

8 May 08

The Role of Dressing in Cold Fusion

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Dressing is the name used to describe an electron screening phenomenon that is present inside all metals. Electron matter imperfectly neutralizes the charge density of interstitial hydrogen ions (protons and deuterons) inside metal hydrides. Imperfect charge density neutralization occurs because of the large difference between electron and ion masses. There is always central volume within which charge density has a net positive value, and outside of which the effect of excess positive ionic charge potential does not extend. The spatial extent of the imperfectly screened volume determines whether or not lattice symmetry is preserved. Preservation of hydride lattice symmetry is a requirement for radiationless cold fusion. One of the experimenter/engineer's jobs is to provide the required lattice conditions.

Cold fusion science depends on the chemistry/physics of heavy hydrogen in metals. The deuteron is the nucleus of a heavy hydrogen atom. The deuteron is almost 4000 times as massive as the electron. 4000 is a big number.

In a hot gas environment a deuteron moves much slower than an electron. On the other hand, from a quantum physics perspective the electron is much bigger than the deuteron. At comparable energies, it has about a 60 times larger deBroglie wavelength. The electron's deBroglie wavelength determines its packing density, and its packing density determines the density of metals and other solids. The density of metals tends to be higher than that of salt crystals. This higher density leads to the phenomenon called the electron fermi sea. The density of metals and ionic crystals are both ultimately a result of the Pauli Exclusion principle, as described in the preceding topic. Because of the higher density of metals, the metal atom's outer electrons, which might be expected to have low escape energies, are squeezed by the Coulomb attraction, and are trapped within a deep potential well that begins at the metal's surface. The trapping energy per electron is called the work function. The work function for Pd is listed in the Chemistry-Physics Handbook as 5.22 volts. The work function is the energy in electron volts that must be given to an electron for it to escape from the metal's surface into vacuum. This energy is about 100 times the kinetic energy of gases at room temperature. Gas atoms at room temperature have about 0.0125 eV of energy per degree of freedom.

The chemistry of cold fusion is mostly the chemistry of metals like Pd, and of their interfaces with an ionic solid like ZrO_2 . The microscopic structures of these materials are largely determined by energy

minimization. Typically, the crystal form that is most stable is the one that has lowest energy. It has lowest energy because it gave away the most heat during its formation process. Electromagnetism tells us that the lowest energy form of palladium deuteride is the form that most effectively mixes positively charged metal atom nuclei, positively charged deuterons, and negatively charge electrons. Perfect mixing would occur in the imaginary non-physics situation in which the charge densities of the positively charged species matched the charge densities of the electrons in every subvolume of space. Such matching is prevented by the relatively large electron deBroglie wavelength (quantum wavelength) in combination with Pauli Exclusion. If the deuterons, the metal nuclei, and the electrons all had the same deBroglie wavelength, the binding energy of the solid would be enormous. If such a material existed, it would take an enormous amount of work to pull the material apart and return it gas + element form.

It is instructive to explore the question: How do deuterium atoms behave in a low concentration solution of D-atoms in Pd metal, for example, with D/Pd ratio about 0.05? The metal is a metal because the electro-chemical forces that hold it together have squeezed the metal's least bound electrons into a many-body liquid-like state called a fermi sea. Metal is only slightly compressible. Even an atom can be made smaller if you squeeze it hard enough. Although Pauli exclusion says an electron fills a calculable electron-available volume, this volume becomes smaller if you can increase the electron kinetic energy of its electrons. You can do this by compressing the material, but you must do a lot of work (force x distance) to get a little shrinkage. Because the fermi sea electrons have low mass in combination with high kinetic energy, as caused by "work-function" compression, their electron matter is very mobile relative to that of the slower moving hydrogen nuclei. As a result, when a proton or deuteron moves or jumps from location to location during diffusion inside a metal, the neutralizing electron matter either moves with the ion or gets replaced. This preservation of an ion-centered neutralized volume during a migration step is a result of a screening phenomenon called dressing. The deuterons and their neutralizing electron matter behave as a single portion of matter inside a fully screened volume, always maintaining zero total net charge despite having a locally unbalanced charge density.

Dressing plays an important role in cold fusion theory. We base our argument on Fukai's book "The Metal-Hydrogen System". Dressing is implicit in Fukai's modeling of the self-trapping of interstitial hydrogen. He refers to "interstitial hydrogen" as "atomistic hydrogen". Interstitial hydrogen is the hydrogen that undergoes diffusion when a concentration gradient exists within a piece of bulk metal. The phenomenon of dressing is essential to an understanding of the behavior of both atomistic and Bloch-function forms of deuterium in Pd.

The term "atomistic hydrogen" is used to distinguish interstitial hydrogen from delocalized hydrogen, which is "extended over all equivalent sites as waves, just like the conducting electrons in metal". Atomistic hydrogen also distinguishes interstitial hydrogen from "ionic hydrogen". In ionic hydrogen H and D matter is present as H^- and D^- ions in salt-like hydrides such as LiD and CaH_2 .

On pages 184-185 Fukai writes*,

"In terms of quantum mechanics, there can be two different views on the state of light particles in a periodic lattice: localized as particles on particular interstitial sites or extended over all equivalent sites as waves, just like conducting electrons in metal. In the latter case, energy bands are formed in contrast to discrete energy levels in the former.

For interstitial hydrogen atoms, the band picture is believed to be largely irrelevant because the wave functions of hydrogen atoms are fairly well localized and the tunneling matrix element, i.e., the overlap integrals of the wave functions on two adjacent sites, can be shown to be fairly small. In addition, in solid-solution phases, the inhomogeneous lattice distortion produced by the hydrogen atoms should make the energy states of interstitial hydrogen inequivalent, acting as a further impediment to band formation."

"Let us consider the situation that exists when a single hydrogen atom is present in a crystal. Since the presence of hydrogen always causes a local (as well as overall) expansion of the lattice, the potential acting between hydrogen and metal (M) atoms can be regarded as being generally repulsive. The outward displacements of the surrounding M should make the potential around the interstitial site lower and broader and, in consequence, also lower the kinetic energy of the hydrogen atom. All this happens, however, at the expense of the elastic energy of lattice expansion, which increases nearly quadratically with the displacement of the M atoms. The situation is shown schematically in Fig. 4.58. The M lattice deforms itself spontaneously up to a certain value that minimizes the total energy, consisting of the energy eigenvalue of the hydrogen atom and the elastic energy of the surrounding lattice. The lowering of the energy levels in the occupied site suppresses the tunneling to the surrounding sites. This mechanism is called self-trapping, or the small polaron mechanism, after an analogous problem of localization of an electron caused by a coupling with the lattice [4.150,151**]".

* Yuh Fukai, *The Metal-Hydrogen System, Basic Bulk Properties* (Springer-Verlag, Berlin Heidelberg, 1993) pp 184-185.

** T. Holstein, *Ann. Phys. (NY)* 325 (1959); T. Holstein, *Ann. Phys. (NY)* 343 (1959).

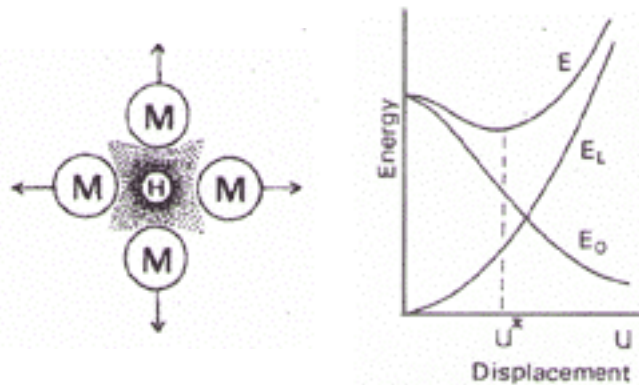


Fig. 4.58 A schematic diagram showing the physics of self-trapping effect. An interstitial H atom displaces the surrounding M atoms so as to minimize the total energy E , which consists of the ground-state energy of the H atom, E_0 , and the energy of elastic distortion of the lattice, E_l .

The author disagrees with the second paragraph of the Fukai quote. For radiationless cold fusion to occur deuterium must be present in dressed, coherently-partitioned form.

The charge neutralization role of dressing is used in the website's Coulomb Barrier paper, "Overcoming the Coulomb Barrier in Cold Fusion". The enveloping electron matter supplied by dressing limits the range of the Coulomb repulsion potential, which is the range of the Coulomb force that tries to keep 2 deuterons apart. This range limitation is expressed in the value of screening radius r_{sc} used in the calculation of the depth of cusp depressions when an anti-correlation overlap form of 2-deuteron wave function minimizes system energy. See the Coulomb barrier paper Eqs. 5, 6, and 7. To preserve lattice symmetry, the magnitude of r_{sc} must be less than the linear separation characterizing crystal unit cells. The magnitude of r_{sc} determines whether or not lattice symmetry is preserved. If $|r_{sc}|$ is too large, self-trapping occurs, as in Fig. 4.58, and radiationless cold fusion becomes impossible.

The local stability of a lattice largely determines whether a small enough value of r_{sc} can be achieved. A locally stable lattice environment is needed. Experiments suggest that the stability of the contact epitaxy-fit interface between an ionic crystal and nanocrystal Pd provides an environment that can host delocalized (quasiparticle) deuterium, and avoid the self-trapping that breaks periodic order. The epitaxial interface is not the only environment in which cold fusion has been achieved. A second identified environment is the three dimensional Pd lattice in which all octahedral sites are occupied. Further added deuterons delocalize over a communicating network of shallow potential wells centered on empty tetrahedral sites plus already-occupied octahedral sites. Both the interfac

and network environments are nuclearly active. In both environments there are wavelike deuterons which are coherently partitioned, occupy non-self-trapping sites, and undergo radiationless cold fusion reactions.

Quasiparticle physics (wavelike particle physics) in a metal differs in fundamental ways from both atomistic and free particle physics. Quasiparticle coupling to the environment is dominated by momentum transfers, rather than by photons created at or near a point. A sudden momentum impulse is called a shock. When shocks occur, a crystallite lattice moves as a whole. Shocks can deliver momentum so as to energize electron quasiparticles in a scattering event, and they can also excite lattice vibration modes in a metal crystallite in a "phonon creation" event. These momentum transfers are simultaneously generated and received at a large number of small volumes. In contrast, in atomistic matter the transfer of momentum is centered on a single point or small volume. This geometric difference makes pure cold fusion events totally immune to generation of energetic particles and gamma rays.

The presence of lattice-scale momentum background shocks seems likely to stimulate cold fusion events, just like a background of photons can stimulate emission of more photons in atomistic physics. There may be more than one way to generate useful shocks in a solid. Whenever a deuteron quasiparticle is created by the transition of a diffusing deuteron from atomistic to quasiparticle geometry, there is a lattice-scale momentum shock that occurs at the instant when dressing electron matter relocates so as to neutralize the simultaneously created deuteron quasiparticle. A similar shock occurs when the quasiparticle deuteron matter reconverts to atomistic matter. In contrast, there is no crystallite lattice scale shock generated when a diffusion atomistic deuteron changes position. Instead, dressing transfers the localized lattice distortion shown in the Figure to an adjacent site. Dressing of deuteron quasiparticle matter seems to be a requirement for useful levels of radiationless cold fusion. It provides the electron matter screening needed to overcome the Coulomb barrier and creates a background noise of crystallite-scale physical shocks that likely promote cold fusion reactions.