Usefulness of Quasi-Particle Ion Band States in Modeling LENR Processes

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Abstract. The density of atoms with 3 or more electrons is determined by Pauli exclusion. Conduction electrons in a metal and reactant deuterium atoms are in Bloch function form, in which corresponding positions in a lattice are equivalent. 2-dimensional symmetry D-atoms are thin, flat, and have reduced Coulomb repulsion between pairs. Fusion takes place inside an interface between an ionic crystal and an epitaxy metal layer. 2-dimensional and 3-dimensional systems are different. Both are real, benefit from shock stimulation, and are Bloch systems; but they require different environments.

1. Introduction

Low Energy Nuclear Reaction (LENR) processes are new types of catalyzed reactions. They depend on causing potential reactants to assume non-classical geometric configurations. Nature does this sort of thing when it creates a metal. But we are now so familiar with a metal's non-classical geometry that we accept it as a routine part of the Quantum Mechanics of solids and liquids. When electrons become part of the electron medium of a metal that carries electricity, we call them quasiparticles. Their charge is "coherently partitioned". They have adopted a many-centers[1] geometry modeled by Felix Bloch. Bloch function physics explains how a solid with a density greater than that of insulators like salt can be a good conductor of electricity.

LENR processes are those in which a laboratory chemical process can cause some sort of nuclear reaction to occur.

LENR processes that produce measurable heat or measurable quantities of transmutation products are of primary interest. There are secondary LENR processes that can occur when an overvoltage main stream process produces a 2-dimensional symmetry product and the process is disturbed or interrupted. The result can be rare side-effects like those that cause MeV nuclear particles to be produced. These strange quantum processes when reproducible have important diagnostic value.

There is no single road to identifiable LENR products

This paper considers 3 classes of process:

Production of heat in electrochemical systems
Production of heat in gas loading systems
Production of MeV particles resulting from overvoltage electrolysis LENR

We first consider the physics by which heat is produced in gas loading systems.

2. Quasiparticle Physics

Quantum Mechanics textbooks typically start off with solving problems like the behavior of an electron in a harmonic potential well, an electron in an inverse square potential (hydrogen atom), or a particle-in-a-box. In these problems there is an identifiable center-of-mass. Bloch asked the question, what happens when the electron is in lattice electric field that extends in 3 directions in space and repeats and repeats forever? In this problem there is no identifiable center-of-mass. Such electrons are called quasiparticles. Corresponding positions in each unit cell of the lattice are equivalent. The charge in each unit cell is its partition fraction. This idealized picture is clearly unphysical and has no boundaries, but the solutions to

Bloch's lattice potential proved effective in describing the observed behavior of electrons in a real metal to within a few layers of the metal's surface. Most of a metal's electrons are not involved in conducting electricity and are permanently part of the metal's atom lattice. Only the quasiparticle electrons carry the electric current. LENR physics is quasiparticle physics applied to deuterons, and in some cases to other ions like protons and Li^+ ions.

Reaction rate modeling of deuteron quasiparticle systems can be studied using time-dependent Schrodinger wave equations, or it can be studied using stationary state wave equations plus time dependent perturbation theory to connect "initial" and "final "states. When one is using stationary state wave equations, one has the option of representing them in terms of a sum over Wannier functions. Wannier functions portray quasiparticles as a sum of random snapshots of collapsed many-centers wave functions. I think it is easier to understand the physics if one avoids the Wannier function approach. I also adopt the view that a complete fusion reaction may occur in successive steps in which the final state of step 1 is the initial state of step 2. In this picture, a sequence of metastable states plays a major role in LENR fusion events. Each transition delivers heat to the adjoining metal lattice.

3. 2-Dimensional Symmetry Reactions

We start our study by focusing on 2-dimensional symmetry LENR. 2-dimensional DD-fusion reactions are examined because they are the easiest to picture. They are called DD reactions rather than dd reactions, because the deuterons are always neutralized by an electron. D designates a D atom. A D atom is a D^+ ion plus its accompanying electron. Neutralization occurs because it is required by equilibrium chemistry, which insists on minimizing system Gibbs free energy. By an electron I mean a quantum of electron charge. In our initial simplified picture we ignore a requirement for imposing coordinate exchange symmetry on an entangled 2-body system, but recognize that the electron is a fermion with spin 1/2. We also recognize that the K-shell of an atom is an entangled spin-zero electron pair.

4. Permeation Transport

It is important to recognize that conduction by quasiparticles is not the only form of D transport. In permeation studies, D quasiparticle conduction competes with D-atom diffusion. D diffusion is driven by the local negative gradient of the interstitial D concentration. D quasiparticle conduction is driven by a difference in D concentration at entry and exit boundaries of a discrete finite volume of ordered lattice.

5. Gas Loading Reactions with ZrO_2 + NanoPd Catalyst

Arata and Zhang (A-Z) made major progress toward production of DD fusion heat when they first used ZrO_2 + NanoPd Catalyst.[2] In switching from Pd black they introduced a highly stable ionic solid into their composite catalyst. ZrO_2 has a large negative Gibbs free energy, which means its crystalline structure is not easily influenced by adjacent layers of metal. The metal is a much more malleable lattice component.

A-Z made a second major step when they switched from using electrolysis to gas loading as their means of adding deuterium to the nanoPd employed.[3] Iwamura had previously made a similar discovery when he discovered that measurable heat could be produced by diffusion of deuterium through a plate with embedded CaO.[4] CaO also has a highly negative Gibbs free energy. These developments suggested that the interface between stable oxides and Pd metal is a likely site for deuteron quasiparticle transport and DD fusion reactions.

6. Essential Role of Pauli Exclusion

Pauli exclusion as applied as an axiom in Quantum Mechanics includes two features. The primary feature is that there is a limit to the number of electrons that can occupy a cell in quantum phase space. Quantum phase space is a 6-dimensional theory space in which occupyable cells are designated by position coordinates x,y,z and momentum coordinates p_x, p_y, p_z. Adding a spin phase space dimension doubles the density of a solid. Pauli exclusion as applied to electrons largely determines the density of atoms having atomic number greater than helium. The electrons largely determine the density of condensed matter because condensed matter is nothing more than an assembly of contacting atoms. In contrast, protons, neutrons, and nuclei play almost no role in determining the density of atoms and solids. This is an enormously important aspect of quantum physics. It also applies to white dwarf stars,[5] and is confirmed by their difference from neutrons stars. White dwarf stars are supported by a completely degenerate electron phase-space lattice. Neutron stars are dwarfs that have lost their electron-based structure by inverse beta decay. White dwarfs have the mass of the sun in a volume equal to that of the earth. Neutron stars have the mass of the sun in a volume whose diameter is that of Washington, DC.

7. Interface between Perfect Crystal Surface and Epitaxy Metal Layer

ZrO_2 crystals appear to be able to provide flat faces on which there are areas with perfect lattice order. Imperfect Pd metal seems able to configure itself so as to form an epitaxy fit to this layer.[6] When a diffusing D encounters the interface volume containing an area of lattice with perfect order, it switches to quasiparticle form. The D atom suddenly becomes a superthin flat atom, as shown in Fig. (1).

If the perfect area exceeds 1000, or maybe 10,000 contacting lattice atoms, additional important physics occurs. The superthin flat atoms have at thickness of 0.001 or maybe 0.0001 times the thickness of a normal metal layer. It then becomes possible for two flat atoms to occupy the same volume of space. Their joint occupancy is no longer prevented by Coulomb repulsion. The required area of perfect lattice order for hosting double flat atoms has been calculated based on a requirement for system energy minimization..

The double flat D atom is a form of flat ^{4}He. Successive momentum transfers deliver released nuclear energy to quasiparticle electrons in the adjoining bulk Pd metal lattice.

Flat ^{4}He extends to a boundary of the perfect order region. At the boundary the flat ^{4}He converts to spherical atom form. This conversion to spherical form completes the primary fusion process.

8. Reduction of Coulomb Repulsion

Fig. 2 shows pictorially why the large area occupied by a super-thin geometry of individual D quasiparticles reduces the Coulomb repulsion between two parallel D atoms. The partition fraction local charge associated with the area next to one of the ionic crystal atoms is repulsed by the same segment area of local charge in its neighbor. Adding up all these neighbor-neighbor repulsions leads to a segment-segment repulsion of $1/N_{cell}$, where a segment area roughly that of a normal spherical D atom cross section. See Eq. (1). The means that the larger the area of perfect order on the ZrO_2 face, the lower the energy of the fusion product ^{4}He. It also means that system energy is lowered if the flat atom can move so as to expand its area.

For a pair of flat atoms at small separation distance d, the Coulomb force $\mathbf{F}_{Coul}$ is:

$$\mathbf{F}_{Coul} = \sum_{1}^{N_{cell}} \left(\frac{e}{N_{cell}} \right)^2 \left(\frac{1}{d} \right)^2$$

As $N_{cell} \rightarrow$, $\mathbf{F}_{Coul} \rightarrow 0$ Eq. (1)

The same process that allows flat D atoms to form ^{4}He allows flat ^{4}He atoms to form flat ^{8}Be and flat ^{12}C. These entities are seen as the players in Mossier-Boss's CR39 studies.[7]

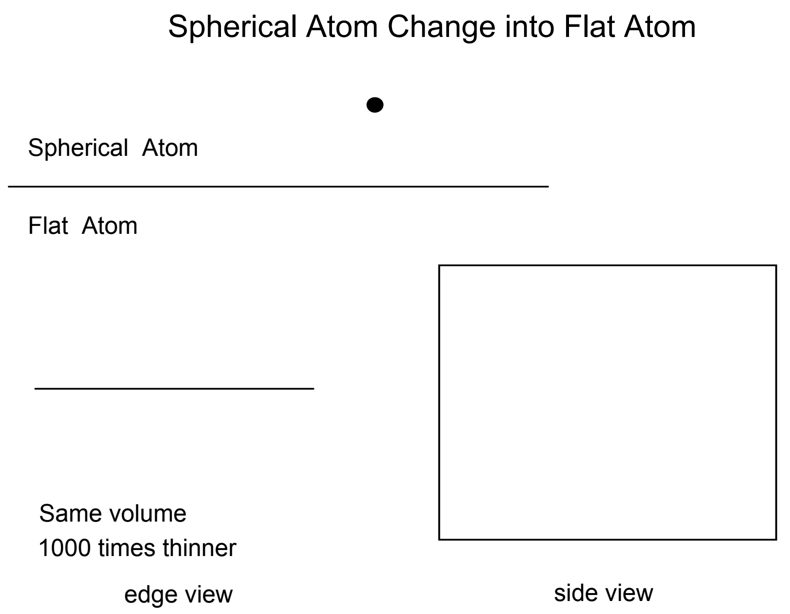

Fig. 1 - A normal spherical atom changes into a flat atom. Its volume is preserved but it becomes much thinner. If the area covers a 1000 atom array, the atom's thickness is reduced by a factor of 1000.

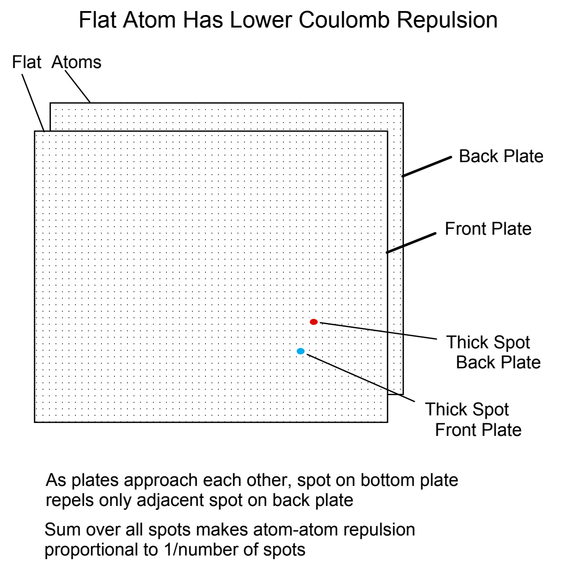

Fig. 2 - Flat deuterium atoms have an array of relatively thick spots. When two flat D approach each other and are separated by nuclear scale distance, a thick spot on the one is repelled only by the corresponding thick spot on the other. Summing over the repulsion potentials shows that the atom-atom repulsion is reduced by the number of thick spots in the array, designated N_{cell}. Each atoms is said to be coherently partitioned into N_{cell} equivalent spots. See Eq,(1).

Apparently similar flat atoms are produced from flat Li atoms fusing with flat D and H atoms in Oriani's CR39 studies.[8] In some of the Oriani experiments the stable ionic crystal involved could be NiO, but in Mossier-Boss's case it may be that the crystalline plastic container used to house the electrolysis cell could be the ordering crystal. In both cases the crystal that imposes lattice order may be an ionic crystal formed by oxidation of an impurity in the electrolyte employed, or on the containment vessel.

9. Interruption of Fusion Cascade

Mossier-Boss and Oriani have observed MeV-energy particle tracks that start and end inside CR39 plastic detectors. The source of these tracks is believed to be the breakup of a metastable ^{8}Be or ^{12}C flat nucleus accompanying its transition to normal atom form. The flat nuclei are stable when residing in their birthing interface. When a flat atom is released from its birthing interface, it can temporarily adopt an independent existence. When electrolytic loading is employed, flat are nuclei probably rare side products of overvoltage electrolysis. Also, it may be that on some occasions the energy transfer cascade that leads to a flat ^{8}Be and ^{12}C atom can be interrupted prior to its transition to its ground state. It is predicted, but not certain, that no CR39 double or triple tracks will be observed in gas loading experiments because of nearly reversible chemistry.

10. 3-Dimensional Symmetry Fusion

The discovery of cold fusion by Fleischmann and Pons appears to be the result of the fusion of 3-dimensional symmetry D quasiparticles in electrolytically loaded PdD_x where $x > 0.85$. 2-dimensional and 3-dimensional systems are different. Both are real, benefit from shock stimulation, and are Bloch systems; but they require different environments.

To explain 3-dimensional cold fusion it is helpful to examine the behavior of atoms in optical lattices.[9] An optical lattice is an array of potential wells separated by barriers created by interfering laser beams. Bose atoms show different behavior when the barriers between potential wells are high than when they are low. When high, the atoms behave as "particles"; when low, they behave as quasiparticles. When high, but not too high, the center of each potential well is occupied by a "particle", while the periphery is occupied by the partition-fraction of a shared quasiparticle. In PdD_x with x near 1, the periphery of the octahedral sites of Pd metal plus the centers of the 2 tetrahedral sites constitute a communication network of shallow potential wells. This network can become occupied by D quasiparticles in the same manner that the interface volume in a 2-dimensional fusion system becomes occupied. Therefore, paired 3-dimensional quasiparticles are subject to the same reduction in Coulomb repulsion between overlapping partners as occurs with 2-dimensional quasiparticles.[10]

11. A Historic Experiment

Oriani and Fisher have described an experiment in which they constructed an electrolysis cell in which they placed paired CR39 detector detectors facing each other in the gas space above the cell's mixed H_2 and O_2 offgas. They observed a shower of MeV particles from a source that moved during the during detector exposure interval. They wrote, "It is clear from Fig. 3 that the shower of charged particles that created the tracks originated somewhere in the region above the lower left corner of the chip. One can also infer that the source of the particles was not stationary during the duration of the burst because of the absence of circular symmetry in the density distribution. .... The intersection of these surfaces occurs approximately 2 mm from the chip surface (Fig. 5B). ..... ¶ ..... . This suggests that a fairly compact source of energetic particles moved away from the chip surface as it rose ....we estimate that the burst produced about 250,000 charged particles ..... ¶ ..... . One might expect that a shower of particles near one chip would have affected the other; indeed this is the case ...."

Based on this description I concluded that Oriani-Fisher showers were caused by clusters of very thin "flake" atoms.[11] It seems to me that for an entity to be suspended in a slowly rising gas stream such as produced by electrolysis requires that the entity be incomparably less dense that any previously known macroscopic material. The flat ^{8}Be atoms described in this paper would seem to fit this requirement

12. Don't Be Too Pure

It is probably desirable that the hydrogen gas that is used to chemically reduce ZrO_2 + nanoPd catalyst during its preparation should not be too pure. The creation of an epitaxy layer on an ionic crystal requires an assembly of Pd fragments, as described by Barcaro et al.[6]. Having both interstitial H and D atoms within the Pd metal should be helpful.

13. References

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