3. Phonons in Cold Fusion

This blog attempts to provide a visual description of cathodes in cold fusion systems loaded with deuterium and/or hydrogen, and discusses the role of phonons (i.e., thermal vibrations) in producing cold fusion reactions in the loaded material. The fact that atoms in materials vibrate has been known since the late 1800s; the characteristics and effects of these vibrations has more recently been investigated as an active area of semiconductor physics.

Loaded Reaction Material

It is possible to estimate the amount of deuterium and/or hydrogen that needs to be loaded into the cathode's reaction materials, such as consolidated nickel particles, in order to produce a useful output of energy. This can be done by considering an example cubic centimeter of the material where the atoms of nickel are each separated roughly by about 5 angstroms (5×10^{-8} cm). A solid piece of nickel would contain approximately 8×10^{21} atoms. Instead of the solid piece of metal, consider reaction material that has been made to contain many very small spaces where the reactions might be made to occur. It is possible, for example, to have a line of at least 3000 such spaces in the distance of 1 cm along each direction of the cube, or a total of 2.7×10^{10} spaces in a volume of one cubic centimeter.

Visualize a nickel surface internal to each of the very small spaces as having an internal circumference of about 10 microns (10×10^{-4} cm). If the atoms were separated by 5 angstroms, the surface would contain about 20,000 nickel atoms around its circumference. This small space could be considered to be "highly loaded" if it were to contain about this number of deuterium and/or hydrogen atoms.

Assume the space could be loaded with 20,000 deuterium and hydrogen atoms (10,000 each), providing the possibility of 10,000 cold fusion reactions, and assume that each of the reactions is able to produce 5 MeV of energy. Since 1 MeV equals 1.6×10^{-13} joule, 10,000 reactions would produce 8×10^{-9} joule. This is only eight nanojules – a very small amount of energy. A total of 2.7×10^{10} spaces in the reaction material, however, may be able to produce 216 joules/cm^3. If this energy were produced each second, then it would result in 216 watts of power for each cubic centimeter of reaction material. This is about the same power density able to be produced by nuclear fission power plants.

Instead of thinking about the nickel surfaces internal to the very small spaces, however, visualize the surfaces themselves as connecting into many 1 micron long linear channels and defects that branch off and that are much more narrow. Each of these more narrow, linear channels could contain several thousand deuterium and hydrogen atoms. Assume that each space branches off to ten (10) linear channels or defects, and that each channel contains 2,000 deuterium and hydrogen atoms (1,000 each), providing the possibility of 1,000 cold fusion reactions. These reactions would produce 8×10^{-10} joule in each channel, 8×10^{-9} joule in 10 channels, or 216 joules in each cubic centimeter of the cathode.

Phonon Characteristics and Effects

Scientists have studied phonons [click on http://news.mit.edu/2010/explained-phonons-0706], or thermal vibrations of atoms in solids, since the late 1800s to explain many important material characteristics. The phonons have energies and vibration frequencies related to temperature of the material. For example, melting can be explained in terms of the increase in the number and amplitude of phonons with temperature to the point that the material can no longer stay together as a solid. Electrical resistance can be explained in terms of diffraction or scattering of electrons by periodic vibrations of atoms in the material. An understanding of thermal vibrations was also used to describe the manner in which heat capacity of materials varies with temperature up to the temperature reached when all modes of vibration are active, known as the "Debye temperature". The Debye temperature for nickel sometimes used in cathodes of cold fusion devices is 183 ^{o}C (456 ^{o}K). The heat capacity for a mole of atoms in most metals has been determined to be about 25 joules per degree Kelvin, or 6 calories per degree Kelvin (6 calories/^{o}K). These values are important to the operation of some cold fusion systems.

Some phonon characteristics have been derived from the study of superconductivity [click on https://www.youtube.com/watch?v=qTzgjnwN2EU]. Values of the low temperatures at which materials lack electrical resistance were determined early on to be proportional to their Debye temperatures. In the 1950s, these transition temperatures also were determined to be inversely proportional to the square root of isotopic mass. Since the mass of atoms in the material is important, their vibrations must be involved. It was subsequently shown that in traveling through material at very low temperature, electric current is carried by a pair of electrons. The pair is formed when two electrons are weakly attracted to each other (overcoming their repulsive Coulomb forces) as a result of being scattered by the vibration of phonons in the material. This is energetically possible because the paired electrons have lost some of their energy, and have lower energy than when they were separate. The phonon vibrations, however, have insufficient energy, to scatter the more massive pairs, and they can then travel through the material unimpeded.

The amount of coupling between the phonons and electrons is expressed by a coupling constant. This is an extremely important microscopic characteristic of metals. The entire phonon spectrum is considered to contribute in some degree to the coupling constant. It is then possible to correlate the coupling constant with kinetic properties of a metal when the entire phonon spectrum is excited. For example, a direct relationship has been shown between the coupling constant and temperature-dependent resistivity. The dielectric constant has been related to the concentration of conduction electrons and to the effective frequency of electron-phonon collisions. Above the Debye temperature, the electron-phonon coupling constant can be determined using optical measurements.

Scientists have used related concepts since the latter part of 1990 to investigate a theory that cold fusion reactions in the cathode could be caused by strong interactions of high frequency phonon vibrations with electrons of deuterium and hydrogen atoms in adjacent channels and defects. The phonon frequencies are generally thought of in the region of 10^{12} to 10^{14} Hertz. The channels and defects are considered to be one-dimensional where positive and negative ions can move rapidly toward each other and fuse. When the deuterium and hydrogen atoms lie in these channels and defects, they have their own spacing in the chain. The interaction is believed to be able to cause some of the electrons to pair up around the deuterium or hydrogen, to produce a negatively-charged atom. The atom with a pair of electrons is more stable than if it had one electron. The phonon interaction is also able to cause electrons to be absorbed into the protons of hydrogen atoms to form neutrons. These neutrons can cause transformation reactions in adjacent material, and would be undesired for long-time operation of cold fusion systems.