O, and it was remedied by this configuration. Each system had its own circulation controls, pressures, gauges, reservoirs, and heat exchangers. The experimental procedure for experiments with target foils followed this path, with exposure times ranging from 3 to 24 h.

Figure 1 shows the M-II 20 kHz, a dual resonating reactor with two concentric flow systems: D_2O flow in dark gray, H_2O in light gray. The white crosses in the H_2O are the ARI calibration heater. The larger dotted line is the 40-mil stainless steel disk separator between the two systems, and the smaller dotted line is the $5 \times 5 \times 0.01$ cm Ti target foil. The Ti 3-A target foil was centered and sealed with a squeezed Teflon ring. The horn and cavitating H_2O system is coupled to the 40-mil through the ss disk to power to the top D_2O system. The gray area in the center is the 20 kHz commercial transducer from heat systems, a Ti horn, cooled by circulating H_2O, light gray. The bolted down top piece consists of a clamping ring that holds a 1/2 inch thick Quartz disk window or the shown 1/2 inch Al disk with vertically conically drilled holes on top of 40-mil FEP transparent seal. This allows for direct observation of flowing D_2O, dark gray, in the top experimental reactor. The set-up allowed for photos, UV irradiation, and videos, when using the 1/2 " Quartz window. The cylindrical body consists top and bottom components that are hatched and bolted together, and are sealed with "O" rings, black dots. The support of pumps and flow distribution systems are not shown. The D_2O ΔT and flow measurement give the power out.

The cavitating D_2O exposure process of TF Ti 3-A took place in the top D_2O chamber of the MII reactor, where the D_2O circulation rates and Ar pressures were adjusted in a closed system that passed the circulating D_2O through its cooling coil in and out of the 16-liter heat exchanger. The circulation rate of D_2O was 3.2 ml/s and flowed over the 40-mil stainless-steel separator, where the TF was located (see Fig. 1). On the other side of the separator, where the

H_2O pump picked up the hot H_2O flowing at a rate of 13 ml/s. through the center of the acoustic horn. The hot flowing H_2O was transported through its cooling coil in and out the 16-liter H_2O heat exchanger. The H_2O circulation was pressurized from 70 to 100 Psig with N_2 gas, where the acoustic horn driver was suppressing the formation of H_2O cavitation bubbles by the N_2 high pressure. The 40-mil thick separator removed the potential damage to the horn in the bottom system of the dual MII reactor that passed a 20 kHz acoustic signal through the 40-mil separator, into the D_2O producing a jet plasma pulse implanting into the TF. This experiment ran for 105 min and the H_2O bubbler broke shutting down the experiment for 30 min for a bubbler replacement. The experiment was restarted and ran for another 90 min and broke again shutting down the experiment, with the D_2O system still intact. The running pressures were for the D_2O system the input pressure of Ar was 45 Psig and for the H_2O system was 90 Psig. This gave a total run time of 195 min. There was no damage to the circulating D_2O system.

The system was shut down and samples of gases, D_2O, and target foil, were moved from the experimental system. These samples were stored at the EQuest lab. in Mountain View, CA, waiting for further instructions. It was fortunate when EQuest was informed about funding negotiated by Tom Passell and others, that EQuest had an agreement with Rockwell International, in Canoga Park, CA and PNNL in Richland, WA for mass spectrum analysis of the LANL samples. NPPL took over the task of the analysis of the TFs. The TFs and liquid and gas samples were removed and shipped to the PNNL MS facilities, where the TF helium analyses were done.

3. Target Foil Information

The calorimetry data was compromised by the breakdown of the H_2O flow system for the Ti 3-A run. The target foil that was removed from the MII reactor was viable and was stored with the other sample volumes and TF for 4.5 months at the EQuest's laboratory in Mountain View, CA. Then selected sample volumes and TFs were shipped to NPPL for MS measurements. The three target foils that measured Ti 3-A, Pd 9, and P13a from the recovered data are shown in Table 1. The TF flow cartoon diagram, Fig. 3, for Ti 3-A, also applies to the general process of all three TFs.

Three TFs were measured by PNNL MS. 12 measurements were made on pieces of TF were cut from the active zone of each TF, about 1/3 of the TF total area (see Fig. 3). Each of the 12 pieces cut was analyzed separately. A piece was placed into ceramic crucible and the TF piece melted, driving off gases under vacuum conditions for MS measurement the ^{3}He an 4 isotopes.

Old and more recent experiments show the way to interesting comparisons with respect to SEM photos of bcc Ti TF [14,15]. Ti tubes of 700 μm long and 1 μm diameter that rose above the surface of the TF appear hollow. Most of the SEM electron beam passes through the tube leaving a shadow on the Ti TF surface. The tubes are common and very fragile, and would have a short lifetime in the D_2O cavitation field. So, the tubes' ability to survive would be a few acoustic cycles. Only the newest would survive when the power is turned off. These fragile tubes would add to the debris of the bcc Ti TF.

These target foils produced ejecta sites equivalent to the *nE* energy, where n is the number of events, of single and multiple alpha events in the low frequency range of 20 kHz. In the high frequency of RF the single event craters dominate. These craters are $\sim$ 50 nm in diameter with about the same energy as a single event, alpha, E of 3.83×10^{-12} J. These single events are shown in SEM photos [13]. These ejecta sites for fcc TF not only show single events but also measure multi events at 20 kHz that will destroy a Pd TF in ten minutes of cavitation exposure. These have been viewed in videos [16]. The spectrum of crater event diameters cover 0.050–10 μm diameter craters in the surface events of fcc TFs (see Fig. 2B). The most prevalent event was the 50 nm diameter crater at a frequency of 20 kHz in cavitating D_2O in the MII reactor, Fig. 1. The fcc TFs produce the same products, heat and alphas, but their final paths are different. The bcc Ti TF Ti 3-A retains ^{4}He within the lattice, and the measured fcc Pd TFs ejects most of the alphas from its lattice at low and high frequencies, see Table 1. The TF lattice, where the M cluster exists for a sub-picosecond, will either eject the alpha, fcc type TF lattice atoms, Pd, Cu, Ni, and Ag, and heat into the circulating

D_2O, or trap the alpha that is measured as ^{4}He in the bcc Ti TF lattice. The two crystal structures of bcc Ti and fcc Pd TFs, with different crystal structures show different cavitation results.

4. Experimental PNNL

The TFs were delivered to Brian Oliver for PNNL specialized mass spectrum laboratory, MSL, analysis about 4.5 months after shutting down the working visit at LANL. The PNNL MSL criteria was for MS measurements of exposed TF active zones' area. Brian M. Oliver had no knowledge of the TFs origin or the exposure, but as in the past applied MSL methodology of ^{3}He and ^{4}He measurements. Brian Oliver cut and weighed the four pieces from each TF lattice. The emphasis of this paper is on the three TFs and 24 MS measurements made by Brian, searching for ^{3}He and ^{4}He. Twelve measurements from the active zone showed no ^{3}He in any of the three TFs. Twelve measurements from the active zone all showed ^{4}He in the TFs.

PNNL MS measurements were of three TF shown in Table 1. All TFs measurements were in the activity zone showed ^{4}He measurements were greater than background levels. The dimensions of all TFs were $50 \times 50 \times 0.01$ cm^3. Figure 3 shows the activity zone where each piece was cut and weighed for a typical TF measurement. four pieces each released gases that were collected by Brian Oliver for his MS measurements for helium isotopes. The natural background levels were determined from measurement of the edge pieces in rows 4, 8, and 12 in Table 1. The Ti 3-A TF, where the three center cut foil pieces showed three different determinations for ^{4}He in the active zone, see Fig. 3 and Table 1. And the cut edge piece, see Fig. 3, measured for the background ^{4}He in the active zone. The data shows the three consistently high results for bcc Ti 3-A TF using the NPPL MS technique for trapped helium in foils. The data collected by this measurement was obtained through a very elaborate protocol of MS standards, blanks, vacuum pumping. and vacuum heating [2]. The PNNL evolved gases were pre-treated so the MS only measured the helium isotopes. After pretreatment, the first gases through the LN cooled column were ^{3}He and ^{4}He. The helium isotopes were identified by their mass charge difference by the MS. ^{3}He and ^{4}He are compared to standards. Ti 3-A TF showed high ^{4}He concentrations above the background level of the edge pieces. Following the identical process, the two fcc

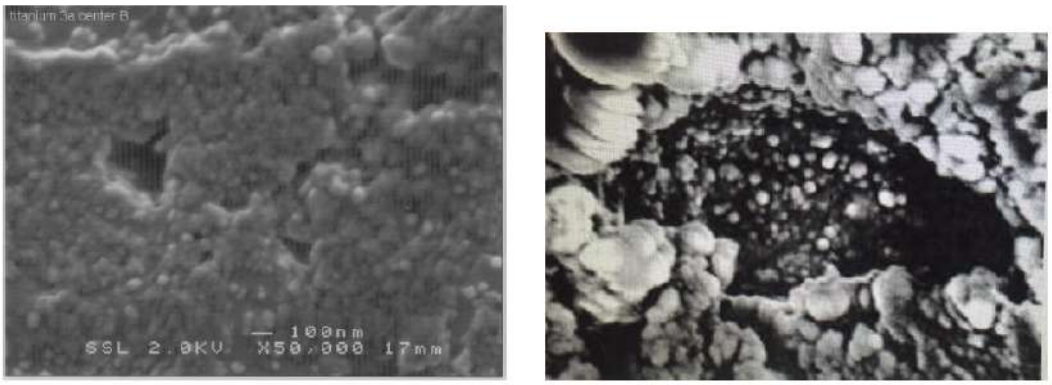

Figure 2. (A) The scale of 2A is shown and the scale of 2B is shown in the diameter of largest of the small condensed Pd spheres ~ 1 μm in diameter. The SEM photo 2A reveals layers of TiO_2 spherical nodules, in the range of 50 nm. This leads to very colorful radiant layers of TiOx on the surface of the bcc crystal of a Ti TF exposed to 20 kHz cavitation. SEM photo 2A by J. Wheeler of Evans Surface Sciences. (B) 2B with about 1/1000 resolution as surface with a few large craters and the TF covered with smaller craters in the sub-micron range. Recently it was observed that target foils of different crystal structures respond to D_2O cavitation in unique ways. 2A, Ti forms a heavy oxide and traps the alpha in a bcc structure. 2B, ejects the Alfa and is a fcc structure. SEM photo by John Dash of Portland State University.

Pd TF showed low ^{4}He concentration very close to the background levels, and are shown in Tables 1 and 2.

A SEM photo of a typical exposed Ti TF surface is shown in Fig. 2A, where the active zone is covered with TiOx in a multi colored surface that was built up in thin layers of TiO_2 after exposure at 20 kHz cavitation exposure. The bcc Ti TF shows in the SEM photo packed layers of small nodules, about 50 nm in diameter, of TiO_2 that gives its bright colored standing wave pattern. No evidence of ejecta site production, see first two paragraphs in Section 6. There is one exception suggested, bursting nano tubes [14]. The bcc Ti TF path was very different from fcc Pd and Ag, Ni, and Cu fcc metal TFs. The many SEM photos of fcc lattice crystals exhibit a size-spectrum of ejecta site craters shown in the SEM photos of a large ejecta crater, Fig. 2B. SEM photos of other fcc lattice TFs, also have similarities showing small condensed metal spheres less than 1 μm in diameter located inside their craters [17].

5. PNNL ^{4}He Data

The purpose of the PNNL measurements was to demonstrate if there was any trapped ^{4}He in D_2O cavitation exposed TF lattices from EQuest 1994 LANL projects. Brian Oliver, Mass Spectroscopist, at NPPL in 1994 followed an elaborate protocol [2] for measurement of the helium isotopes in the metal Ti and Pd TF . The samples were delivered to Brian Oliver at PNNL, Richland, WA for MS measurement. The process used by Brian Oliver at PNNL mass spectroscopy facility was to extract and measure gas trapped in metal lattice target foils exposed to cavitating D_2O. Three pieces were cut from the center of the TF exposed active zone, and weighed, Fig. 3; Table 1, column 1. The fourth piece was cut from the edge of the TF and was used to determine ^{3}He and ^{4}He background.

The crucible was heated in vacuum and cooled preparing for the 7.63 mg cut piece. The piece in the crucible was evacuated of all gases, and then heated at known rate (see Fig. 3). The evolved gases from the piece passed into a 0.25 inch packed charcoal column with hydrogen getters. The column was cooled with liquid nitrogen. The remaining eluting gases were held for the proper time. D_2 and T were removed as well as condensables, air, CO_2, Ar, etc. Then the ionized gases were passed into the MS magnetic field and sorted for mass 3 and 4 ions, and the peak size determined the helium atom peak count. All the pieces were the same except that the TF densities were different. The density for the Ti TF 4506.0 mg/cm^3 and Pd TF 12023.0 mg/ cm^3. are used in the calculations.

Converting Brian Oliver data, the procedure was to cut a piece from the TF active zone. [2] It weighed 7.63 mg. Next the volume of the active zone 0.0833 cm^3 $\times$ density of Ti in mg/ cm^3 $=$ 37500 mg. See the above paragraph. The ratio of these mg values is R$=$ 492. See Table 1; row 1, column 3. R is the multiplying factor for converting PNNL ^{4}He measured data into Ti TF ^{4}He content 42.5 $\times$ 10^{+12} atoms, Table 1, column 4. Follow this procedure for each piece and Ti 3-A TF and the 2 Pd TF and Table 1 data is filled, using the proper density.

These procedures and protocols for helium measurements were developed over many years. All ^{4}He data from PNNL were in units of 10^{+9} atoms, and is shown in Table 1 in column 2. The measured ^{4}He for this example piece,

was measured at 86.4 $\times$ 10^9 atoms and no ^{3}He atoms were found as mentioned earlier. From the PNNL measurement the ^{4}He atoms (see column 2 of Table 1) must be multiplied by the ratio of masses R in column 3 to convert the atoms of ^{4}He measured to the ^{4}He atoms in the active zone of the three TFs. D_2O cavitation affects the active zone, pink area Ti TF, Fig. 3.

Figure 3 shows a cartoon diagram shows PNNL MS and results for TF Ti 3-A.

Table 1 shows The result of the PNNL MS measurements showed the presence of ^{4}He trapped in the Ti TF lattice [2]. The gases that were trapped in the lattice of melted TF pieces were released. The TF's background ^{4}He atoms from the edge piece were subtracted. They were not in the zone of activity of the TF. The cavitation activity was confined to 1/3 the total TF volume. This was a PNNL MS measurement of the ^{3}He and ^{4}He isotopes only.

(This measurement includes background ^{4}He content and the trapped ^{4}He in the lattice that will be subtracted to yield the alphas produced.)

The data shows the numbers of ^{4}He atoms measured from the Ti lattice trapped alphas during its D_2O cavitation

Table 1. MS analyses of target foil Ti and Pd 4506 mg/cm^3, D, or Pd at 12 020 mg/ cm^3.

	Foil mass (mg)	Measured ^{4}He 10^{+9} atoms	Ratio R active mg/piece mg	$R \times$ mg weight ^{4}He MS total $\times$ 12^{12} atoms
Centre cut sample Ti 3-A				
Center 1	7.63	86.4± 2	492	42.5
Center 2	4.46	47.9± 2	842	40.3
Center 3	5.21	51.9± 2	720	37.4
Edge	7.18	2.6± 1	523	1.36
Centre cut sample Pd 9				
Center 1	9.01	6.1± 1	111	0.678
Center 2	8.64	5.01± 1	116	0.580
Center 3	9.33	6.4± 1	107	0.687
Edge	5.78	2.1± 1	173	0.364
Centre cut sample Pd 13a				
Center 1	8.25	6.2± 1	121	0.753
Center 2	10.92	6.8± 1	91	0.624
Center 3	10.48	10.4± 1	95	0.994
Edge	6.03	2.4± 1	166	0.399

*Mass uncertainty is ± 0.02 mg.
The ^{3}He was the first out of the column followed by ^{4}He. No ^{3}He was found.

exposure of 195 min.

Summary of the MS PNNL measurements of TFs cut pieces average trapped ^{4}He atoms are listed in Table 2.

It was recognized that Ti TF was different from the other TF in cavitating D_2O as there were no observed ejecta sites and there was a gray powder visible. Also, the other fcc TF with SEM photos showed ejecta sites, and matched crystal lattice group with observed ejecta sites. The several SM photos of bcc Ti show the ejecta tubes [14]. Table 2 shows red for bcc and yellow for fcc. The different crystal types may help to explain other differences noted in the text. Alphas or ^{4}He are produced in sub-surface M clusters and remain in the TF lattice of Ti, see Table 2 red. fcc TF lattices in a cavitation system ejected alphas produced in sub-surface M clusters, see Table 2 yellow [13,19].

The fcc Pd TF are showing some small residue of ^{4}He in its lattice that just exceed the error measurements that may point to interruptions on an atomic scale in the action of a damaged ejecta mechanism in the M cluster in the fcc lattice.

The bcc Ti TF is showing 39 times background ^{4}He. This poses the question, was the Ti TF a static or a dynamic system? The static system would be a constant build-up of ^{4}He in the lattice during the 195 min of the experiment. The dynamic system would be an equilibrium of helium produced in the lattice and helium lost from the lattice. If a helium flux exists it was of an unknown flow rate. There is a short treatment of this in Section 6.

The bcc Ti foil was unique showing no crater evidence via SEM photos. However, in SEM photos of fcc metal TF craters ranged from 0.05 to 10 μm. See Fig 2A and 2B. There are SEM photos that show 1 μm bcc Ti ejecta tubes on or near the TF surface [14,15]. Were these phenomena related to ejecta sites? SEM photos of fcc TF, Pd, Ag, Ni and

Table 2. The calculated MS Measured Lattice Trapped ^{4}He Results from LANL and PNNL 1994.

Target foil sample	^{4}He total 10^{+12} atoms	^{4}He back ground 10^{+12} atoms	^{4}He - BG 10^{+12} atoms
Ti-3A	40± 2	1.4± 1	39± 2
Pd 9	0.65± 0.15	0.36± 0.15	0.29± 0.15
Pd13a	0.79± 0.15	0.40± 0.15	0.39± 0.15

Cu, show craters with diminishing sizes as the input frequency increased [16]. At 20 kHz cavitation inputs produced the largest events, but harmonic modes may be responsible for single events [13]. Also, one must consider the driven oscillations of TF as it became the source for resonating and collapsing bubbles as presented in ICCF 20 at Sendai, Japan, 2016 [19].

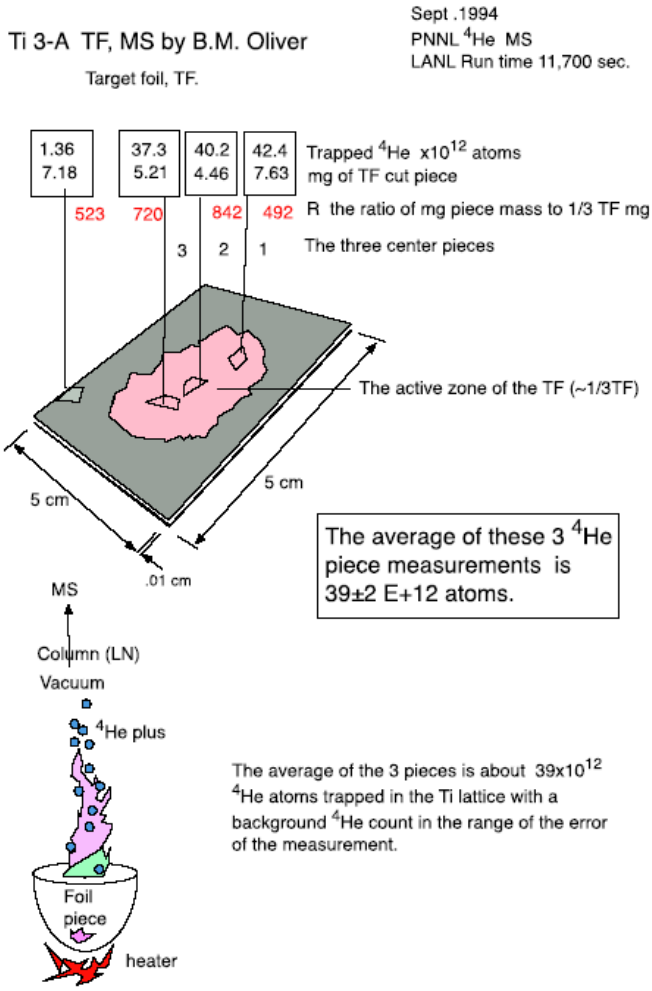

Figure 3. A cartoon of the first row of Fig. 1 showing the MS process of Brian Oliver's PNNL methodology and measurement of the helium isotopes with the final average measurement of $39\pm 2 \times 10^{+12}$. A weighed piece Ti TF is heated in a crucible under vacuum, and the evolved gases were passed through a 0.25 × 12 inch LN cooled column, that quickly elutes ^{3}He and ^{4}He into mass spectrum device measuring 4,250 ^{4}He column 3 of the table.

6. Discussion

In SEM photos, there is a possible correlation between fcc ejecta and bcc micro tubes that were bursts of TF atoms. The very delicate hollow 1 μm tubes of bcc Ti SEM photos show burst of its lattice atoms ending in TF 1 μm tubes. These tube events might be compared to the ejecta from the ejecta sites in fcc Pd and other fcc lattices. The SEM photos of bcc Ti TF show Ti tubes that were partially transparent to an SEM electron beam. They produced shadows during the SEM photo process, and indicated the hollow nature of the bcc Ti tubes [14,19]. And their fragility shortened their lifetime to a few acoustic cycles, and led to a high production rate of lattice atomic debris. These 1 μm tubes, Ti or TiO_2, could originate from near surface M cluster events that were produced in a bcc Ti crystal TF that was a fusion alpha burst, ejecting the Ti TF lattice as 1 μm tube into the cavitating D_2O. Can alphas be ejected via these delicate short-lived Ti tube networks, with their debris circulating in the D_2O? This ^{4}He will find its way to the Ar gas phase above the Ar saturated D_2O for measurement.

For sub-surface M cluster activity, there was a concentration of about one He for each 50 Ti lattice atoms in the Ti TF surface active zone. For the purpose of this of discussion, the active surface TF was one atom deep. When the experiment was turned off, a flux of ^{4}He atoms ended, and the atoms were trapped. Either the Ti lattice had trapped ^{4}He from a steady additive situation, or from a flux rate of ^{4}He in the bcc Ti TF lattice where helium was free to move out of the lattice. The measured $39 \times 10^{+12}$ atoms of ^{4}He represented only helium trapped in the lattice at shutdown, and not counted was the ^{4}He lost from the Ti lattice during the running time.

The ^{4}He results pose a question. Where were the gammas [12] ? An interesting comparison, following the expected path of gamma radiation from the number of ^{4}He atoms measured over the Ti 3-A experiment's running time of 11,700 s is $3.4 \times 10^{+9}$ counts/s representing the expected ^{4}He flux. This compared to the known flux from 1 g of radium at $3.7 \times 10^{+10}$ counts/s that is 1 Curie by definition, and their energy is 10 MeV for radium gammas. The comparison shows that potential gamma radiation expected from ^{4}He is a factor of 10 lower than for the 1gm of radium but double the intensity of the radium and about 0.5 MeV. No gamma radiation count was detected from experiments while we were present working at LANL, and none was reported. This means that there must have been another path for giving up heat formation of an alpha to the lattice. This is just an idea and shows that the expected gamma energy chose another path or mechanism to dissipate the binding energy of the alpha that was faster than the usual gamma. It must be faster and new and excludes the usual path to gamma. Suggested paths are image charge [11] and the BEC [l8] in the M cluster. The foil is gone now. All that is left is the NPPL MS data trail that tells part of the story. It was during the sub-picosecond in the Ti-3A M cluster that the M cluster alpha was created [13,14]. The location of ^{4}He is based on speculation for the purpose of discussion. So if the radiation from the active zone surface area is 1 atom thick the ratio is about 1–50 Ti atoms.

The PNNL MS measurements of ^{4}He were given in values of 10^{+9} units. That was the way the PNNL MS instrument was set. Also, it supposes that alphas were a product. Ti 3-A and Pd 9 and Pd 13 TF ^{4}He values were worth reporting. They informed us about reproducibility with the three pieces from the center cut from the activity zone of the bcc Ti TF, Table 1. Because of the good reproducibility the magnitude is believable. The confidence levels of the PNNL MS data lived up to its reputation. The data shows that the fcc Pd TF sub-surface M cluster bursts into a single event shown in the TF activity zone. These single events produced crater ejecta velocities can be found from SEM photos of single event ejecta sites $E = 0.5\,mv^2$ [13]. The binding energy for alpha is $\sim 4 \times 10^{-12}$ J and from the fcc Pd ejecta site is $3 \times 10^{+3}$ m/s and mass ejected Pd atoms 1.2×10^{-19} kg and energy is 4.4×10^{-12} J. This is equivalent to the energy of single alpha producing events of 4×10^{-12} J. In the fcc Pd TFs there was a low level of ^{4}He atoms trapped in the lattice as low steady state lattice population, and were not ejected, remaining in the lattice at low levels close to the background level (see Table 2). When the experiment was turned off there was perhaps a flux of ^{4}He that was left trapped in the lattice matrix of the Pd foils. Or was the ^{4}He just a continual build-up of ^{4}He atoms in the surface lattice of the Pd TFs? The same question can be applied to the bcc Ti TF. If there was a continuous flux,

that means the number of helium atoms produced was larger than in an accumulation method over time, and the system used to calculate the Ti $39 \times 10^{+12}$ atoms was a low result of the total potential atoms produced. In the flux system, a build-up of ^{4}He was ejected into the cavitating D_2O and migrated to the gas phase, where helium atoms could be collected and measured. In the Ti 3-A experiment the steady state temperature profile dropped off during the system failure during the 30-minute repair. Then the system recovered to the same steady state temperature. The experiment continued until the final breakdown and stopped any further activity in Ti 3-A TF.

Sample TFs that generated craters did not lose all their ^{4}He atoms. Some were trapped in the fcc TF lattices of Pd, Ni, Ag, and Cu. The cavitating D_2O implantation is a destructive process. On top of this cavitation damage was a faster much smaller in size and more powerful alpha event process in the M cluster resulting in the lattice ejecting some target foil. Several videos of this phenomena show the glistening small areas of TF viewed through 0.5-inch-thick Quartz window looking at the D_2O cavitation vaporization of the target foil's continuous erosion [16]. Decoupling from the driving piezo supports the idea that the foil was also a generator of implanting bubble jets in recent RF stimulated cavitation producing measured acoustic beats [19].

^{4}He ejected atoms pass from the fcc TF into the Ar saturated cavitating D_2O, and were found and measured in the Ar gas above the circulating D_2O [2]. The bcc Ti target foil is unique, showing an altered mechanism, with no large ejecta site craters as measured in 20 kHz SEM photos of TF, Fig. 2A. Helium residing in the bcc Ti TF lattice as measured in PNNL MS was different as TF M clusters left ^{4}He in the TF lattice. The energy of formation of 3.83×10^{-12} J per 1 alpha, is speculated to originate from implanted deuterons in an M cluster that often produces a single alpha event at high frequencies at 2 MHz [17,20], but also many single events at low frequency. Multiple events produced in fcc TF increased in the number of alpha energy events in proportion to their crater size. The ^{4}He presence and containment were found in the active zone of the TF volume (see Fig. 3). Investigation by SEM Tomography analyses is needed to examine in the interior of the bcc Ti TF to confirm the existence and location of the lattice bubbles or atoms which would settle this speculation, but it has not been done yet on TFs in First Gate Energy's possession. These are the unique characteristics of Ti TF at 20 kHz, showing less surface damage, and a relatively high count of trapped ^{4}He in the bcc Ti, TF crystal lattice. For a Ti TF crystal lattice, sh $\rightarrow$bcc, change phase at 1200 K reverts back to the bcc if it was not already there [20]. This contrasts with the fcc crystal lattice TF, particularly the two Pd TFs above that were measured and showed alpha ejection events, single and multi. These fcc Pd TFs showed small amounts of ^{4}He collected from experiments measured by PNNL MS. A wide distribution of ejecta from single to large multi events were measured with 20 kHz devices and in the higher frequencies [19]. At 1600 kHz Pd TF, the major ejecta population was the single alpha ejecta and its fcc ejecta debris [13,17].

7. Conclusion

It is difficult to produce good data. The expensive analyses required were not done and few opportunities come along to make measurements that stimulate new work. This is one of those good opportunities. In storage in the First Gate's Lab are 60 exposed target foils collected over 27 years that have never been looked at or tested by SEM, MS, or other methods. Over a period of 23 years and many experiments, a new appreciation for the cavitation process was realized as new results and data altered the thinking of old experiments. This is an opportunity to evaluate data using new cavitation knowledge. The stored gas sample cylinders were contaminated, but the TF samples were not, because all activity in the TF lattice active zone were frozen when the power to the experiment was shut down. The contents and lattice changes remained frozen in their TF crystal lattices. Metal TF foils remain unchanged from that day forward, including the two Pd and Ti 3-A target foils that would retain helium isotopes in their crystal lattices until melting to give up their helium data information. Target foil lattices are less vulnerable in the storage than the valved off 50 cm^3 cylinders of liquids and gases.

The irradiation of the TF by nanometer plasma jets of deuterons can produce high pressure, 100 GPa, in bubbles

in TF lattices [6]. The fcc lattices of TFs Pd, Ni, Cu, and Ag, are more favorable to the production of surface eruptions in the form of craters, in the fcc TF (forming surface cavities, ejecta sites) than in bcc TF lattices. Ti bcc and other bcc Zr crystals favor the production of small bubbles or single atoms trapped in the bcc lattice [21]. Is there a parallel between Ti tubes and Pd ejecta sites as both appear very explosive? There have been no SEM photos of any tubes in the fcc TF lattices.

There have been several experiments involving bcc Ti lattice helium production, no gamma production mentioned, but neutron counts measured heat production equivalent to 10^{15} helium atoms produced in 2.7 h [4] in the Russian paper in 2015. This has a connection to the 1960s–1980s. Many accelerator experiments were done with beams of deuterium and helium ion collisions with lattices of various metal targets that found helium present trapped in nm size bubbles at 100 GPa with deuterons and He; not a bad fit with sonofusion. In most cases the helium and or deuterium ions were accelerated into various target foils [4,6,13]. A very powerful petawatt laser device is described as accelerating ions into thin fcc Al TF, where a pre-pulse creates surface ions on an fcc Al TF. The ions are accelerated back into the TF surface in time frames of femtoseconds; also, not a bad fit for the sonofusion model [8]. Using a bcc Ti TF would be very interesting as it would accelerate deuterons into a stable TiD_2 TF with the production of a possible alpha event, where the ^{4}He would stay, much like sonofusion events in Ti 3-A. This is a proposed path to the helium found in Ti 3-A target foil data. Energy density in smaller bubbles may have higher energy densities. Keep the energy densities as high as possible. All particles are found in the creation of stars, but here only their shadows exist (on paper).

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References

[1] EQuest Sciences, and later First Gate Energies, a small research company dedicated to cavitation studies and sonofusion lead to measurable fusion events. The company founded by Dick Raymond, Larry Klein, and Roger Stringham, 1989.
[2] B.M. Oliver, 1995 Helium analysis of metal and gas samples, U.S. Department of Energy, Pacific Northwest National Laboratory, Battelle Memorial Institute, Richland, WA, May 1994.
[3] B.M. Oliver, J.G. Bradley and H. Farrar , Helium concentration in the earth's lower atmosphere, *Geochim. Cosmochim. Acta* **48** (1984) 1759.
[4] O.D. Dalkarov, M.A. Negodaev and Ruetskii, Investigation of heat release in the targets during irradiation by ion beams, *Russian Acad. of Sci.* **8** (2015), ISSN 2410-4914.
[5] P.B. Johnson and D.J. Mazy, Helium gas bubble superlattice in copper and nickel, *Nature* **281** (1970) 359–360.
[6] A.N. Zhiganov and A.Y. Kupryazhkin, Grain-boundary diffusion and solubility of helium in submicrocrystalline palladium, *Tech. Phys*. **50** (2005) 1026. doi:10.1134/1.2014533.
[7] G.L. Copeland, R.W. Hobbs, G.L. Hoffman and J.L. Snelgrove, Perform of Loe-Enriched U3Si2-aluminm dispersion fuel elements in the Oak Ridge Research Reactor, NCL Collective store, Argon National Lab, 1987, p. 6.
[8] T.Z. Esirkepov et al., Prepulse and amplified spontaneous emission effects on the interaction of a petawatt class laser with thin solid targets, arXiv:0568v1 (2013).
[9] G. Chambers, NRL X-ray diffraction studies of exposed Pd target foil at LANL, 1994.
[10] M.A. Liberman, J.S. De Groot, A. Toor and R.B. Spielman, *Physics of High-Density Z-Plasmas*, Springer, Berlin, 1999.
[11] N.M. Lawandy, Interaction of charged particles on surfaces, *Appl. Phy. Lett*. **95** (2009) 234101-1-3.

[12] J. Yoon, *The Curious Story of the Muon-Catalyzed Fusion Reaction*, Stanford University, 2016.
[13] R.S. Stringham, Conservation of E and M, single cavitation heat events, *J. Condensed Matter Nucl. Sci*. **15** (2015) 55, www.iscmns.org/CMNS/JCMNS-Vol15.pdf.
[14] R.S. Stringham, Sonofusion produces tritium that deacys to helium three, *Proc. ICCF 15*, V. Violante and F. Sarto (EDs.), , Oct. 5– 9, 2009, p. 57. Some parts need a rewrite.
[15] G. Mogilevsky, Q. Chen, A. Kleinhammes and Y. Wu, The structure of multilayered titania nanotubes based on delaminated anatase, *Chem. Phys. Lett.* **460**(4–6) (2008).517–520. DOI: 10.1016/j.cplett.2008.06.063.
[16] 20 MHz cavitation input to M LL reactor 0.5 inch Quartz window of target foil in circulating DOD. Videos of exposed TF shows the destruction of the FCC lattice of Pd; the first 1993 at EQuest Lab, second at LANL in 1994, and third at Stanford Research International in 1995.
[17] R.S. Stringham, When bubble cavitation becomes sonofusion, *JCMNS* **6** (2012) 1–12.
[18] A. Wenz and M. Kronerett, //www.physi.uni-heidelberg.de/∼ fschney/2008SS-Preseminar/BEC_BCS.pdf ; Physikalisches Institute Heidelberg (2008).
[19] R.S. Stringham, EM resonance of a piezo antenna produces heat, helium, *ICCF20,* Sedai, Japan, Co-charis Yashiro Iwamura and Jirohta Kasagi (2016).
[20] Over a period of 27 years three different input frequencies were used; 20 kHz, 46 kHz, and 1600 kHz and as the frequency increased the average ejecta size dropped essentially to 1 alpha/per event.
[21] A. Arjhangmehr, and S.A.H. Feghhi, Evolution pattern of collision cascades in *bcc* V with different grain boundary structures: an atomic scale study, Published online: 26 Apr 2017.