5. Design of a Practical Cathode

Insert Photo of volcano produced on surface
of cathodes in cold fusion experiments

From previous blogs, it is possible to gather together information for design of cathodes that can be used in future cold fusion generators. The last 30 years have demonstrated that it is difficult to cause cold fusion reactions to occur, at least consistently over a long period of time. When they do occur, it is assumed that the conditions need to be replicated well for the reactions to continue or be repeated. It is known that several material parameters are involved in phonon phenomenology, and, therefore, that future improvements in cathodes could be expected to be implemented by advanced understanding and application of those parameters. Temperature is identified as one of the most important parameters. One can assume not only that the cathode must be heated at least to its Debye temperature (183^{o}C) for consistent operation, but that the cathode's temperature operating point will need to be accurately controlled, possibly even within a couple of degrees, for the cold fusion reactions to continue. The cathode can be heated to this temperature with a separate, built-in electric heater. Any additional heat produced internally in the cathode by cold fusion reactions must be removed to produce useful energy output. This additional heat will need to be removed in a regulated manner so that the temperature internal to the cathode is not reduced below its operating point.

Results from cold fusion experiments have demonstrated that several types of reactions are possible – fusion, transmutation, and fission. Very low energy, slow neutrons produced in the reactions, for example, are able to transmute some of the nickel in the cathodes to copper. Energy may be able to be produced in some transmutation reactions. These types of reactions, however, can change the composition of reaction material in the cathode, potentially making it less useful, and are undesired for long-term generator operation. Operating conditions that support fusion reactions will need to be maintained, instead of those that would cause transmutation and fission.

Experiments have also demonstrated that sufficient energy can be produced in the microscopic, local vicinity where reactions occur to melt the reaction material. This concern stems from the observation of "volcanoes" formed from melted metal on the surface of (palladium) reaction material. The volcanoes have a diameter of a few tenths of a micron to tens of microns. Depths are about the same as the diameters. Temperature of the material would need to be raised by at least 1500 degrees for melting. Since the heat capacity of metals is 25 joules per mole per degree, about 20 reactions at 5 MeV each (a total of 100 MeV or 0.016 nanojoule) would provide enough energy to "melt" a million (10^6) atoms of the material. The volume of a 5-micron diameter volcano (cone) with a depth of 5 microns would contain 10^{12} atoms before the volcano is formed. Thus, about 20 x 10^6 reactions would be required to melt the material for a 5-micron volcano. Before the volcano is formed, a thin (one to a few atoms thick) crevice or defect formed in the center of this volume with a width and (triangular) height of 5 microns might contain up to about 10^8 deuterium atoms that would be available to produce this energy. This indicates that the number of reactions in each microscopic reaction volume will need to be limited (perhaps to less than 20 reactions for each million atoms) to prevent reaction material in the cathode from being changed, particularly for generators that are required to operate consistently for long periods. Melted areas of the cathode would probably not be able to serve as sites for additional reactions.

Now consider deuterium and/or hydrogen gas outside the cathode. Molecules of gas impacting the surface of the cathode will travel at high velocity due to their temperature (thermal or kinetic energy). Gas pressure on the surface of the cathode is due to the numbers of gas molecules and their kinetic energy. Velocity of the molecules can be easily calculated if this were of interest. The average density of molecules at any instant can be calculated from the ideal gas law, PV = n RT, where n is the number of moles of gas (1 mole = 6.02 x 10^{23} molecules) and R is the universal gas constant (R = 0.082 liters-atmospheres/moles-^{o}K). If the system were operated at 10 atmospheres of pressure and 456 ^{o}K (183 ^{o}C, the Debye temperature for nickel), then one liter of the gas would contain 1.6 x 10^{23} molecules. A volume of one cubic micron (10^{-12} cm^3) would contain 1.6 x 10^{11} molecules. As shown above, relatively few of these molecules need to get through the cathode and into the microscopic cracks and crevices where reactions occur.

An earlier blog indicated that inside the cathode, by comparison, the small volumes internal to each of the great many very small cracks and crevices can be visualized hypothetically as containing either about 20,000 or 2,000 deuterium and hydrogen atoms, providing either 8 x 10^{-9} joule or 8 x 10^{-10} joule (8 or 0.8 nanojoule) of energy per reaction site. For a practical cathode for long period operation, however, the amount of energy produced per reaction site must be reduced substantially. One way to do this is to limit the quantity of deuterium and/or hydrogen gas provided to the sites down to about 100 atoms, for example. If this were done, power rating could be expected to be proportionally impacted. A larger cathode to increase the number of reaction sites would be required to maintain power rating. In addition, relative quantities of deuterium and hydrogen can be controlled to enhance the type of fusion reactions that will not cause as much local heating in the reaction sites. Fusion of deuterium with hydrogen produces helium-3 and gamma radiation that does not need to be absorbed close to the reaction sites. Fusion of deuterium with deuterium will produce reaction products that need to be absorbed close to the reaction sites. Thus, much better cold fusion generators can be expected to be developed based upon fusion of deuterium with hydrogen.