Small Power Cells Based on Low Energy Nuclear Reactions (LENRs) - a New Type of "Green" Nuclear Energy

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ABSTRACT

Low Energy nuclear Reaction (LENR) cells are a new way to use nano-structured electrodes in power cells to produce nuclear reactions at low temperature. While still in the research stage, this promises ultimate development of "green" nuclear powered "batteries" offering remarkable energy densities well beyond present technology. The background for this technology and current research on LENR are discussed.

Keywords: nuclear battery, low energy nuclear reaction (LENR), cold fusion, distributed power units, mobile power cells

1 INTRODUCTION

Normal hot fusion power requires collision of two deuterium nuclei or deuterium and tritium nuclei. This requires a very high energy or "temperature" to overcome the Columbic repulsion between the nuclei. Temperatures of order of 10^9 ^oC (even hotter than the "sun") are then involved, requiring a "plasma" of these nuclei. The temperature is so high that no solid container can hold the reactants, and a magnetic field or inertial effects have to be used to contain them. To avoid the problem of creating and containing the hot plasma, people are now seeking a way to make similar nuclear reactions happen at very low initial energy, i.e. low temperatures. Such reaction systems are termed low energy nuclear reactions (LENRs).

LENR first gained attention in 1989 when Pons and Fleischmann reported that nuclear fusion was produced during electrolysis of heavy water on a palladium (Pd) electrode [1]. This was called "cold fusion". They reported excess heat production of a magnitude of which the only possible source were thought to be nuclear processes [2]. They further reported measuring small amounts of nuclear reaction byproducts, including neutrons and tritium [2]. These reports raised hopes of a cheap and abundant source of energy [3].

The original Pons-Fleishmann (P-F) type reaction involved Deuterium-Deuterium (D-D) Fusion, where the reaction channel passes through deactivation of the ^{4}He by transferring energy to the lattice which ultimately appears as heat (Figure 1). In association with excess heat, researchers have also reported observing gamma rays, neutrons, and tritium (^{3}H) production, with the quantities in excess of background levels. In addition, a number of researchers have reported transmutation reactions that involve interaction between deuterium/hydrogen (D/H) and atoms in the host lattice, typically heavy metals (See figure 1).

D-D Reactions

		% branching	
		hot fusion	***"P-F" type***
	T + p	***50***	***< 0.1***
D-D	***He-3 + n***	***50***	***$< 10^{-6}$***
	He-4 + gamma	***$< 10^{-5}$***	***99+***

Transmutations

p + metal → products or "fission" product array

Figure 1: Comparison of the LENR Type Transmutations and the D-D reactions. (Both "hot fusion" and P-F)

Transmutation reactions can be broadly classified according to their products. Some experiments have observed a large array of reaction products with mass numbers ranging across the periodic table. These reactions are traced to multi-body events leading to a heavy compound nucleus, which can both decay, and fission into an array of elements [4]. The other set of experiments lead to one or few distinct isolated products [5]. These reactions may or may not involve multi-bodies but the net result is direct formation of the reaction products as opposed to the disintegration of a compound nucleus. Earlier works on transmutation reactions involved thin films on microspheres, while the recent studies at the University of Illinois have converted it to thin films coated on a flat alumina substrate as illustrated conceptually in Figure 2 [6-8]. In this design, a double-layer Pd/Ni thin film, at 8000 Å and 1000 Å respectively, was used as a cathode. The electrical current flow is parallel to the thin film surface so that a high current density and high proton flow rate are obtained along with a high deuterium density [6]. It is reported that the excess heat evolution during electrolysis runs was detected compared with smooth Pt by a high sensitivity open-type calorimeter [7]. Besides, long exposure of photographic films to electrodes removed after extensive runs indicate low levels of soft x-ray and/or beta particle emission. More importantly, a possible close correlation was found between the product emission and the excess heat by computing the excess power from both [6].

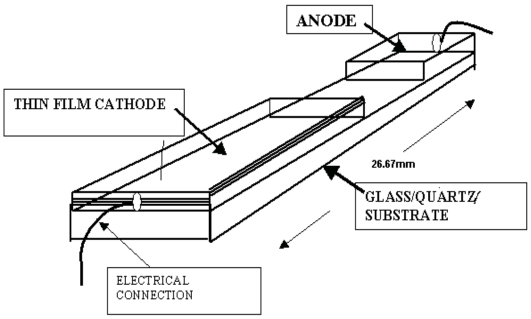

Figure 2: Recent Work Uses a Unique Integrated Thin film Plate-Type Electrode.

2 SMALL PORTABLE LENR POWER UNITS

The observation of MeV particle emission, combined with the transmutations and excess heat measurements, provide extremely strong evidence for nuclear reactions occurring in the thin films during electrolysis. The results, combined with recent observations of localized D/H condensation sites [9] have made the exploration of LENR small portable power units possible.

The localized D/H condensation sites in Palladium which are fundamental to LENRs have been studied in some detail to determine their detailed properties. For these studies D (or H) condensed in dislocation loops have been achieved by cyclically loading and unloading D/H in Palladium films. The Superconducting Quantum Interference Devices (SQUID) magnetic measurements described in Ref. 9 show the resulting “clusters” have ultra high densities and exhibit characteristics of a type- II superconductor. The hydrogen clusters are strongly bound and can only come out at temperature above 800 ^{o}C. A density calculation suggests hydrogen densities approaching 10^{24}/cc consistent with superstoichiometric hydride formation in the deep dislocation cores (Figure 3). In view of their high density and close atomic spacing these sites are thought to be the location of high LENR rates and nuclear emissions.

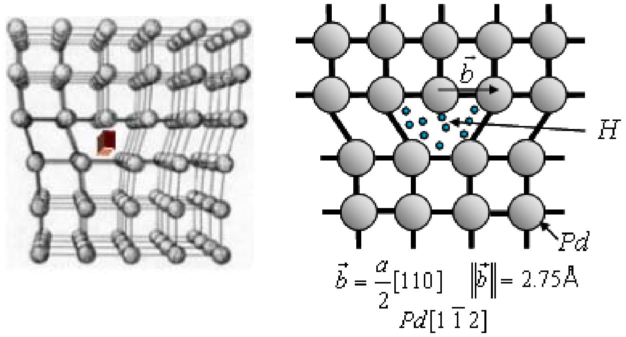

Figure 3: SQUID magnetic measurements show clusters have characteristics of a type-II superconductor. Cluster regions can have hydrogen densities approaching 10^{24}/cc. (left) 3D scheme of typical edge dislocation core (see orange bar) in the Pd crystal. (Right) Cross-section of the dislocation.

While these clusters have extremely local high density, the low fractional volume of the clusters (where the energy producing reactions occur) limits the total volume integrated reactions to low levels per unit volume. Material manufactured with abundant nano or micro structures would solve this problem. One approach is based on the fact that dislocation loops mainly form at the near surface of the material. Thus multi-interface nano-structured materials provide more locations per unit volume for dislocation formation. Several methods to manufacture high dislocation loop densities are under study. We term such electrodes a “massive cluster electrode” (MCE) for controlled cluster reactions. If successful, a high reaction rate per cc should result, leading to a very attractive LENR type “nuclear battery” power cell at small sizes.

To avoid use of expensive materials, the power unit may ultimately use materials other than Pd such as Nickel with direct hydrogen charge [10]. It is encouraging that higher hydrogen loading at dislocation cores than in the bulk material has been reported in such nickel materials. Hydrogen interactions at dislocations in Silicon have also been extensively studied [11], but no work has yet been done to investigate their application of LENRs. As the understanding of the technology of H/D condensation in the defects of various solid materials continue to grow, development of a “family” of candidate host materials is just a time issue.

Based on the excess heat measurements described earlier, local power densities exceeding a kW/cc in the thin films are possible, promising very high energy density power units. Since the radiations emitted (protons, alphas, and x-rays) are not very penetrating (do not escape the cell structure) and no long lived radioactive reaction products are observed, such LENR power units would offer a remarkable “green” nuclear power technology. A sketch of a small D-cell equivalent LENR battery is shown in Figure 4.

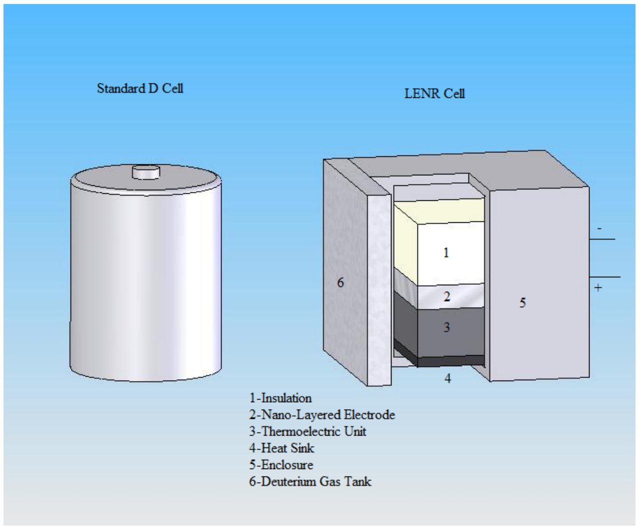

Figure 4: Small LENR Battery - design based on present experimental database.

The cell shown has a deuterium gas “fuel” tank attached. Gas loading is used rather than electrolysis for compactness. Heat flow is directed to the outer casing through a thermoelectric element using an insulation and heat sink design. This type of battery must be used in devices where natural convection air cooling or other heat flow dissipates heat from the battery casing. The design shown uses modular sections connected in series to gives a 1.5 V output at ~ 0.1 A.

The battery run time is determined by the amount of deuterium stored in the attached fuel tank. The unit shown is designed for 1000 Ahr per gas fill. Refilling the depleted storage tank is provided by pump down and gas injection through a filtered line connected to a “filling station” or to a small high pressure deuterium gas container.

The main technological steps needed before construction of this battery are to finish development of the nano-layered MCE type electrode described earlier and integrate this with the thermal-electrical energy management sub-system.

3 CONCLUSION

While LENR studies are still in the research stage, there is mounting evidence that this technology may lead to a very attractive small “green” power units. If so, small self powered battery-like units could be constructed with very high energy densities, well beyond present 1000 W-hr/kg battery technology. This revolutionary development would drastically affect the distributed mobile power industry. Some insight into the far reaching effects of these changes can be gained from the visionary book by J Rothwell [12]. Much more R&D is needed, however, to achieve this vision.

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