The ColdFusion/Lattice Assisted Nuclear Reaction Colloquium At The Massachusetts Institute of Technology, March 21-23, 2014

Title: Assuring Sufficient Number Of Deuterons Reside In The Excited Band State For Successful Cold Fusion Nuclear Reactor Design

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Purpose The purpose of this presentation is to discuss new mechanisms to assure the number of deuterons that can be excited into the band state are sufficient to provide highly probable nuclear fusion reactions resulting in successful commercial cold fusion reactor designs. [1] Region 3 and possibly a new Region 4 of M. Swartz's Operating Point Manifolds (OOP) are examined to obtain relatively high thermal and electrical power levels.[4] Dynamic direct deuterium gas loading of the host lattice enabling or assisting the cold fusion reactions is considered.

Introduction The basis of any physical theory is a set of experimental results. T.A. Chubb and S.R. Chubb, in their work to establish an Ion Band State Theory, introduced the notion that the Schrodinger equation that is used to discuss the wave-like quasi-particle behavior of deuterons and electrons in the band state can be influenced by the number of periodic unit cells, Ncell, that a host metal lattice such as palladium contains.[1] Talbot Chubb stated that the D+ - D+ interaction can be viewed as acting continuously with an interaction = e^2/xr12, where x is an effective dielectric constant due to electron screening. This electron screening is provided by Bloch function electrons which are part of the Fermi sea that is responsible for metal conductivity. When the correlation interaction is viewed as continuously occurring in each unit cell, x has the value Ncell. They also asserted that based upon results of experiments performed by Y. Arata that the Coulomb Repulsion Term of the equation should be modified to have Ncell, the total number of cells in the crystal lattice, be placed in the denominator of the repulsion term. **The Chubb's also asserted that when Ncell is greater than 10^5, the repulsion term tends to**

zero and the probability of overcoming the Coulomb barrier is a certainty. Professor P.L. Hagelstein, MIT, in his review of the Chubb theoretical model has indicated that no known mechanism exists that can assure that a necessary and sufficient number of deuterons can reach the energy level of the ion band state, thus preventing highly probable Bloch Wave Function (special case of the Schrodinger equation) overlap of two deuterium waves producing a 4He++ wave and 23.8 Mev of heat energy. The authors have studied this **issue** in detail and are reporting in this paper, ways a mechanism could be identified and established in cold fusion reactors that could produce commercial electrical power levels.

Discussion

Many cold fusion/LANR experimenters have shown that fusion of deuterium can occur by tunneling of a deuteron from one potential well to an adjacent potential well in a host metal lattice such as palladium or nickel. R. Nieminen, [2],[3] has shown that deuterons that are in the potential wells are already in the band state when they are localized at the bottom of the wells. These deuterons have a very narrow low energy level band width. When the deuterons are excited within the potential wells they can reach a band state level that allows them to tunnel into adjacent potential wells and they can fuse with a relatively low probability, certainly much less than what could be achieved should the deuterons be excited across any band gaps, and transported into the ion band state. We think that the tunneling particle fusions of deuterium account for most of the fusions that occur in Regions 1 and 2 of M. Swartz's Optimal Operating Point Manifolds. [4]

In Region 3, Y. Arata has shown that with a double structured cathode that predictable amounts of 4He and 3He and excess heat can occur as the result of extremely high deuterium loading of the inner chamber of the cathode containing palladium black crystals. After approximately 22 days of loading, very high temperatures and pressures, and **solid metal loading** are obtained. In a private communication, Y. Arata was asked why he used palladium black in his DS Cathodes. He replied that he was trying to determine the minimum size that palladium crystals could consistently and reliably produce helium and excess heat. In a comment at the Naval Research Laboratory in Washington, D.C. in 1996. Y. Arata said that he did not recommend using palladium crystals smaller than 0.4 microns in diameter, due to increased probability of melting of the crystals. Dr. Talbot Chubb worked very closely with Dr. Arata and visited Arata's laboratory at Osaka University, Japan where he and Arata calculated the expected excess heat and helium that they expected in Arata's DS Cathode using Dr. Chubb's band state theory. The experiments that followed in Arata's laboratory clearly verified the accuracy and precision of Chubb's band state theory.

Peter Hagelstein raises the question, what mechanism makes it possible to have the high number of fusions taking place in Arata type experiments? During the period since ICCF-18 at the University of Missouri, and the present, we have studied the works of several chemists, electro-chemists, physical chemists, solid state physicists, et al[5] that are expert in band state theory. In nearly all books and papers reviewed the discussion was on electrons in the band state of metals such as palladium. R. Nieminen, and associates,[2],[3], considered positive ions as well as negative ions in their experiments. In discussions of their work they frequently discussed where the band states were occurring and the effects of temperature, pressure, and width of the bands, as well as, the width of the band gaps between bands. A general result was in many books by these authors. They frequently stated that the band width increased with temperature and pressure. **They also stated that the bands occur within and outside of the associated crystal.** Examination of the Bloch waves, [5] shows that the deuteron waves can be both propagating inside the lattice as well as outside of the lattice giving the possibility of a band **contiuum** versus a **band gap**. They pointed out that any existing band gap decreases between the band on the surface of the crystal and a band outside of the crystal as the temperature and pressure increases. We think the greater the temperature and pressure on the Couch-Baker and the Waisman-Summeri curves, [6], [7], the greater the probability of a positive ion, such as a deuteron, will transport across the band gap into the ion band state outside of the crystal. It is very possible that this can explain the jump in performance as the result of laser stimulation presented by D. Cravens at ICCF-10 [8]. It is possible that by **plating** palladium or other host crystal lattices with gold **provides an enhanced medium for a band state outside of the lattice**, and to be host to a band state region in which Bloch wave functions can overlap producing very high probability of d+d fusion. Another force that could be put on the movement of deuterons across the band gap and into the ion band state outside of the crystal could be provided by a negative electromagnetic field such that the force vector would be in the direction of increased excitation and aid transport of deuterons across the band gap, if any**. We think there can be conditions where there is no band gap to cross when Block wave periodicity requirements are met and the band states are a continuum at the surface of the lattice and outside [5].**

New Mechanism

A new mechanism is needed that utilizes the parameters listed above and additional ways to excite localized and delocalized deuterons across the band gap and into the ion band state**. R. Nieminen and his associates[2],[3] point out that the increased weight of a deuteron over light hydrogen gives the deuteron improved methods for transport to higher excited energy band state levels because the heavier deuterons act like particles vs. the very light proton nuclei of light hydrogen. They also indicate that delocalized deuterons vs. localized deuterons in potential wells have a much higher probability of achieving transport to an ion band state.** If the new mechanism greatly increases the number of deuterons in the band state, then the necessary and sufficient number of fusions would be possible with corresponding heat produced by the increased number of fusions. This discussion also points out the need to have a high delocalized deuteron flux, with a high transport rate, moving continuously through the reactor core to assure the required thermal power level for practical reactors. Once the new mechanism is developed it will be necessary to remove the fusion heat produced such that the reactor core will not be quenched rapidly.

Reactor Designs Each cold fusion/LANR reactor design that will produce commercial power levels will require a specific new deuteron transport mechanism to assure wave function overlap in the band state and a compatible coolant will be needed to carry away the heat of fusion to a steam generator in the primary loop of the reactor. Most user requirements will dictate the use of direct deuterium gas pressurization of the reactor core. Gas loading will be the preferred choice because electrolytes are liquid and can freeze and change state. Compressed deuterium gas will also be more practical for aerospace and marine applications. **We suggest that the preferred designs will have a high rate deuterium gas cooled flux moving through the reactor core where the deuterium coolant will provide BOTH the fuel and the coolant for the heat of fusions.[9]** The burn-up rate will be less than one percent of the fuel over several years of operation, and the nuclear ash of the fusions will be Helium gas that can be added to the deuterium gas coolant without complications since the helium is an inert gas. The mixture of the deuterium and helium will not be a problem because the partial pressures of the two gases will permit a single gas dynamic system [9].

The multi-parameter reactor designs will most probably have an operating temperature between 450 degrees C and 1000 degrees C, keeping in mind that palladium melts at 1555 degrees and a safety factor is required. The anticipated fuel/coolant loop operating pressure will be very high, possibly several thousand psia, to assure the band gap width is narrow enough to allow a large number of deuterons to be excited into the band state. The mass rate of flow of the deuterium gas fuel/coolant will have to be sufficient to remove the total heat of fusion. This required gas flux rate will be much greater than the normal diffusion rate of deuterium through palladium metal. Therefore we think holes will be required for the coolant/fuel to flow rapidly through the reactor core host lattice palladium plates. Thousands of holes can be “drilled” through the palladium plates to provide the necessary heat transfer to the coolant. These holes can also increase the surface area for diffusion of the fuel (portion of the coolant) into the host palladium crystal lattice and a large number of delocalized deuterium will be continuously available to be transported into the ion band state. It is suggested that the holes be on an angle theta from normal and be on positive and negative angles in alternating core palladium plates to provide a turbulent flow through the reactor core allowing eddy currents of fuel/coolant to occur on the surface of the holes through the reactor core plates increasing the surface fusion regions of the palladium plates. We studied the fractal nature of surfaces and noted the periodicity and symmetry are most dominant on the surface of materials that have undergone fractal structural development. [10]. In particular, we think ‘’The Menger Sponge”, Plate 145 of reference [10] , is an interesting design. The “cube” is full of holes and has periodicity on all surfaces as characteristic of fractal process. Crystals grown with a useful host metal such as palladium, and with a **reverse** fractal material deposition process, using a grid computer programing technique, could produce **building block** reactor core lattice crystals that have holes for cooling as well as palladium atoms for deuterium occupation and fusion reactions. These grown crystals, in their development could be used to determine which sub volumes of the crystals would be ideal for fusion reactions and the volumes that would be vulnerable to melting quenching, similar to Dr. Arata's use of palladium black to determine how small sized crystals could be, without melting. Then, with adjustments made to the crystal deposition growth program could provide optimization of the crystal design. A similar process could be used to optimize the gas dynamic flow of the deuterium coolant vs. the flow required for diffusion of the deuterium gas into the host palladium volumes to assure the required number of fusion reactions.

Designers of cold fusion reactors must realize that they must use imaginary tools when necessary to understand why the reactors are radiation-less because of the host lattice spreading out the energy of fusion reactions. In quantum mechanics, it is required that what happens in the first unit cell of the host lattice, is what happens in all cells of the lattice. Whereas in reality, SEM analyses show that different things happen in one region of the host lattice and other things happen in other unit cells. Therefore, it is our opinion that particle physics be the norm for fusions occurring within the potential wells of the palladium lattice and the and the use of the term "cross sections" to indicate the probability of the reactions within the lattice. On the surface of the lattice and outside of the lattice to use Bloch wave function expressions from use of the Schrodinger equation and wave like quasi-particle mechanics to explain the overlap of deuteron waves to make 4He++ waves, that give off 23.8 Mev of heat, that is given up to the coolant, and transported to the steam generator by the primary loop. When Ncell is greater than 10^5, the Coulomb barrier is completely overcome and the wave overlap with a probability of 1.0 and no term like "cross sections" is needed. The Chubb physicists believed that the simple placement of Ncell in the denominator of the Coulomb Repulsion Term of the Bloch modified Schrodinger equation is necessary to provide an excellent approximation of the removal of the Coulomb barrier (e^2/r12Ncell tends to zero as Ncell increases) and that the deuteron Bloch waves will have a very high probability of overlapping and producing helium and heat in volumes where lattice periodicity has unbroken symmetry. They pointed out that when the periodic order is broken that the wave propagation would also stop. This leads to understanding why smaller crystals have a higher power density than larger crystals and with the Block waves spreading out the fusion energy, the periodicity assures that the reactions are radiation-less. The use of **fractal** process grown crystal lattices may provide periodicity volumes for deuterium fusion and holes for the passage of the bulk deuterium gas for cooling and pathways for laser triggering if need. [8],[9],[10]

Computer codes are essential to handling the numerous parameters that we have mentioned in this discussion. We recommend that existing codes for fission reactors be utilized where applicable when suitable modifications are made to the codes to characterize the cold fusion/LANR reactor being designed. And, of course, hybrid computer simulations should be used to analyze the performance of the reactor kinetics and instrumentation and controls, power change requirements, and other operational parameters. In gas cooled reactors, the gas dynamics are very important especially at the very high pressures and temperatures needed for a high number of fusion reactions in the reactor core. [6], [7],[8],[9}. The mechanism for assuring the required number of deuterons are transported into the band state must be tailored to the design of the total reactor primary loop system and will be different for each design. In time, when many different reactors are operational with commercial power levels, it may be possible to make more generic statements as to what deuteron transport mechanisms are involved.

Recommendations

It is recommended that reactor contractors be given the opportunity to develop gas cooled cold fusion reactors designs. Atomics International, for example, has develop commercial high temperature gas cooled **fission** reactors and in the process developed special fuel multi-level fuel spheres which contain the radioactive fission products and permit sufficient cooling for reactor core fuel spheres producing 230 Mev per fission. This enormous amount of heat can be compared with the 23.8 Mev per fusion reaction in a cold fusion reactor core. It is possible that it could be a relatively easy transition from a fission high temperature gas cooled reactor to a cold fusion high temperature gas cooled reactor.

In February, 2013, Oregon State University installed a $4.8 Million scale model simulator for gas cooled reactors. It is recommend that this simulator be considered for design studies for cold fusion gas cooled reactors by mainly changing the reactor core from a fission heat producing core to a cold fusion heat producing core. The cooling system would also have to be modified since we are advocating that the coolant also be the fuel for cold fusion.

And finally it is recommended that the U.S. Department of Energy (DOE) be approached with proposals to convert fission high temperature gas cooled reactors to cold fusion high temperature gas cooled reactors because they are radiation-less and produce only helium, an inert gas which can join the coolant vs. highly radioactive fission products which have very difficult logistic storage problems. The (DOE) has the charter for developing nuclear reactors.

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