Multilayer Thin Film Electrodes for Cold Fusion

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ABSTRACT

The application of the "swimming electron layer" theory[1,2] to the design of multilayer electrodes is discussed. A key advantage of this approach is that the enhanced reaction rate at interfaces between select metals results in a high power density throughout the volume of the electrode.

Design criteria and fabrication techniques devised for the multilayer thin films are discussed. Initial experiments using a dense plasma focus (DPF) for loading these targets are described along with the design of an electrolytic cell intended to test scaling to high powers.

1. Introduction

Since the first exciting announcements[3,4] experimental results have lead the theoretical explanations for understanding the mysterious cold fusion phenomena. Many theoretical explanations offered to explain the experimental results on cold fusion were examined critically by Preparata[5], who stresses the key problem of overcoming the coulomb barrier, before the deuterium nuclei could fuse. Most of the theories Preparata reviews, plus his own[5], fully treat the cold fusion as a quantum mechanical tunneling effect. This does not, however, fully explain the high reaction rates observed in recent experiments which are thought to involve surface or interface effects[6,7]. Thus the "swimming electron layer" theory was developed to address this issue. This model is based on the surface

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tension effects on an exotic plasma at the metal interfaces, which can cause and give enhanced reaction rates. The process of cold fusion in deuterated multilayer targets will be considered according to this model in the following Section whereas, the status of the experiments in progress will be discussed in Section 3.

2. Application of the "Swimming Electron Layer" theory to Cold Fusion

Many experiments so far have indicated that cold fusion is a surface related exothermic phenomena. The "swimming electron layer" theory is consistent with this observation and suggests the use of multilayer thin foils in order to induce reactions throughout the volume of an electrode. This will in turn allow direct scaling to high power levels in minimum size cells.

Multilayer electrodes suggested in this model will have closely spaced interfaces at which cold fusion would occur to provide a high power output. Related experiments using coated electrodes have been reported by Arata and Zhang[6], whereas multiple large volume Pd/Si layers have been studied by T. Claytor[7]. Both experiments were quite successful and thus provides encouragement for the multilayer film concept.

The metal pairs used in the present experiments for fabricating multilayer electrodes is selected so that the metals do not diffuse into each other in order to maintain well-defined interfaces. The differences in Fermi levels of these metals adjust at the interfaces such that an electron layer is created that is most effective in shielding the positive charges of fusing deuterons. The dynamic shielding effect of the electron layer may further be enhanced if the electrode is connected to the negative terminal of a power source that floods the conduction bands of metals with electrons. Thus, when one uses an AC power source or ramps the current from a DC source during the electrolysis, a dynamical non equilibrium condition is created. This effect is related to the enhanced reaction rate observed by others using oscillating or ramped voltages[6,7].

The basic process is viewed as involving colliding thermal deuterons at the interfaces of multilayer electrodes. At the low speeds involved, the D^+ nuclei will be polarized (see Figure 1). The shielding of the positive

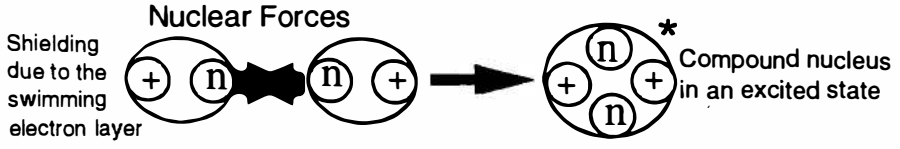

Figure 1. Cold fusion of D^+ shielded by swimming electron layer.

charge in this state by the swimming electron layer allows a very close approach, where the nuclear forces become effective to form a compound nucleus in an excited state.

3. Experimental Methods

Experiments using multilayer electrodes are under way. Thin film foils for DPF experiments are made by electron beam evaporation from water-cooled copper crucibles onto cooled aluminum disks. Layer growth is controlled by a quartz crystal monitor; a deuterium atmosphere can be used if needed to provide preloading. Five such foils have been successfully fabricated to date.

The extension to electrodes for later electrolytic cell experiments is also under study. Nickel cathodes in the shape of hollow cylinders to be used in electrolysis, will be coated with alternating multiple layers.

The selection of metal pairs for multilayer interface effects favors the highest difference for the Fermi energies consistent with adequate diffusion coefficients for loading and an adequate solubility of deuterium in at least one of the pairs. Some potential candidates are tabulated in Table 1. along with their Fermi energies calculated by H. Hora[8] according to formula 6.39 in Reference 8.

Table 1. Table of Fermi Energies for various Metals.[8]

Metal	Ti	Ni	Co	Fe	Pt	Pd	Th	Ce	Zr
E_F eV	5.35	7.35	7.34	7.01	5.91	6.04	3.54	3.35	4.42

The Pd/Ce pair has a difference of 2.96 eV in Fermi energies whereas the Ni/Ce pair has 4.02 eV difference. Thus the Ni/Ce pair offers a maximum difference and will be used extensively in our later experiments. Targets now under study use 10-30 layers of Ti/Fe with layer thicknesses of 10-20 nm. These materials were selected initially based on the ease of handling them and the fact they meet the desired criteria (but are not optimum). Several were fabricated in a deuterium atmosphere to obtain a pre-loading of deuterium.

In some cases a diffusion barrier layer is applied on the outer most surface of the electrode to ensure a sustained high loading ratio of deuterium. A thin layer of Fe-Ni alloy is used for this purpose since it has an extremely low diffusion coefficient for D^+. High currents of D^+ can be driven through such a barrier layer if a minimum thickness is selected as discussed by Uhm and Lee[9].

A 25-kJ DPF device at the University of Illinois is being used to load multilayered foils. The DPF implantation offers distinct advantages[10]: the

plasma cleans the outer surface, eliminating oxide layers; higher energy ions provide good penetration and a number of different foils can be "screened" for performance quickly. The U of I DPF gives a 3 - 5 x 10^5 Ampere 40 ns pulse using a unique axial magnetic field for stabilization. Foils are placed in a special holder with their surface at the base of the pinch plasma. Multiple pulses (80-100) are used for high loading. Various diagnostic techniques including auto radiography[10], charged particle detection and calorimetry are employed. State-of-the-art facilities for sputtering and vacuum evaporation are used for the fabrication of multilayer foils with 50-100 individual layers of 10-30 nm thickness.

The extension of this method to cylindrical electrodes is underway. A unique electrolysis setup with dual cells and hollow cylindrical multilayer cathodes has been designed to study power production in this configuration. Results from the DPF experiments will be used to select optimum metal pairs for the cell electrodes. This cell arrangement is such that a precise measurement of the generation of excess heat can be carried out simultaneously with studies of nuclear particle emissions. The scaling of the design to large powers is also relatively straightforward.

4. Conclusions

The approach proposed here is unique in describing cold fusion as an interface phenomena, consistent with both the "swimming electron layer" theory and with recent experimental results that indicate reaction mainly occur at electrode surfaces. Techniques have been developed to fabricate multilayer thin film electrodes which should produce a high power density throughout the electrode volume. Experiments are in progress to verify this.

5. References

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