Study of a Power Source Based on Low Energy Nuclear Reactions (LENRs) Using Hydrogen Pressurized Nanoparticles

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ABSTRACT

We are studying anomalous heat, attributed to Low Energy Nuclear Reactions (LENRs), generated from metal alloy nanoparticles loaded with hydrogen (or deuterium) through pressurizing the vessel containing the particles. The primary result thus far is that the excess energies observed in experiments to date are all well above maximum estimation of what could be attributed to known chemical reactions. The discovery of ultra-high-density hydrogen cluster formation in void and dislocation loops has allowed us to develop host materials that give reasonably reproducible results The hydrogen in these clusters is close to metallic density and theory shows the cluster atoms can react when another hydrogen diffuses in transferring momentum to the cluster atoms.

Keywords: low energy nuclear reactions, hydrogen presurrized nanoparticles, power source, hydrogen clusters

1 INTRODUCTION

Anomalous heat, attributed to Low Energy Nuclear Reactions (LENRs), is obtained by pressurizing metal alloy nanoparticles with deuterium gas. The reactions are enhanced by creation of ultra-high-density deuterium clusters in the nanoparticles. Experiments comparing various nanoparticles and plans for a proof-of-principle unit are presented.

Our previous experimental results have demonstrated the formation of ultra high density hydrogen/deuterium nanoclusters with 10^{24} atom/cm [3] in metal defects (Figure 1). [1-2, 5-6] Both experimental [7-11] and theoretical studies [12] have demonstrated that due to the close distance (ca. 2.3 pm) [7] between ions in the cluster, they can easily be induced to undergo intense nuclear reactions among themselves and some neighboring lattice atoms. In view of their multi-body nature, such reactions are termed Low Energy Nuclear Reactions (LENRs) – a terminology generally accepted by workers in the cold fusion field. Because the interacting ions have little momentum, the compound nucleus formed in these reactions is near the ground state. Thus few energetic particles are emitted from its decay. Triggering excess heat generation, i.e., heat generation from nuclear reactions, in LENR experiments has been accomplished in various ways, all involving the

loading of protons or deuterons into a solid metal or alloy material.

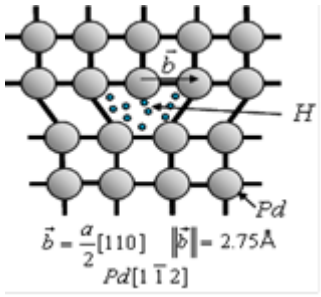

FIGURE 1. Scheme of edge dislocation loops in pd containing condensed h/d.

Electrochemical loading was the initial approach of the experiment, and remains the most practiced approach. Gas loading is also widely used. It is currently gaining more attention due to its smaller heat capacity and thereby higher temperature change as compared with an electrolysis system. In addition, a gas can be easily be heated to temperatures greater than 100 ^{o}C without excess pressure production. So, the excess energy production from a gas-loading system can be observed more efficiently and in a relatively higher temperature range, making the technology compatible with existing energy conversion methods. Although the nuclear physics of LENRs is independent of the loading method, advantages of the gas-loading system described above using Ultra-High Density Deuterium (UHD-D) clusters can be taken advantage of to move the field towards a practical power unit. In this study, we report the anomalous heat generated from metal alloy nanoparticles (Pd/Ni/ZrO) loaded with deuterium through pressurizing the sample chamber. Our gas-loading system is based on the design we first developed for thin film studies in 2010. Figure 2 shows the setup. Inside the large outer chamber (8-inch diameter) is a much smaller cylindrical

pressure chamber (1-inch diameter), shown in Figure 2. This arrangement uses a vacuum between the two cylinders to minimize heat losses and also provided a basis for measurement of heat flow for the calorimeter measurement. The nanoparticles are placed in the smaller chamber and loaded with deuterium (D_2) or hydrogen (H_2) gas. Three thermocouples are attached to the small cylinder – two at the sides and one at the bottom – to record the temperature during the loading and unloading process. The experiments describe here used D_2 gas and Pd rich nanopartices. Other work with H_2 uses Ni rich alloy nanoparticles. A cold trap is connected between the smaller cylindrical chamber and the D_2 gas cylinder in order to provide extra purification for the flowing D_2 gas. During the D_2 gas loading and unloading process, the large chamber remained under a vacuum to reduce heat losses. The remaining heat loss is predominantly by radioactive heat transfer which can be calculated for calorimetric purposes from the thermocouple data.The insert (upper right) shows details of the small pressure vessel which had 25 cm^3 volume.

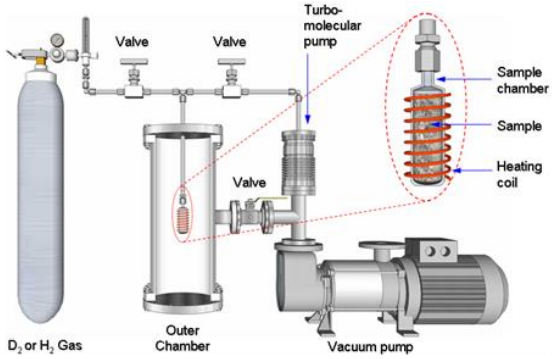

FIGURE 2. Schematic of the gas-loading system.

2 INITIAL EXPERIMENTS

Initial experiments with this system employed a "dynamic" loading where the system is first rapidly pressurized and after about 500 seconds depressurized. This is intended to study the initial adsorption effect, followed by desorption. The experiments loaded high purity D_2 gas at 60 psi into 20 grams of Pd-rich nanoparticle powder also containing Ni and ZrO (termed #1 nanoparticles). The initial rapid D_2 gas pressurization caused the temperature increase from ca. 20 ºC to ca. 50 ºC which produced ca. 1480 J energy release. That release is well above the exothermal energy 690 J that is calculated as the maximum possible from chemical reactions involving hydrating. (Note that the total heating energy was calculated by considering the heat capacity of both the sample cylinder and the nanoparticle powder, and the chemical exothermal energy was calculated using ΔH = ~35,100 J per mole of D_2 for the formation of PdDx for x < 0.6.) The further rise in temperature from ca. 50 ºC to ca. 140 ºC during unloading D_2 gas is important because it is opposite from what would occur normally as deloading is an endothermic process. Thus, the heating is thought to be due to LENRs that are enhanced because of the increased deuterium flux inside the nanoparticles. Side chemical reactions are always a concern. However, more experiments have been done recently to to show that we have eliminated side reactions such as oxygen and deuterium reactions. In this experiment, the input power, including power consumed by gas compression process and vacuum pumping process, is negligible compared to the output power. For example, considering the pumping process, the whole system can reach ca. 10^{-2} Torr within one minute. The volume of the sample chamber is less than one percent of the whole system, thus the power needed for vacuum pumping is negligible. The exact power used for gas compression is difficult to determine exactly, but calculation of the energy required is approximated by the power required to compress deuterium. Although many more studies are needed to absolutly converm the source of the excess heat this result has provides evidence of significant excess energy gain (Total energy out - energy in/energy in). In this short run the gain is already greater than 1.0. Since the input energy is mainly due to exothermal heating during adsorption of the gas into the nanoparticles at the beginning of the run, the gain can be significantly increased by longer run times such as achieved in Figure 3.

3 PARAMETRICGAS-LOADING

We have performed various experiments to study the effect of changing some key parameters and to study longer run times. Each run involves loading and deloading deuterium gas into nanoparticles by pressurizing and vacuuming the sample cylinder. Two sets of different particles were used. The temperature profile for 23 g of nanoparticles (#1) during a 60 psi deuterium pressurization is shown in Figure 3. We can see that the temperature rises right after gas pressurization starts. The increasing rate is low at the start, but then exponentiates until reaching ca. 115 oC. The initial slow rise is attributed to exothermal heating during the loading process, while the fast rise is thought to be due to LENRs. This is consistent with the theory that the LENRs are triggered once a certain threshold temperature is reached. The temperature rising phase lasts about half an hour and then begins to decrease. The total energy produced in this 4.2 hour run was ca. 4800 J. The maximum exothermic energy from chemical reactions is calculated to be 700 J, suggesting the LENRs dominated with a gain (LENR energy out/Chemical energy in) of ~ 6. This is viewed to be conservative. For example, if the calculation was based on the observed desorption energy, the value will be roughly twice of the above value In this run, the averaged power density about 15 W/gram. The run in Fig. 3 was followed by another three runs using the same set of #1 nanoparticles.. These three runs all gave relatively low temperature rises. compared with the first

run, The decreased temperature rise in the latter runs suggests the nanoparticles may have deteriorated, or sintering may have occurred due to repeated use. This issue is understudy.

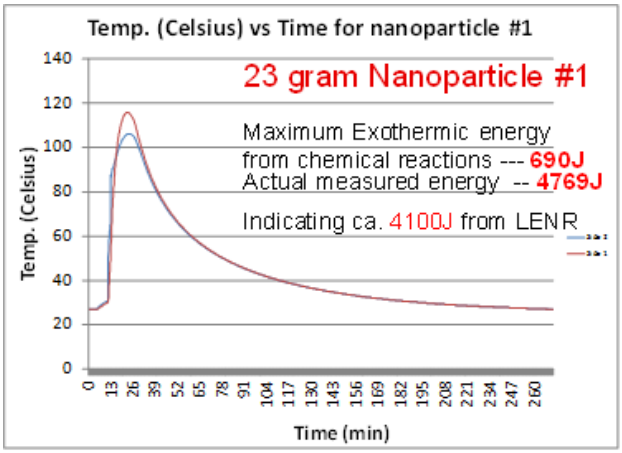

FIGURE 3. Temperature profile during the 60 psi deuterium loading of the #1 nanoparticles. Two different curves were recorded by two thermocouples attached to the sample cylinder at different sites. In this case, 99.99% deuterium gas was used.

4 ADIABATIC EXPERIMENTS

Following these early experiments improvements were made in nanoparticle manufacturing to provide much smaller size. In this case, three different alloys were employed for the nanoparticles, type A is Pd rich similar to type #1 used earlier in Figure 3 experiments. Type B and C contained both Pd and Ni, along with about 60% ZrO. Type B had roughly equal percentages of Pd and Ni while C was Ni rich. As shown in following experiments, these new nanoparticles awere much more reactive than the early ones. A series of experiments were performed to compare various types of nanoparticles. For these runs the outer vacuum chamber shown in Figure 2 was removed and smaller weight of nanoparticles was employed in order to save total experiment time. A set of six runs for the Type A nanoparticle were run. Only the initial run times up to 100 seconds from start of pressurization are analyzed for the comparisons. Due to the decreased weight of nanoparticles used in these runs (2-5 grams vs. 23 in Figure 3) and the faster heat loss due to the outer chamber removal, the temperature increase phase iwas much shorter than that in the earlier runs. As our main purpose for these experiments was to determine the best nanoparticles and to overcome sintering problems, the assumption of adiabatic conditions with the outer chamber removed were acceptable for such short run times. Moreover, due to the fast heat loss, the analysis of the data is only done for the period of temperature increase. Some nanoparticles were reused, either with or without treatment, following an initial run. This was done to study the effect of sintering and possible treatment of sintered particles. The highest gain achieved (LENR energy out/estimated maximum possible chemical energy in) was 15.1 using Type C nanoparticles. The gain in these new sets of experiments more than doubled compared with previous ones due to the improved procedure of making nanoparticles.. Since the adsorption (chemical) energy release occurs at the beginning of the run and then ends, longer runs than employed for these comparisons can give gains of many thousands. The highest power density achieved was 42.7 W/gram using type A particles. This is largely due to the rapid heating achieved with these particles (about 10 sec. to the peak vs.70-100 sec. for other particles.) Runs 2 and 6 used the same nanoparticle employed in runs 1 and 5 respectively. Both suffered a significant reduction in performance, e.g. gains reduce roughly an order of magnitude. This is attributed to sintering effects caused in the initial run, even though it was fairly short. However, results from run 3 suggest that the sintering problem seems solvable. In this run, particles from run 2 were treated by reheating in the air for two hours. When these particles were run they were able to release energy of 426 J/gram, only 3% less than that achieved by the fresh particles in run #1. This is very encouraging, plus we are continuing studies of ways to treat (added coatings, etc.) the nanoparticles to achieve longer initial runs prior to their re-treatment. Initial results seem promising, but much more study and long run experiments are required to fully evaluate long run time issues.

5 CONCLUSION

The primary result thus far is that the excess energies obtained in all experiments to date are all well above the maximum estimate of what could be attributed to chemical reactions. The external power/energy involved, such as deuterium gas compression and vacuum pumping, is minimal compared to the output, suggesting very large energy gain. This result then is extremely encouraging relative to this gas-loaded cell becoming a remarkable power unit. The prime issue under study is to extend the run times using revised nanoparticle treatment combined with a pressure control to maintain a flux of ions in the nanoparticles following the initial loading. Finally optimization of the particle alloy and gas needs study involving the many system trade-offs. Along this line, our ongoing experiments are designed to compare Ni-rich-alloy-H_2 with the present Pd-rich-alloy-D_2 system. Also, in order to understand the power scaling with pressure and weight of the nanoparticles, the earlier studies reported here need to be refined. Assuming the issues identified are resolved, numerous game-changing applications can be envisioned, for both space and terrestrial power. There are also numerous commercial uses on land, e.g. use in small power units for residential use including hot water heaters, use in larger power units for local power sources in

commercial plants, and also military bases. Space applications, ranging from station keeping on to propulsion would also be revolutionized with such power units.

ACKNOWLEDGMENT

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