Recent Results from Gas Loaded Nanoparticle-Type Cluster Power Units

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ABSTRACT

Our recent gas loaded nanoparticle experiments are an outgrowth of several years' study of ultra-high density regions ("clusters") of Hydrogen (H_2) or Deuterium (D_2) found in voids or dislocation loops in the thin film electrodes. We extended these techniques to creation of clusters in pores in nanoparticles employed in gas loading nanoparticle experiments. The nanoparticles use various alloys ranging from Pd-rich to Ni-rich. D_2 or H_2 gas at pressures up to 100 psi is used, with the Pd-rich or Ni-rich nanoparticles, respectively. Pressurization creates LENRs among the cluster and host atoms. The energy obtained from LENRs is many magnitudes larger than any input energy such as the initial absorption energy. No detectable radiation has been observed outside of the pressure vessel containing the nanoparticles, but low energy beta particle emission as well as transmutated elements from "used" nanoparticles are under study. These results are the basis for design of a prototype power device intended for 3-30 kWe distributed power units for co-generation applications in homes and light industry. The advantages and projected economics for these units will be discussed along with the basic physics of this LENR process.

Keywords: LENR, Distributed power, Nuclear power, Nanoparticles, Co-generation

1. Introduction

Our previous experimental results have demonstrated the formation of ultra high-density hydrogen/deuterium nanoclusters with 10^{24} atom/cm^3 in metal defects (Fig. 1) [1]. Both experimental and theoretical studies have demonstrated that with the close distance (ca. 2.3 pm) between ions in the cluster, they can easily be induced to undergo intense nuclear reactions among themselves and neighboring lattice atoms. In view of their multi-body nature, such reactions are termed Low Energy Nuclear Reactions (LENRs). Because the interacting ions have little momentum, the compound nucleus formed is near the ground state so few energetic particles are emitted from its decay.

Electrochemical loading was the initial approach by many, but gas loading is also widely used. Although the nuclear physics of LENRs is independent of the loading method, advantages of the gas-loading system using Ultra-High Density Deuterium (UHD-D) clusters moves the field towards a practical power unit. Here we report the "excess" heat generated from metal alloy nanoparticles loaded with deuterium through pressurizing the sample chamber.

Our gas-loading system is shown in Fig. 2. A small cylindrical pressure chamber (1-inch diameter – see Fig. 2B) is located inside the large outer chamber (8-inch diameter – See Fig. 2A). This arrangement uses a vacuum between the two cylinders to minimize heat losses and provide for measurement of heat flow. The nanoparticles placed in the smaller chamber are loaded with D_2 or H_2 gas, depending on the nanoparticle alloy employed. Three thermocouples are attached to the small cylinder – two at the sides and one at the bottom – to record the temperature. The experiments described here used D_2 gas and Pd rich nanoparticles.

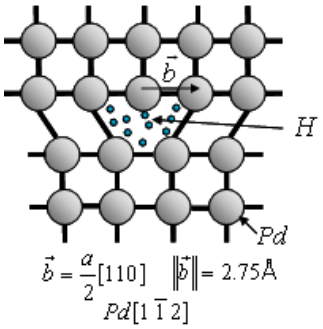

Figure 1. Schematic of edge dislocation loops in Pd containing H_2/D_2 clusters

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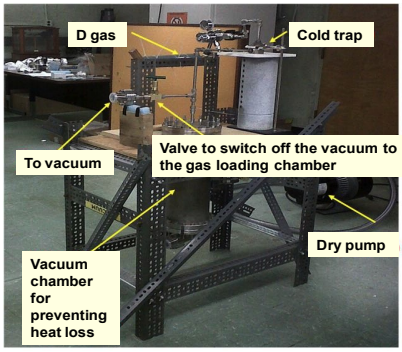
Other work not discussed here uses H_2 with Ni rich nanoparticles. A cold trap gives extra gas purification. During the D_2 gas loading and unloading process, the large chamber remained under a vacuum to reduce heat losses. The remaining heat loss is predominantly radiative heat transfer that can be calculated from the thermocouple data. Figure 3 provides further explanation of the operation of this gas loading system.



A

Diameter =1 inch
Length = 3.69 inch
Vol. = 48 cc

B

Figure 2. (A) Gas loading system; (B) Sample cylinder that contains nanoparticles.

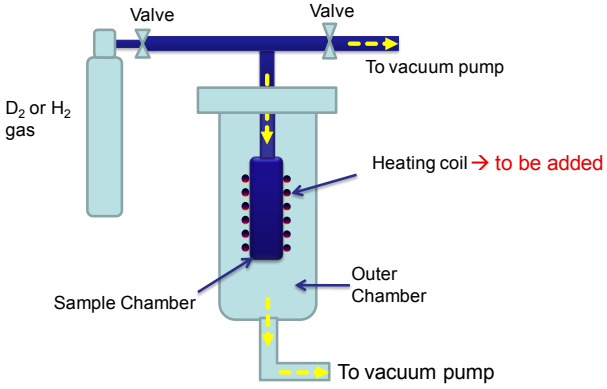


Figure 3. *Sketch of the gas-loading system.*

Recent experiments employed a "dynamic" pressurization technique where the system is first rapidly pressurized and then after about 4-500 seconds quickly depressurized. This explores the initial adsorption effect, followed by desorption. Typical results shown in Fig. 4 used high purity D_2 gas at 60 psi and 20 grams of Pd-rich nanoparticle powder (termed #1 nanoparticles). The temperature profiles used three thermocouples at different locations on the sample cylinder. The initial rapid D_2 gas pressurization caused the temperature increase from ca. 20 °C to ca. 50 °C that produced ca. 1480 J energy release, well above the exothermal energy 690 J that is calculated as the maximum possible from chemical reactions involving hydrating. The rise in temperature from ca. 50 °C to ca. 140 °C 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 attributed to enhanced LENRs from the increased deuterium flux inside the nanoparticles. During desorption. In this experiment, the input power, including power consumed by gas compression process and vacuum pumping process, is negligible compared to the output power. This result provides evidence of a 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 at the beginning of the run, the gain is significantly increased by longer run times. Some data from such runs is shown nest,

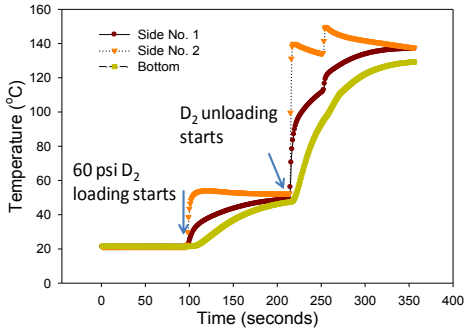


Figure 4. *Raw data (temperature profile) from the dynamic experiment of the gas-loading system. The purpose of this very short dynamic run was to demonstrate the rapid temperature rise following a sharp pressure rise and the same upon sudden depressurization.*

2. Recent gas-loading nanoparticle experiments

We have performed long run time experiments to study optimization of the gain. Two sets of different particles were used. The temperature profile for 23 g of nanoparticle #1 (same as in the dynamic run of

Fig. 4) for a 60-psi deuterium pressurization run is shown in Fig. 5. We can see that the temperature rises right after D loading starts. The heating rate was initially low, but then exponentiates until reaching ca. 115 ^{o}C. The initial slow rise is attributed to exothermal heating during the loading process, while the fast rise is attributed to LENRs. This is consistent with the theory that the LENRs are started 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. 4770 J. The maximum exothermic energy from chemical reactions is calculated to be 680 J, thus the LENRs dominated with a gain of ~ 6.

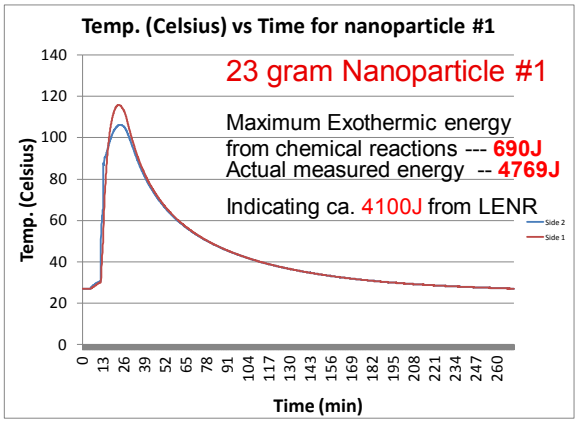


Figure 5. *Temperature profile during the 60-psi D_2 loading of the #1 Pd rich nanoparticles. Two different curves were recorded by two thermocouples attached to the sample cylinder at different sites. In this case, 99.99% deuterium gas was used.*

In summary, our experiment has established a remarkable proof-of-principle power unit at ca. 150 W/20 g, when using D_2 gas. Assuming a linear power/weight scaling, a 3-kW LENR unit (not including the gas tank) would use 0.5 kg or 0.3 liters of nanoparticles. Since the LENR data used is based on very preliminary experiments, significant improvements should be possible.

A new company, LENUCO has been set up to commercialize this technology. The first goal is to develop units in the 3-kW$_e$ range for house use. These would be stackable to form 30-kW$_e$ units for small manufacturing applications. Thermoelectric energy conversion to electricity would be employed and the units would have s cooling stream to allow use for co-generation (electrical-heat) operation. An earlier conceptual design for such a unit is shown in Fig. 6. While this design was for gas loading of thin films, it is easily transformed to using nanoparticles in the film locations.

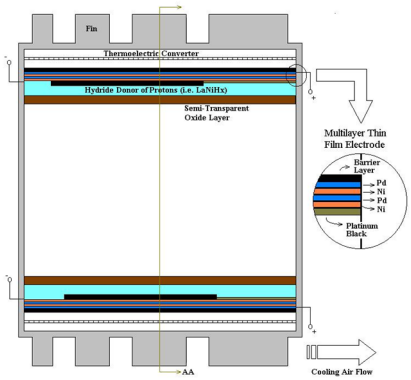


Figure 6. *Conceptual design of a gas loaded cell using thermoelectric energy conversion and air-cooling. This base 1.5-kWe module can be stacked to provide a 30-kWe unit for use in distributed commercial power units.*

Like other nuclear energy sources such as fusion and fission, a LENR cell offers a very high energy density. LENR power offers other distinct advantages. Fission power faces limitations due to the need for long-term storage of its radioactive waste. Fusion has less radioactivity involvement but with early plants using D-T fuel, it still faces tritium containment issues and induced radioactivity of plant materials due to the intense flux of 14.7-MeV neutrons. Also, scaling down to small home sized power units is virtually impossible with these two nuclear sources. A LENR-based power source has reaction products that are mildly radioactive, mainly with beta decay from transmutation reactions. But with the short range of the betas, this radioactivity can easily be contained and quickly decays. The fuel it used, such as D_2, or H_2 is virtually inexhaustible. Also scaling down and up in power are both possible for LENR power units.

The market for such distributed power units is the same as accessed by current renewable power units, e.g. solar and wind. An economic study shows that the 24/7 operation of the LENR translates into a distinct advantage giving an economic payback period of about 3 years, less than other renewable energy competitors. The main cost is the replacement of spent nanoparticles after 6 months to a year. Servicing the unit with a replaceable pressure vessel easily does this. The spent nanoparticles are reconditioned at the factory and used in subsequent units. The "footprint" of these very high energy density units is also considerably smaller that other

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renewable energy power units, making placement in homes/factories considerably easier.

3. 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 gas compression and vacuum pumping, is minimal compared to the output, providing a very large energy gain. This result then is extremely encouraging relative to this gas-loaded power unit becoming a remarkable power source. The prime issue under study now is to extend the run times using a time-varying pressure control to maintain the flux of ions in the nanoparticles following the initial loading. If this is successful, the distributed power units described are a game changing technology. In addition, there are a number of other possible application, 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 even DOD war fighter camps. Space applications, ranging from station keeping on to propulsion would also be revolutionized with such power units.

Acknowledgments

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References

[1] Miley, G. H., and Yang, X., "Deuterium Cluster Target for Ultra-High Density," *18th Topical Meeting on the Technology of Fusion Energy*, San Francisco, CA, 2009.